Industrial Ecology for a Sustainable Future

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Welcome to Stockholm and the 3rd International Conference

Industrial Ecology for a Sustainable Future

The ISIE-2005 conference highlights the contributions that industrial ecology can make towards attaining a sustainable future for the planet and its population. The conference provides a forum to introduce theoretical advances and to discuss practical experience, to learn about IE modelling and to explore the human dimensions of applying IE in corporate, public policy, and consumer decision making.

The conference in Stockholm 2005 is a major event in the history of Industrial Ecology. There has been an overwhelming response to the ISIE-2005 conference, which will guarantee an event of very high interest. The ISIE Governing Council, Organizing Committee, and Technical Committee, thank you for joining us at the ISIE-2005 conference.

The conference will take place in the Swedish capital, Stockholm - a city built on 14 islands. Well-preserved medieval buildings stand alongside modern architecture. Stockholm is a city of contrasts – land and sea, history and innovation, a small town and a big city, and long, light summer evenings in June. All this leaves the visitor with a wonderful variety of impressions.

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June 12.
Technical session T1

Session A:
IE in a Global Context

Chairmen:R. Ramaswamy

Location: Lindstedtsvägen 3
Room: E2.

“Closing the Loop” on Industrial Waste: Spontaneous By-Product Recycling between Industries from the Victorian Era to Earth Day.

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Summary:
In recent years, a growing number of historians have turned their attention to the historical environmental behavior of firms. Some have argued that industrial behavior before the modern environmental regulatory era (1970 and beyond) was characterized by the near absence of *loop-closing*, a modern term that refers to the creation of links between different industries for waste recycling. Others have identified precedents in this respect that are said to have been achieved largely through the leadership of governmental outlets and Progressive Era reformers. This essay presents evidence taken from several books and articles, published from the early Victorian Era to the beginning of the 1970s, and suggests that loop-closing was a widespread spontaneous phenomenon in past market economies. A few explanations for current beliefs to the contrary are then offered. While there is no point in arguing that past industrial activities did not generate important pollution problems, perhaps our ancestors should be given more credit than they generally are for being creative and resourceful in their capacity to profitably solve environmental problems.

Industrial Ecology and Ecological Economics

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So far, the relationship between industrial ecology and ecological economics has barely been addressed, at least in an explicit way. Establishing and clarifying such a relationship might contribute to the development of both fields through 'economies of scale' (more concentrated research efforts), more significant cross-fertilisation of ideas and creating a consistent body of knowledge, that might eventually have a bigger impact on policy and decision makers.

'Ecological economics studies how ecosystems and economic activity interrelate' (Proops 1989, p. 60). To achieve this goal, it involves three levels of considerations:

- primary – biophysical – physics, chemistry, ecology and biology – the economy is only a subsystem of a larger natural system, thus natural science considerations are essential to any economic analysis;
- secondary – economic – here, to some extent, ecological economics coincides with neoclassical economics, and environmental and institutional economics in particular; and
- tertiary – strategic – systems perspective and precautionary principle – including all the other two types of considerations.

They are all equally important and interconnected, and linked to further, less emphasised issues, such as ethics, philosophy, engineering, political science.

The principal issues related to the biophysical considerations include:

- economic and natural systems coevolve;
- the Earth's carrying capacity has to be obeyed;
- resources and energy are not created *ex nihilo*, so they should be used efficiently;
- man-made capital cannot substitute for natural capital;
- 'all production is joint production' (e.g. Faber et al. 1998), the production of goods always gives rise to additional unintended outputs, often harmful to the environment; and
- resources and energy cannot be fully recycled, as at some point the amount of exergy required for recycling outweighs the amount of energy embodied in the recycled output; all strategies for 'closing the loop' – reuse, recycling and recovery of materials etc. – should be supported wherever environmentally and economically viable.

Secondary considerations involve issues such as the analysis of government, empowerment and transaction failures, and market failures and internalisation, or 'getting the prices right', in particular. Tertiary considerations include adopting a systems perspective, that eventually justifies the application of a precautionary principle (principally due to our ignorance of the economy-environment interactions) and of pollution and waste prevention strategies.

A review of a number of definitions of industrial ecology reveals that, to a large extent, they refer to the same issues, to which they add the so-called industrial ecological metaphor comparing industrial systems with their natural counterparts. To satisfy the metaphor, first of all, the issues previously referred to as the biophysical considerations of ecological economics have to be respected. Furthermore, the industrial ecological metaphor stresses concrete features of ecosystems that industrial systems should follow (e.g. Korhonen 2004), which might be named as the operational strategies to reach this metaphorical comparison:

- efficiency and resilience which translate into the sustainability of an ecosystem;
- sufficiency and 'roundput', or minimisation and efficient use of materials and energy;
- diversity and interdependence, which are emphasised by treating companies as organisms and the economy as an ecosystem which also calls for a systems approach;
- information and communication, or underlining their importance as the strategies to improve the interconnectedness within an industrial ecosystem; and
- other, less frequently emphasised issues, such as locality (or community) – reducing the system's dependence on external resources and focussing on local interdependence; avoiding the use of toxic substances, or, at least, like in nature, producing and storing them locally and in minimum quantities; and preference to natural materials and making use of the capacities of natural systems to perform their functions.

Thus, industrial ecology is closely related to ecological economics, and the main issues that they have in common are the biophysical considerations and the conclusions that stem from them. They both require the integration of the knowledge from ecology, economics and other fields of science and their recommendations; and thus foster the integrated, interdisciplinary and long term approach supplemented by invoking systems thinking.

So far there has been relatively little cross-referencing between them; for example during the two previous ISIE conferences only one paper directly linked to ecological economics. However, far more often many similar issues were discussed, than the distinctive names of these fields were explicitly mentioned.

Other similarities stem from the fact that both are principally of normative character and use similar tools (such as input-output analysis) and followed a similar historical pattern of development. Finally, the relationship under question is particularly evident with reference to industry and products – relatively rarely do ecological economists discuss the issues related to industry or products, even though they evidently constitute part of what they are interested in. It can be argued that industrial ecologists relieve them from this task by taking it over, while keeping the same set of instruments and methods of analysis.

That some issues, like that of substitution of natural with man-made capital, are not directly addressed in industrial ecology does not mean that they are excluded from the scope of its interest. Many aspects of the industrial ecological metaphor are not discussed explicitly, but are implicitly accepted by the industrial ecological community. Industrial ecology is a more concrete and specific strategy on how to fulfil some of the prescriptions of ecological economics. It is more focused and practice-oriented than ecological economics. Still, most articles and books on industrial ecology might as well, already in their titles, refer to ecological economics. It could not, however, work that easily the other way round. Thus the analysis presented here confirms that both areas are closely related and, moreover, that it is ecological economics that is relatively broader and thus encompasses industrial ecology.

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Circular Economy: An Emerging Strategy Tool in China

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China is on the progress towards the comprehensive well-being society one of which goals is to quadruple GDP by the year 2020. Obviously, China won't realize this macro goal without changing the current production and consumption patterns. Thus, some pioneering efforts at all levels are observed since the turn of new century. On January 1, 2003, China Cleaner Production Promotion Law took into effects, which is the first law with the term of "Cleaner Production". At local level, eco-industrial parks and circular economy (CE) initiatives emerge. Some circular economy efforts by Task Force on Circular Economy at Tsinghua University are discussed here.

Circular economy, a term being corned at the turn of new century in China, advocates that economy system should be constructed on the base of material recycling. According to the circular economy principle, the traditional development pattern with linear flows of resources-products-wastes should be replaced by a new one with circular flows of resources-products-resources. Our CE initiatives can be categorized into 3 types.

1. Implementation demonstration at municipal or provincial levels, including the first demonstration city – Guiyang, the first demonstration province – Liaoning Province, the first bidding project – Jiangsu Province, the Capital of China – Beijing, and the countywide city – Yima City of Henan Province.
2. Policy and strategy studies for central governmental or non-governmental sectors, including the State Council, the State Development and Reform Commission, the State Environmental Protection Administration, the Chinese Academy of Engineering and the China Council for International Cooperation on Environment and Development (CCICED). The outcomes contribute to *the National Middle & Long-term Planning of Science & Technology* and *on promotion of Circular Economy* - an issued paper by the State Council.
3. Some important measures to implementing CE, including water resource conservation, water reuse and recycling in urban, solid wastes recycling and so on.

All these initiatives show some main features:

1, they came from varieties of governmental sectors, including economic development, urban construction, environmental protection, and sci. & tech.;

2, they came from different regions, including Yangzte River Delta - the most developed region, the West – undeveloped region, the Middle – less developed region, and the Northeast Old-Industrial Base;

3, the contents include development strategies, master planning, regulation and policy, and technical support;

4, both bottom-up and top-down methodologies are adopted in these initiatives.

From these initiatives, some preliminary outcomes are obtained:

1. To deepen the conception of CE. Some related concepts including cleaner production, industrial ecology, ecological economics and sustainable development are distinguished. Comparing to "Mass Production, Mass Consumption", CE is a more eco-efficient development pattern. Furthermore, the meaning behind CE concept in China is different from recycling-oriented society in Japan, pollution prevention principles should be stressed in current situation.
2. To develop some analysis tools and planning methodology. Material Flow Analysis (MFA) is adapted to analyze environmental burdens at local levels, with some modifications to fit the data sources and features of China. Scenario planning is adopted to give some development patterns. In some cases, multi-objectives optimization and uncertainty analysis were carried out.
3. To fasten the implementation of CE at local levels.
4. To contribute to the development strategy and macro plans at national level.

Circular economy initiatives provide promising choices to realize sustainable production and consumption. With these clear visions at local or regional level, strategies, action plans and innovative practices should be formulated and taken into action. Meanwhile, multi-stakeholder involvements, long-term efforts, and co-ordination and cooperation among difference agencies are required.

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A World Trade Model Based on Comparative Advantage with Bilateral Trade.

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This paper describes a World Trade Model with Bilateral Trade. The model is a linear program that based on comparative advantage determines world prices, scarcity rents and international trade for m regions, n goods and k factors. By including transportation sectors and geographically dependent transportation requirements for each traded good the model is capable of determining bilateral trade flows and region specific prices. The formulation of this model and its major properties are presented. Results from a preliminary analysis with 10 regions, 12 goods and 3 factors are presented.

Global Cycles:Realizing Business Advantage from Industrial Ecology Initiatives in a Multinational Value Chain

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Many multinational companies are attempting to make industrial ecology (IE) an integral part of their innovation process. In an increasingly complex global supplier network, exploring the potential for IE innovation often reveals aspects of operations where limited infrastructure constrains most innovation efforts, not just those related to industrial ecology. Process enhancements that support an IE model of production therefore often establish an infrastructure and culture for innovation in other aspects of operations. These broader system improvements further enhance the value prospect of IE innovation activities. In its nearly three decades of operating in the global marketplace, Nike's footwear business has in many ways exemplified how multinationals can look to their supply chain for business advantage. During the past 8 years, Nike has begun to implement IE principles throughout the global value chain and life cycle of its products. These initiatives have fostered strategic and tactical learning internally, for Nike partners and in the business community at large. This paper will explore specific projects that Nike's Footwear Business has implemented with its global suppliers, contract factories in Asia and retail outlets worldwide to establish IE as an essential approach to creating business value across the triple bottom line of sustainability. Case examples will include interaction with materials suppliers on product environmental attributes, manufacturing process optimization at contract factories in Asia and extended product responsibility (ERP) programs with downstream partners. In addition, the paper will describe an application framework that Nike and its partners have recognized as essential to successful IE implementation.

Industrial Ecology as a working concept in a spatial and temporal "NIMBY" situation

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The temporal and spatial implication of NIMBY (Not In My BackYard) syndrome is examined from the perspective of sustainable development. The temporal feature considers the issue of intergenerational equity while the spatial dimension is concerned with intragenerational equity. Decision-making support systems generating information and knowledge using tools and concepts from both the natural sciences and social sciences are important in drawing the full picture of global metabolism now and in the future. This notion is embedded in World Commission on Environment and Development's concept of "Our Common Future". The role of industrial ecology as a science of sustainability is important in addressing different systems and issues using a holistic approach. However, the scope and methodology of industrial ecology should be revitalized in generating such information and knowledge. The experience gained so far from working with industrial ecology applications in the countries in the North should be critically evaluated in terms of its contribution to a global sustainable development. There is a need to recognise that addressing global scale problems such as climate change that threaten current and future generations requires a systematic approach to understanding the current and future pattern of global production and consumption. In this paper, a number of aspects that contribute to the revitalization of industrial ecology in light of this application will be identified. To this end, some conceptual discussions are made about intergenerational issues. Besides, quantitative data on raw material and product flows between different parts of the world are analysed as a background in the intragenerational part of the discussion. A revitalized industrial ecology is one with the capability to provide with an insight into the quantitative and qualitative composition of the production and consumption profiles of different parts of the world. This is important in optimizing current and future flows of materials and products at the global level using ecological, economic and social metrics.

The relation of Industrial Ecology versus natural ecosystems, and the fundamental principles for Industrial ecology in anthropogenic systems.

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Ecological systems and industrial systems may have much in common. Both systems are characterized by flows of material and energy between components, both contain components that use energy to transform materials, and both contain energy and material flow-regulating interactions such as competition and mutualism. These shared traits are reflected in the metaphor "an industrial system is an ecological system" that is central to industrial ecology (IE). At the same time, critical differences exist between the two systems, some of which might limit the value of ecological systems as prescriptive models for industrial systems.

Natural ecosystems are considered very efficient processes in regard to energy use and the ability to reuse all of the wastes generated. Nature does this through the ability of different organisms working together, e.g. one's waste is another's raw material. Study of the inputs and outputs of ecosystems (material flows) quickly reveals the efficiency of the processes. Industrial Ecology is the discipline learning from and applying these natural systems concepts to industrial and other human activities.
Operating from the premise that in natural systems, there is no waste, Industrial Ecology is a theoretical framework to examine environmental and efficiency flows in existing industrial operations, but also to guide the development of new systems. One of the goals of IE is to model industrial systems on natural ecosystems, in which waste products from one process are inputs for another.

The objective of the article is to critically discuss the metaphor of Industrial Ecology versus natural ecosystems. The question of how efficient natural systems are is discussed. The question of what fundamental principles that may be the base for industrial Ecology are looked upon. The article will also critically examine some basic attempts to formulate normative principles for anthropogenic systems. One such example is principle of the "The Natural Step". Finally the relation of Industrial Ecology to Sustainable Development principles is also discussed.

Industrial Ecology and Agro-Industrial Policy in Developing Countries

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Industrial Ecology could be critically important in developing countries where the availability of resources to the people is very poor. A policy platform that is based on the optimization of resources would also appeal to every citizen in these countries and this would ensure their involvement – so critical to the implementation process of any program.

Among the many specific aspects of developing countries that demand attention, is the fact that the pattern of resource flows in developing countries and hence the resultant threat to sustainability could be very different than what it is in the industrialized West.

Typically, the flows of materials through the large, organized manufacturing facilities in the developing countries could be very small in relation to the overall material flow. Table 1, showing the comparative drawal of water in different countries by different segments of the socio-economy, is very revealing. If any action has to be taken to preserve water in India, for example, or stop the deterioration in its quality, the action may have to go far beyond the large, formal manufacturing facilities. More particularly, since the material flows through the agricultural sector are critical, it is important to look at the agro-industrial systems holistically.

Table 1: Fresh Water Drawals in Different Countries
Source: World Development Indicators, World Bank 2002

Country	**%age Agriculture**	**% age Industry**	**% age Domestic**
U S A	27	65	8
India	92	3	5
Sri Lanka	94	1	5
Bangla Desh	86	2	12

The Resource Optimization Initiative (ROI), a new program to promote Industrial Ecology in the planning processes of developing countries, has just initiated a few field projects in India on an experimental basis. These are outlined below.

1. A comparative study of the resource flows through the entire process connected with cultivation of Rice and Sugarcane - including cultivation, processing industry or related manufacturing (such as sugar production, alcohol distilleries etc) and the net societal gains from the entire chain of activities including economic value additions, employment generation etc would be undertaken. The study would be done in one of the states in India to start with, on the basis of secondary data available and will be corroborated with field visits. An effort would be made to estimate the resources that go into the entire system including water, energy, land, pesticides, fertilizer etc and the possible damage to land and water resources. Notes would also be prepared, as a first step on the basis of published literature, on options to reduce the resource load into each of these systems, including possible opportunities for symbiosis. Based on such studies policies for optimum land use and cropping patterns could be developed.

2. The resource impact and the net social benefit of cotton cultivation, as in the case of the Sugarcane and Rice systems, and related cluster of industries would be assessed. This would include the different kinds of cotton, including GM, to understand the relative impact on resources, primarily land, water and energy. This is important as in India nearly 30 % of all the pesticide use in the country is for the cotton crop. The related industries with cotton would be included in the study such as oil extraction, ginning, production of cotton linters (used in the manufacture of some chemicals), animal feed, agro fuels etc. (No attempt would be made to include end products using cotton such as made up garments etc.) An effort would be made to compare the resource impact with that of tobacco cultivation and processing, as both the crops are grown in similar soil conditions.

Fieldwork on these projects has just begun. It is expected that preliminary results would be available before May 2005 and would be presented at the conference.

These studies would probably yield some new metrics to evaluate alternative agro-industrial networks and programs in developing countries – for example, employment generation per kiloliter of water consumed. Such metrics could be useful in framing Ago-Industrial Policy in developing countries that optimize use of the community's scarce resources.

Session B:
Sustainable Consumption

Chairmen: A. Carlsson-Kanyama

Location: Lindstedtsvägen 3
Room: E1.

Consumption and Industrial Ecology: Critical Review and Prospects

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One of the key contributions of IE to sustainable consumption are studies of household metabolism and household environmental impact. Further contributions include areas of eco-design and environmentally friendly product development or service for product substitutions, as well as contributions from the social sciences. The modeling of household environmental impacts (HEI) is often seen as a prerequisite for sustainable consumption efforts. Significant effort has therefore gone into household metabolism studies, which built on the energy analysis efforts developed in the 1970s. A review of household metabolism studies shows that there is a variation of approaches. Many studies use only input-output tables, some use a hybrid analysis which offers a finer resolution on the product level, and a few use only physical data. Studies for OECD countries universally show that private transportation, nutrition, and housing (including heating) are the most important categories. For both transport and housing, this is due to direct energy use, while for food this is due to the high pollution intensity of the products bought. In many countries, recreation and "luxury" consumption like hotels and restaurants are increasing in importance. Some studies have gone beyond looking at average households by looking at different income groups, family sizes, settlement type and demographic variables. The studies show that single households cause substantially more pollution than the average household and that the pollution per person decreases with household size. Pollution increases with income, but not proportionally, because luxury consumption has a somewhat lower pollution intensity. I illustrate some of those elements with results from our own analysis of Norwegian households. Recent advances in the field include addressing the issue of trade and the consumption of imported goods, and the inclusion of many impact categories, not only energy use. Household environmental impact assessments have provided a number of key insights. Nonetheless, recent contributions have been limited to repeating the same approach for different countries and context, without providing surprising results. While the tool of HEI assessment may prove to be valuable, there is little to be gained from a continued pursuit of a purely empirical approach. Instead, more interesting research questions need to be asked, and more practical attempts to implement sustainable consumption need to be undertaking. One option for strategic sustainable consumption research is the development of scenarios, which test out solutions and evaluate changes that are required to achieve sustainability, and assess their impact on economic actors. Another task is to target implementation efforts and evaluate examples of sustainable consumption. This requires making a connection between different research directions and discipline, a more direct involvement in implementation efforts, and larger funded projects. I will provide some examples indicating the direction this research needs to take in order to be both relevant and interesting.

Sustainable Consumption Research Exchanges (SCORE!)

An EU Funded Network Supporting UNEP's Ten Year Framework of Programs on Sustainable Consumption and Production

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Sustainable consumption and production (SCP) is key policy priority world-wide. The EU is – pending successful negotiations – likely to fund a research network in this field. The network will ensure that experts that understand **business development, (sustainable) solution design, consumer behaviour** and **effectiveness of (policy) instruments** work together in shaping them. Furthermore, this should be linked with **experiences of actors** (industry, consumer groups, ecolabelling organisations) in **real-life consumption areas.** Since in the EU a network with these characteristics is absent, we propose to set up a **Co-ordination action in the field of SCP, emphasizing on "user awareness" for sustainable consumption, involving key expertise covering all relevant steps of the value chain in the priority consumption domains Mobility, Agro-Food, and Energy/electronics.** These domains contribute to over 70% of the life cycle impacts of household consumption, are a priority in the EUs Enviromental Technologies Action Plan (ETAP), and give good examples of user awareness schemes (e.g. labeling). This paper is one of the first announcements of the network, describes its envisaged structure, and the possibilities for contributions. Apart from this we will present results from SusProNet, the EU network on sustainable product service (PSS) development and the potential to reach SCP via PSS.

Influencing Corporate Behaviour through Consumer Networks.

Lewis Akenji (Association of Conscious Consumers)

The growth of consumption, besides satisfying consumer needs, has increased environmental, cultural and health issues such as waste production, increased pollution, the spread of unhealthy food. Since consumers are the central benefactors of the market economy, conscious consumption patterns could support the economy of the region towards ecologically sustainable direction. Realising this, classical consumer organisations are widening their activities from consumer representation and protection to include Sustainable consumption, Corporate Social Responsibility, Green Accounting, etc.

There has been tremendous growth in consumption since the political and socio-economic changes in Central and Eastern European states changed to, and based their economic growth on market economy. These 15 years have had effects on the lifestyles of the people. An open economy means that a boom in national production and an influx of corporations have carved new attitudes around the former lifestyles and cultures. The tendency, and reality, is that the people are still new to the capitalist economy; without any principled control in the response of excited consumers, this has ushered in a wave of wanton consumerism that is threatening the quality of products, economic regulation, rights of consumers, as well as the social and natural environment.

Faced with the above, most NGOs used to operate chaotically as they were understaffed and lacked the proper training. In typical situations, such organisations, consigned to operating on a day-to-day basis, acted without structure or coherence. This left gaps and loopholes in how actions for sustainability were implemented. But these organisations have found a way of filling that large intersection between consumption patterns and the environment.

Networking for Sustainability

The program seeks to establish a regional network of non-governmental organisations (NGOs) from Central and Eastern Europe (CEE) dealing with joint issues of environmental and consumer protection. Such a network identifies the need around the region to have a common platform that can facilitate work on cross-boundary cooperation, to look at problems affecting the region from a wider angle, and to increase the capacity of civil organisations that do not have access to necessary resources.

How will this network influence consumers, and thus producers?

- The network will develop comprehensive consumer approaches towards businesses. These programs will not be limited to one country but have wide implementation across the region. Demand for actions under e.g. Corporate Social Responsibility, the Triple Bottom Line - environmental, economic and social - of sustainability, Business Ethics, Green Accounting show that consumer and environmental issues as irrevocably interrelated;
- Through common projects and programs, training, exchange of information, the network will improve the performance of participating organisations, build their internal capacities, and give a platform of common coordination, monitoring and evaluation. This will maximise the potential of NGOs to engage society in driving positive action;
- It will represent the interests, points of view of consumers in the region towards businesses and policy makers; and also shape a common viewpoint for new EU member states.

The program sees the joint forces of international umbrella organisations like Consumers International and the EU European Consumer Organisation, as well as national and regional NGOs from the CEE region. The Network will be launched in May 2005 in Budapest.

According to the European Union: "Companies are aware that they can contribute to sustainable development by managing their operations in such a way as to enhance economic growth, increase competitiveness and ensuring at the same time environmental protection and promoting social rights. Thus, Corporate Social Responsibility (CSR) is a concept whereby companies integrate social and environmental concerns in their business activities and in interaction with their stakeholders on a voluntary basis ('triple bottom line')."

Thus if companies adopt the CSR concept, they can reduce the externalities associated with their activities. They can reduce the tasks and burdens of government authorities and civil organisations, which monitor and regulate companies, or act in order to mitigate the social and environmental effects of negative externalities. Responsible companies therefore reduce the tasks and costs of consumer protection and environmental protection institutions, the competition authority and other governmental bodies; Responsible companies create more value to the society and the environment.

About the Association of Conscious Consumers, ACC.

ACC is a non-profit, public-interest NGO with the aim of creating awareness about the effects of consumption patterns of individuals and the public on the economy, the environment and the future of the planet as a whole. The association aims to contribute to positive changes in consumer values and the operation of businesses, supporting the improvement of our natural and social environment. We are strongly convinced that conscious consumer decisions help the (re)formulation of a liveable world and an ecologically sustainable economy, where companies do not achieve advantages over each other by reducing work safety or environmental protection costs, nor by forcing consumers through huge promotion campaigns to buy unnecessary products, but they meet the standards of good and healthy products, satisfying real consumer needs and in an ecologically responsible manner. We focus on:

- Ethical Consumption and Sustainability, including Corporate Responsibility, Public, and Individual responsibility;
- Interactions between Consumer Patterns and the Natural Environment including recycling schemes, labelling, pollution, etc;
- Public Education and Access to information.

New Approaches for Household Energy Conservation; In Search for Personal Household Energy Budgets and Ditto Reduction Options

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Introduction

During the nineties it was increasingly acknowledged that households and lifestyles are entities relevant to the quest for ways of reducing long-term energy impacts [1]. Since most consumer activities take place within households, a large part of our resource use is performed by these households. Direct (energy for space heating, electricity and gasoline) and indirect (needed for the production, distribution and waste disposal of goods and services, e.g. the production of food) energy flows through households add up to about 80% of the total energy flows through society for the Netherlands [2].

In contrast with other sectors and in spite of several information campaigns over many years, the direct energy consumption in households is still rising. Besides the increase in direct energy also the indirect energy requirements per household increased. Wilting [2] calculated that Dutch households require about as much direct energy as indirect energy. Although indirect energy requirements are important when looking at household energy conservation, thus far most research focused only on direct energy.

The main determinants of the spread in energy requirements are income and household size. On household level you see a large spread in energy requirements even within a group with the same income and household size. This diversity makes it hardly possible to address households effective by means of information in a more general way. Personalization of information could be a solution but is often very labor-intensive and time consuming. Because of the intensity of the contacts, feedback etc. such an experiment is only suitable for small groups, but the personal approach and the feedback appeared to be a powerful strategy.

The findings described above generate new research questions and possible solutions worthwhile to investigate like: is it possible to develop a large scale instrument which will be successful in reducing energy requirements in households. A more personal approach seems to have a good chance being successful. While direct energy only covers about 50% of the total household

energy requirements, the second question arises: is it possible to develop an instrument with which indirect energy in households can be measured in an easy way and can be reduced.
In the project presented here we developed a tool to address households, on the subject of energy conservation and, in such a way that:

- participants are approached more personal (reduction options and feedback)
- the approach will not be labor-intensive
- besides direct energy also indirect energy was taken into account.

The tool was tested and evaluated in a field experiment. The main questions in the evaluation were: did participants reduce their total energy requirements and was it possible to question and measure the indirect energy requirements and reductions.

The research was carried out as a field experiment with a group of 300 households in the city Groningen (the Netherlands). The combination of: personalization and feedback, indirect energy and scalability makes this experiment unique.

Tool

To develop a tool suitable for a scalable approach we choose for an interactive web-site. The challenge was to develop a web-site which looks good, was user friendly, personalized according to the questions as well as the energy reduction options and was able to gave feedback on the changed behavior. The questionnaire which stood central in this website addressed options for reducing direct energy as well as indirect energy requirements. The indirect energy requirements of consumer items were determined by a hybrid based easy to use Energy Analysis software program (EAP) developed by Wilting at the Center for Energy and Environmental Studies [2, 3, 4].

Experiment

Participants were selected on a voluntary base through advertisement in a local paper and direct mailing. In total 443 households responded positively but only 347 started the experiment.
The participants were randomly divided in two groups:

- an experimental group which received information about the objective, personalized reduction options and personalized feedback.
- a control group which was not exposed to interventions: this group received no objective no personalized reduction options and no feedback.

Of the 443 households which indicated to participate the experiment in the first place 190 (experimental group 137, control group 53) completed the experiment successfully.

Results

The results are summarized in table 1. The reduction % for the indirect part is not significant but the reduction for the direct part is clearly very significant.

Table 1. Average savings on household level.

	% reduction indirect energy	% reduction direct energy	% reduction total average
Experimental groups	-3.8%	+7.9%	+5.1%
Control group	-2.7% (0.632)*	-1.8% (0.000)*	-0.7%

* the values between brackets are the significances calculated by the univariate analyses of variance.

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Optimal Household Refrigerator Replacement Policy

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Refrigerators-freezers are one of the most energy consuming home appliances accounting for 14% of electricity consumption of the entire US households in 2001 [1]. With tightened efficiency standards between 1990 and 2001, the average energy efficiency of new model refrigerators improved more than 150% between 1980 and 2002 [2]. However, consumers are continuing to use existing less-efficient models resulting in the average useful lifetime of refrigerators over 14 years.

Although last decade witnessed dramatic progress in refrigerator efficiency, inefficient, outdated refrigerators are still in operation, sometimes consuming more than twice as much electricity per year compared with modern, efficient models. Replacing old refrigerators before a designed lifetime can be a useful policy to conserve electric energy and greenhouse gases. However, from a life cycle perspective, product replacement decisions also lead to economic and environmental burdens associated with disposal of old models and production of new models. This paper examines optimal lifetimes of mid-sized refrigerator models in the US, using a life cycle optimization model based on a dynamic programming [3]. This model accounts for burdens and costs associated with the production, use and end-of-life management phases each refrigerator's life cycle. Life cycle profiles, that represent overall performance based on parameters such as the energy efficiency and deterioration behavior of each refrigerator, determine the timing of replacement decisions over a specified time horizon.

Model runs were conducted to find optimal lifetimes that minimize energy, global warming potential, and cost objectives over a time horizon between 1985 and 2020. Figure 1 shows the life cycle energy consumption for a model year 1997 refrigerator based on the first year of usage. The use phase dominates the energy consumption even after one year. On the other hand, the purchasing cost of a new refrigerator ($430-670 in 1985 dollars depending on model year) is the most significant element of the consumer's life cycle cost. Compared with the purchasing cost, the annual end-use electricity costs ($20-110 in 1985 dollars depending on model year and age) are relatively small.

Results presented in Table 1 show that optimal lifetimes range 2-7 years for the energy objective, 2-11 years for the global warming potential objective depending on model years. On the other hand, 18-years of lifetime minimizes the economic cost incurred during the time horizon. Model runs with a time horizon between 2004 and 2020 show that current owners should replace refrigerators that consume more than 1000 kWh/year of electricity (typical mid-sized 1994 models and older) would be an efficient strategy both cost and energy standpoint.

The life cycle optimization model results for refrigerators provide useful insights for key stakeholders including manufacturers, regulators, and consumers. Opportunities for enhancing the life cycle management of household refrigerators by guiding product design, regulatory efficiency standards, market based accelerated retirement program, and consumers' decisions will be discussed.

Figure 1: Life cycle energy consumption and cost based on 1-year usage of mid-sized 1997 refrigerator model. (CR = Consumer Reports, AHAM = Association of Home Appliance Manufacturers survey).

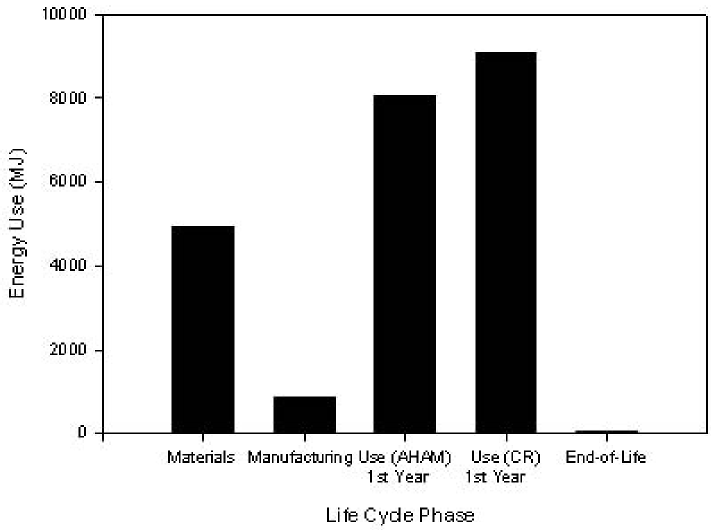

Table 1: Optimal lifetimes of refrigerators and cumulative life cycle inventories for the time horizon between 1985 and 2020 with the baseline assumptions: 1%/yr. increase of efficiency between 2002-2020
(CR = Consumer Reports, AHAM = Association of Home Appliance Manufacturers survey).

Objective	*Electricity use data source (1985 – 2002)*	*Optimal lifetime (years)*	*Cumulative energy use/GWP**	*Cost (1985 dollars)*
Energy	CR	2,5,4,6,5,7,7	357,558 MJ	$3,793
	AHAM	4,4,9,5,7,7	335,618 MJ	$3,186
Cost	CR	18,18	444,503 MJ	$2,534
	AHAM	18,18	407,907 MJ	$2,350
GWP	CR	2,7,3,5,8,11	22,197 kg CO_2	$3,633
	AHAM	4,5,8,5,7,7	20,956 kg CO_2	$3,211

*Integrated time horizon (ITH) = 100 yrs.

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Sustainable consumption – Australian case studies

Sven Lundie, Manfred Lenzen

Current consumption and production patterns of modern societies are currently unsustainable, i.e. outside the long-term carrying capacity of ecosystems. One measure to quantify the impact on bioproductivity caused by the consumption of populations is the Ecological Footprint, which calculates the land area which would be needed to sustain the bioproductivity use of that population indefinitely. This area is then compared to the actual biocapacity of the land that the given population inhabits. Populations with a higher ecological footprint than available land must obtain additional bioproductivity from trade, and hence exert pressure outside their boundaries. Ecological footprints can be calculated in four different ways; each approach may have advantageous and disadvantages regarding its use for educational and/or for policy design and planning purposes.
The theoretical background of how to address the issue of "sustainable consumption" is given in this paper. Case studies from New South Wales and Victoria (Australia) analyzing consumption patterns of urban and metropolitan populations over time are presented and analysed.

Environmental Impacts of Consumer's Time Use: Evaluating Alternative Consumption "Technologies by the Waste Input-Output Model

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In most developed countries, consumers are much more interested in saving consumption time. Electric home appliances and high-speed transportation equipments, for instance, give us convenience with saving time. However, these timesaving devices often increase environmental loads because they cause more energy consumption and waste discharge. In general, the economic development is regarded as mass exploitation, mass disposal as well as progress in saving time. It is thus quite important to properly consider consumer's time use in analyzing sustainable consumption (SC). We propose a new method, for evaluating environmental impacts of consumption patterns, which deals with the time-use aspect of consumer's behavior as well as the monetary aspect.

When consumers change their lifestyle for SC, income and time that are required also change. These changes frequently lead to increases in environmental loads as a whole because of additional consumption by saved income and time, as is pointed out by E. Hertwich [1]. These effects are called the rebound effects. It is broadly recognized that these rebound effects must be duly considered in the comparison between consumption patterns. In the SC literature, the income rebound effects have been analyzed in many researches (Takase, Kondo and Washizu [2] among others); on the other hand, the time rebound effects have been rarely examined at least in empirical studies. The notable exception is Jalas [3] in which the time rebound effects are neatly included, while the income rebound effects are not discussed. To consider the rebound effects with respect to both income and time, we introduce a new model.

Our model consists of two components; one is the waste input-output (WIO) model (Nakamura and Kondo [4]) and the other is an economics model describing consumer behavior. The WIO model is an extension of the conventional input-output model that takes into account the interdependence between the flow of goods and waste. By this model, we can evaluate the environmental impacts directly and indirectly induced by three stages of consumption (such as purchase, use and disposal) for each goods. The WIO model describes the correspondence of consumed goods to environmental loads induced by the goods.

To tackle the time-use aspect of SC, we develop an economics model of consumer behavior a notable feature of which is similar to the idea proposed by K. J. Lancaster, R. F. Muth, and G. S. Becker in 1960s. In our model, consumers are supposed to carry out their consumption activities using various consumption "technologies." For example, consumers "produce" their activity of passenger transportation by several consumption technologies, such as by car, by train, by bus or even on foot. Likewise, the activity of having a meal can be attained by consumption technologies, such as by cooking at home or by eating at restaurants. Because goods and time required for each consumption technology differ, a consumption technology is expressed as a bundle of inputs, that is, goods and time. Car transportation needs a passenger car, gasoline and 10 units of time, for example, while transportation by train requires the train fare and 20 units of time. In our model, consumers are assumed to choose their optimal allocation of time as well as income to each consumption technology to maximize their satisfaction. In other words, our consumer model describes how goods and time are consumed for each activity through consumption technologies.

By connecting this consumer model and the WIO model, we can evaluate environmental loads induced by goods required for each consumption technology. Environmental impacts induced by each consumption activity are also calculated in this way. It is noteworthy that some of the income and time rebound effects are incorporated into our model because income and time are supposed to be used up before and after changes of consumption patterns in the consumer model. We will also present several scenario analyses, such as shifts of transportation, spending leisure time and eating modes, where environmental impacts of alternative consumption technologies are compared. In some scenarios, the question which consumption technology is more sustainable might be undetermined beforehand. This research will answer this question and show the direction for SC to general consumers who face the time constraint in addition to the budget constraint.

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The Car Culture Wars: Lessons for Industrial Ecology and Sustainable Mobility from a Social Problems Perspective

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The study of social problems, in terms of their framing, public mobilization and policy response, is a very productive domain of social scientific inquiry. Indeed, the subdisciplinary specialization of environmental sociology was originally conceived around the investigation of how novel environmental issues have become (or for that matter not become) sources of political concern. Among scholars active in this area, the car is regarded as an anomalous case because campaigns to address it as a social problem have been limited to a distinctly technical series of critiques. Efforts to interrogate the automobile have been largely confined to questions constructed around narrow safety considerations (e.g., location of fuel tanks, availability of restraining devices, height of wheelbases). Furthermore, misgivings about operator competence have typically been restricted to ensuring adequate training for novice drivers and to legislating against drunken driving. Despite its commendable role in extending the range of human movement, cars annually lead to the reconfiguration of countless hectares of land, the death of thousands of people, and the exacerbation of numerous environmental dilemmas. Under these circumstances, it is perhaps surprising that the social censure of the automobile has been so anodyne. At the same time, there are indications that a "car culture war" is steadily developing between, on one hand, fervent automobile enthusiasts and, on the other hand, a growing array of urban planners, public health professionals, and social activists. These developments are contributing to a more expansive debate, one that moves beyond the tightly focused issues that have previously animated public discussions concerning the efficacy of automobile dependent lifestyles. This dynamic context is likely to have a number of important implications for industrial ecologists and others working to foster more sustainable mobility.

Session C:
Policy Cases

Chairmen: G. Keoleian / B. Frostell

Location: Lindstedtsvägen 5
Room: D3.

Emissions Trading and Industrial Ecology

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The European Union has relied heavily upon emissions trading as a strategy to promote reductions in greenhouse gases needed to meet the targets established in the Kyoto Protocols. The conventional theory of emissions trading claims that it spurs innovation. This claim might lead one to suppose that emissions trading stimulates industrial ecology.

This paper questions the claim that emissions trading offers significantly better innovation incentives than traditional regulation, relying on an analysis of the induced innovation hypothesis – the hypothesis, common in economics, that higher prices for production inputs stimulate greater innovation than lower prices. This hypothesis would suggest that a trading program, by lowering the cost of routine compliance, might produce less of an incentive for innovation than traditional regulation. This might imply that trading will not encourage more industrial ecology than a traditional regulation. But the possibility that incremental industrial ecological change might have value in a trading program that it would not have in a performance standard approach might suggest that trading will stimulate at least some industrial ecological change. This paper explores the possibility that emissions trading might encourage some incremental ecological change, while providing weaker incentives for major industrial ecological change than pollution taxes or performance standards. It will also explore an alternative economic incentive program, called an environmental competition statute, that seeks to stimulate industrial ecological competition. Companies commonly compete to improve the quality and value of the goods they produce. Yet, companies have few economic incentives to compete in improving environmental quality when there are substantial costs involved. This statute would create a strong incentive to compete to improve environmental quality, something that emissions trading does not do and environmental taxation only does in a limited way. It does so by allowing companies that pay money to reduce pollution to collect the costs of doing so from competitors that fail to equal their environmental achievements. This may have great utility in addressing the ecological industrial challenges posed by climate change.

Industrial and Environmental Policies in China

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China's economic growth has been extremely rapid in the past two decades, with an annual growth rate of about 10% in the last two decades. Subsequently, environmental problems are threatening China's sustainable future. Pollution damage is estimated to be around $54 billion annually and closed to 8 % of Chinese GDP. Policy makers in China are facing the tradeoffs between economic growth and environmental protection. Growth of total factor productivity plays an important role in GDP growth in Chin. The costs of alternative production and pollution abatement technologies, which are influenced by TFP, are important determinants of the environmental compliance cost. Thus, it is important to understand the interaction between environmental regulation and technological/productivity change. In the long run, the most important single criterion on which to judge environmental policies might be the extent to which they spur new technology toward the efficient conservation of environmental quality. Most of the empirical studies in the literature, however, are focused on the analysis in developed countries, especially in US. To our knowledge, there are no existing studies that have estimated the efficiency of environmental technology and management, systematically analyzed its determinants, and assessed empirically the impact of environmental regulations on productivity in China. We employ economic techniques and find that efficiency in Chinese environmental management is deteriorating. Our results show that Chinese environmental efficiency (or productivity) is decreasing while market productivity is improving. Main determinant of market productivity change is R&D while main determinant of environmental productivity is pollution abatement expenditure instead of pollution tax.

Keywords: China, technological progress, environmental regulations, and productivity management

Corporate Synergy System – A Successful Experience of Greening Supply Chain in Taiwan

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Similar to developing Asian countries, a large segment of industrial production in Taiwan comes from small and medium enterprises (SMEs). SMEs account for 97.7 percent of all Taiwanese enterprises that provide service and parts of products to large companies. However, these SMEs have limited capabilities in quality control, business management, and environmental performance. To enhance performance in these areas by SMEs, the corporate synergy system (CSS) has been promoted since 1984. Additionally, under governmental assistance, a nonprofit organization, i.e., the Corporate Synergy Development (CSD) Center was established in 1990 to provide related assistance. The Corporate Synergy System is a management mechanism that involves the formation of partnerships among business organizations to help each participating firm enhance their productivity, technological capability and management efficiency. Generally established within supply chains, CSS is initiated under the leadership of a large company that acts as the central firm, and the up-stream suppliers and down-stream buyers in the chain are organized to work together to achieve certain common goals. To date, more than 2,200 companies belonging to 140 CSSs in 13 major sectors have been organized in the manufacturing industries that produce 35% of the total industrial output of Taiwan.

The Industrial Development Bureau (IDB) of the Ministry of Economic Affairs (MOEA), an agency supporting Taiwanese industry, is also responsible for upgrading pollution control, environmental, safety and health issues in the plants. Before 1994, most applications for assistance were for end-of-pipe problems, among which SMEs consist of about 80% of the firms. Following 1994, most of applications for assistance involved industrial waste minimization and occupational safety and health, but SMEs represented only 50% of the total of firms requesting assistance. To effectively help SMEs to enhance their environmental performance, IDB has been providing assistance in waste minimization and occupational safety and health through CSSs since 1996, enabling the participation of SMEs to increase to 90%. After 2001, the scope of assistance was extended to Design for Environment and ISO 14001

Environmental Management System.

This work not only describes the processes of cooperation between Taiwanese government and enterprises in greening the supply chain using CSS, but also explains the roles and functions of the participants and consulting team. This work also describes how the central firm invites about approximately 15 suppliers to involve themselves in the cleaner production program, and all participants run from a kick-off meeting to obtain commitment from the top management of each company. This study also illustrates how external technical consultants facilitate central firms in improving their performance and results quantification, as well as invite suppliers to exchange experiences. Also explained here is how central firm together with consultants to help individual supplier for technical assistance and provide incentives to good performing suppliers, such as increased purchase quantities, upgrading purchase priority, shortened payment period and other related measures. As of 2003, some 577 enterprises in 47 CSSs were found to be participating in green supply chain programs, and the ratios of investment to profit were between 1:2.5 and 1:10. The CSS program has been demonstrated to be both environmentally and economically beneficial, and it also boosts enterprise image.

Keywords: Corporate Synergy System (CSS), Greening supply chain, Small and medium enterprises (SMEs)

Using Life Cycle Assessment to Inform Nanotechnology Research and Development

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By reducing the energy and materials required to provide goods and services, nanotechnology has the potential to provide more appealing products while improving environmental performance and sustainability. However, while nanotechnology offers great potential, it is unlikely to be the first entirely benign technology. A technological push towards greater investment in nanotechnology without a commensurate consideration of the net environmental benefits will likely lead to cases where the nanotechnology substitute is inferior to the product or process replaced. Changing a product to reduce its environmental impact after the product has been developed can cost orders of magnitude more than making the change during research and development. Whether and how soon the promise of improved environmental quality could be realized with nanotechnology depends on phrasing life cycle questions during research and development and pursuing commercialization intelligently.

Efforts have been initiated to develop a fundamental understanding of the behavior of nanotechnology-based materials in natural systems and their influence on biological systems. This understanding will improve the ability to project the direct environmental and health effects of these materials. To obtain a complete picture, it is also necessary to consider the life cycle implications of nanotechnology-based products. I present a framework employing technology scenarios and prospective hybrid life cycle assessment to estimate the economic and environmental life cycle implications of forecasted nanotechnology applications. The results of two case studies are summarized. In the case of using nanocomposites in light-duty vehicle body panels, the ability to disperse nanoscale particles in polymers would reduce vehicle weight thereby improving fuel economy. In the case of nanofabricated catalysts, the ability to position and stabilize platinum-group metal particles in automotive catalyst would reduce the amount of platinum-group metal required to meet emissions standards thereby reducing mining and refining activities. For each application, a conventional product is compared to its nanotechnology-based substitute to assess whether the nanotechnology substitute can be cost-effective and improve environmental quality.

While each analysis provided a detailed, quantitative assessment of the economic and environmental life cycle implications from projected nanotechnology advancemans, they were limited by the quantity and quality of available information. Based on the findings and limitations, I discuss the use of life cycle assessment to inform nanotechnology research and development, evaluate when life cycle inventories based on conventional materials and processes are appropriate for nanotechnology applications, and assess limitations caused by the gap between scientific knowledge and the understanding of the risks of nanotechnology. The findings presented here indicate that policy makers and industry can identify technology scenarios and employ prospective life cycle assessment during early research and development to evaluate future products and emerging technologies. The ability to evaluate life cycle implications of alternative courses of action during research and development improves the ability to evaluate tradeoffs, optimize products for all aspects of life cycle performance, and make more strategic R&D choices. A more informed understanding of the commercial, societal, and technological possibilities and its consequences will enable better decisions in regards to the selection, development, and commercialization of nanotechn

How does Environmental Policy Integration Depend on Characteristics of Environmental Problems? Examples from two Swedish Sectors.

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Thanks to efforts during the latest decades we know more and more about environmental impacts from different activities. It is however evident that often the development towards reduced impacts is slow, even though environmental hotspots are identified. Integration of environmental polices into all decision-making has been proposed as a way to sustainability, for example in UN documents as the Bruntland commission and Agenda 21, and it is also a key strategy in the EU environmental work (e.g. the Cardiff process). Analysis of the concept and practice of environmental policy making (EPI) is thus important for understanding the barriers to sustainable development.

In this study we try to identify patterns in which issues are successfully integrated and which are not. Environmental impacts of the agricultural sector and the energy sector in Sweden has been investigated with the help of a hybrid IOA-LCA method. An environmental analysis allows the ranking and estimation of the significance of different environmental problems for society as a whole in relation to National Environmental Quality Objectives. At the same time policy documents have been studied and interviews with policymakers have been made to analyse sector institutions and how integration of environmental policies works. An analysis of current policies allows us to estimate the commitment given to solving different environmental problems (i.e. differential level of EPI for different environmental issues). We have seen in a preliminary assessment a lack of correlation between these two variables - the most serious problems in the sectors are not necessarily the ones being addressed most forcefully by the political system. How do we explain this divergence in policy design? An analysis have been made by comparing the hotspot issues identified in the environmental analysis with the findings from the interviews as regards a few characteristics of the problems. In particular we discuss the following explanatory variables: the status of the knowledge base, the existence of particular institutional structures, and the positions of actors (winners and losers of policy design) in the policy-making system. Patterns found between the variables are presented and discussed, as well as implications for future studies.

Individual Implementation of Extended Producer Responsibility (EPR) Programmes - A Systematisation of the Understanding Based on the Analysis of Concrete Implementation Practices -

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Policies based upon *Extended Producer Responsibility (EPR)* aim to reduce the environmental impacts of products across their *entire life cycle*. The intent is to induce design changes in products and thus reduce impacts *at source* by provision of *incentives* to *producers* through an extension of responsibility.

Since the 1990s, the concept of EPR has been incorporated into the environmental policies of a growing number of governments, especially those of OECD countries. To date, these policies have predominantly addressed end-of-life management. By extending responsibility related to end-of-life management to manufacturers, an EPR programme aims not only to improve the end-of-life management *per se*, but also to provide incentives to manufacturers to design products that generate less environmental impacts at the end-of-life phase. Provision of responsibility is intended to link the *upstream* (design phase) of the product's life cycle with *downstream* (end-of-life management).

Despite the theoretically envisioned environmental improvements *upstream*, the focus of most governments, as well as entities that run EPR programmes, has been on the improvement of end-of-life management rather than promotion of design change. In this relation, an issue increasingly discussed is the application of so-called *individual* or *collective* responsibility when implementing EPR programmes.

In essence, *individual responsibility* means that manufacturers are responsible for the end-of-life management of their own products. *Collective responsibility* suggests a situation where producers of the same product group fulfil their responsibility for the end-of-life management of their products together regardless of brand. While an EPR programme based on individual responsibility is assumed to provide more incentives for design changes than one based on collective responsibility, individual implementation is perceived to face various administrative and institutional challenges. The perception of the challenges, combined with the lack of clarity of what individual responsibility actually means in practice, has discouraged adoption of EPR programmes that enhance possibilities for individual implementation.

The examination of five EPR programmes for EEE and batteries from the viewpoint of individual versus collective responsibility combined with the practices of individual producers indicates the existence of a variety of implementation mechanisms that incorporate elements of individual responsibility. Utilising the existing practices and typologies of responsibilities found in previous research, the author seeks to systematise the understanding of individual responsibility.

A *producer* bears an *individual financial responsibility* when *he/she initially pays* for the end-of-life management of *his/her own products*. A producer bears an *individual physical responsibility* when 1) the *distinction* of the products are made at minimum by *brand* and 2) the producer has the *control over the fate of their discarded products* with some degree of involvement in the organisation of the downstream operation. When the products are physically handled together, the distinction of the *properties* of the products, including their features on end-of-life management, should be made. Producers bear the *individual informative responsibility* for the aggregation and provision of information concerning the properties of their product and product systems.

The distinction of products does not require the physically separate handling of products. Existing practice suggests that the distinction of products can be made in various stages of the downstream operation. The timing found in the current practice includes the point when the end-user discard the products, at the intermediary collection points and at the recovery facilities. The manner of distinction – actors involved in the distinction, the roles of producers, and the like – also varies. Factors that affect the selection of the form of individual implementation include the end-value of the products, feasibility and ambition of the producers to establish its own downstream infrastructure, types of end-users, existence of other producers that share the same level of ambition regarding the end-of-life management of their products and the like.

From the viewpoint of promoting upstream changes, what matters most is whether or not the producers, not consumers, pay the actual cost of recycling. Even when consumers pay flat fees irrespective of brand, there exists a mechanism for producers to pay for the recycling of their own products. When the fee is visible, differentiated fees that reflect the degree of design for end-of-life would enhance the communication of the end-of-life property of the products to consumers. The experiences of EPR programmes for packaging suggest the possibility of differentiated fees. However, the properties of complex, durable products pose practical difficulties in actualising the correspondence between the size of the fee they pay and the actual recycling costs.

In light of various practical approaches discussed above, individual implementation should be considered first. The producers should be provided with opportunities to explore alternative solutions as when and how they would like to distinguish their products from the rest. In light of global destination of products, it is desirable that products carry with it the information necessary for distinction of their properties, by way of, among other things, marking on components.

Efficiency Metaphors as Scientific Policy Instruments

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The science of Industrial Ecology is based on a prescription of a certain form of efficiency. This means that in order for Industrial Ecology to become operational, industrial actors need to arrive at a specific efficiency perception. While the risks involved in the normative stance of Industrial Ecology have been under lively discussion, much less attention has been given to the implications that the implicit policy imperative has on the very nature of the field. This emerges partly from the fact that as a rather young scientific community Industrial Ecology has little experience of reflexive scrutiny on policy involvement. We propose that cases where scientific communities have used prescriptive metaphors close to those of Industrial Ecology serve as fruitful test material for the viability of the Industrial Ecology metaphor.

We examine the various prescriptions that the different institutes of the Kola Science Center of North-West Russia have attempted to imply on the Kola Peninsula mining industries. Emerging from the past planned economy, some of these prescriptions are based on efficiency metaphors identical to Industrial Ecology, most prominent being the concept of complex utilization. We claim that at a time when the complex utilization prescriptions were coherent for the scientific community as a whole, the metaphor was able to penetrate industrial decision-making and lead to construction of integrated industrial systems. Similarly, as the current scientific community is in conflict as regards its message to the society, complex utilization has a low potential for penetration as a dominant metaphor.

If the Kola Science Center is a case of failure for an Industrial Ecology type of prescription, what is the lesson for the scientific community? Is there something wrong with the efficiency metaphor and the prescription of Industrial Ecology? More generally, if the scientific community sees itself as a source for policy recommendations, how should it manage the promotion of its policies?

Policy Instruments on Product Chains-What can be Leant from Battery Experiences?

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The various stakeholders in the battery chain have since at least 30 years been the targets for various efforts aiming at either reducing the amount of toxic metals in the products or to substitute dangerous variants for less harmful ones. Stakeholders in this context are producers, retailers, consumers and local authorities with responsibilities for waste handling. Policy instruments applied have varied over time but in Sweden much focus has been on consumer information and administrative measures. Other policy instruments applied include voluntary agreements. This paper examines lessons learned by various stakeholders with the aim of deepening the understanding of how policy instruments in product chains can be applied more efficiently. Interviews are carried out and the results will be available during spring 2005.

Session D:

Economics, Business Economics and Industrial Ecology

Chairmen: J. Korhonen

Location: Lindstedtsvägen 17
Room: D1.

Eco-efficiency analysis. The finnish experience

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The measurement of the efficiency of material and energy flow conversions is one of the first concrete step towards imposing quantitative objectives on an economy complying with the principles of sustainable development. The main aim is to link together output (welfare) and input (use of natural resources). The advantage in using this linkage instead of, for example, the so-called "green" GDP is that no controversial methods need be used for setting prices on the external costs of material and energy flows. Nevertheless, it is capable of providing an estimate of the direction of progress. They also take into consideration the often overlooked fact that the current production systems of market societies can be economically efficient even when they squander natural resources and energy.

In their most simplified form, the key figures of economic efficiency express output in relation to expenditure, i.e. efficiency is yield over costs. Common indicator of the intensity of material use is the quantity of material used per unit of economic output, i.e. the weight of material per GDP. The indicator of the GDP/TMR ratio has been advocated by many researchers as the one to best describe the development of Eco-efficiency at the national level. However, it has been argued that the overall picture of the material use of an economy will be confused by the inclusion of unused resources (hidden flows) in an aggregate indicator (like the TMR). The TMR measure is quite problematic, since its insensitivity to the size of external trade reduces its informative value.

There are various methods of measurement with which the trend of the overall eco-efficiency can be viewed at the level of the whole society. In this article, the conventional Gross Domestic Product (GDP), the Human Development Index (HDI), the Index of Sustainable Economic Welfare (ISEW) and the Direct Material Flow (DMF), as well as Total Energy Consumption (TEC) are mainly used in the empirical analysis. As a highly aggregated and rough background indicator, the DMF is comparable to GDP in economic terms. The efficiencies of the Finnish conversion of material and energy flows into welfare did not develop until after 1993. After that a clear upward turn in Eco-efficiencies can be observed. Obviously, this development owes a great deal to the boom in the electronics industry, and more closely to the manufacturing of mobile phones and related components.

What then could be done in order to foster the eco-efficiency of the Finnish economy towards the Factor 4 and 10 targets? These actions can be divided into three categories, namely, (a) technological improvements in production policies, (b) environmental policy actions aimed at reducing the use of materials, and (c) social policy action aimed at evening out the distribution of the wealth generated. Obviously, the most efficient policy would be a mix of all these. From the economic point of view technological improvements can be created best by raising the prices of natural resources and energy.

For details see Hoffrén, Jukka: Measuring the Eco-efficiency of Welfare Generation in a National Economy. The Case of Finland. Statistics Finland. Research Reports 233. Helsinki 2001.

Management and policy aspects of Industrial Ecology: an emerging research agenda

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This presentation is based on the international symposium ‘Business and Industrial Ecology’ held alongside the 2003 Business Strategy and the Environment Conference in Leicester, UK and on the Business Strategy and the Environment special issue that was the outcome of the event. The main message is that the dominant natural science and engineering aspects of industrial ecology (IE) need to be linked to management and policy studies. IE has rapidly evolved into a new field with the concept of an ‘industrial ecosystem’ that uses the metaphor of sustainable ecosystems to provide innovative routes to change present unsustainable industrial systems. The editorial article identifies three themes as organizing categories in linking IE to management and policy studies. First, the systems and network philosophy of IE can be coupled with inter-organizational management studies to complement the more traditional intra-organizational environmental management. Second, management and policy studies complement descriptive IE studies of physical flows of matter and energy to produce prescriptive suggestions for how industrial systems can be moved through human action toward the vision of IE. Third, the metaphor is a source of inspiration and creativity in the transformation of management and strategic visions towards a new sustainability culture.

Decoupling trends of material flows, CO_2 emissions and energy consumption in selected countries

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One vital problem in the field of sustainability analysis has been the lack of reliable data, which has limited the operationalization of new theoretical concepts. The author notes that it may be too early to claim sustainability analysis to be useless in the field of environmental policy analysis. In the field of ecological economics, decoupling or de-linking environmental impacts from economic growth has become an important element of scientific debate on growth versus the environment. The political importance of decoupling necessitates some test to determine whether environmental pressure moves into desired direction or not. The aim of this paper is to analyze this important question.

In this paper, the author first presents a theoretical framework with some new concepts for decoupling analysis. On the basis of this theoretical framework, the author then presents an empirical study concerning the decoupling process of three different environmental indicators in 20 selected countries. The paper describes the decoupling process with (1) material flows measured by domestic material consumption (DMC), CO_2 emissions from fuel combustion and total primary energy supply (TPES) in the EU-15 member countries, United States, Japan and major developing countries including China, India and Brazil.

Theory of industrial ecology

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The central question of the theory of industrial ecology (IE) is: Whether IE is/will be a form of descriptive or prescriptive science? Some debate the same (more or less) question by asking whether IE is objective or normative? This author argues that in the case of the physical flows of matter and energy the description of the ecosystem flows can produce an important prescription for the industrial ecosystem overall goal and vision of ecological sustainability. However, the ecosystem cannot tell us what to do in practice and we cannot prescribe concrete solutions or practical measures for industrial ecosystems based on ecosystem description. In the case of the structural and organizational characteristics and properties of industrial ecosystems, it is very difficult (or impossible) to derive anything prescriptive for industrial ecosystems from ecosystem description.

Keywords: Industrial ecology theory; Ecosystem; Industrial ecosystem; Descriptive science; Prescriptive science; Material and energy flows; Structural and organizational characteristics/properties

Where is Corporate Social Responsibility Actually Heading?

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A discrepancy is indicated between the emergence of *environmentalism and the sustainability agenda*, and *accomplished environmental improvements*. Despite the increasing number of success stories, environmental and social progress is not keeping up to the same advancement pace. The enormous information asymmetries among actors in society and the dangerous circularity of rating and selection of firms may well obstruct the changing of the *State of the World*. Sustainability indexes may lead to investments in twice as much greenhouse gas emissions per turnover which is probably the opposite of what the environmental conscious individual investors have in mind. Thus, actions that diminish the need for *image building* are suggested. The scope of corporate environmental and social responsibility should be extended to better coincide with the actor who has the largest potentials to make a change, including governmental bodies by strengthened environmental and social public procurement – that is to *Walk the Talk* themselves.

Keywords -Corporate Social Responsibility, Hijacking Environmentalism, Information Asymmetries, Sustainability Indexes, Environmental image building.

Theory of industrial ecology: The case of diversity

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In *Theory of Industrial Ecology* (Korhonen, 2004a) two categories for classifying the properties/characteristics of industrial ecosystems were presented and evaluated; the physical flows of matter and energy (1) and the structural and organisational characteristics/properties (2). This contribution takes a closer look at the theory by focusing on the concept of diversity, an important concept in ecology and biology and an often-cited concept in sustainable development research. The research objective is to analyse whether or not the concept of diversity can be important and useful for developing industrial ecosystems, if yes, how, and if not, why not? Seven arguments presented in the literature arguing for the importance of the concept of diversity are evaluated. Some of the arguments hold while some of them do not hold.

Keywords: Theory of industrial ecology; sustainable development; Ecosystems; Industrial ecosystems; Diversity

Session E.
Eco-Industrial Parks and Networks

Chairmen: A. Chiu

Location: Lindstedtsvägen 5
Room: D2.

Do industrial ecosystems have lifecycles?

Marian Chertow
Yale University

The biological analogy in industrial ecology is central to the study of industrial ecosystems – networks of technical organisms in geographic proximity sharing resources including water, energy, by-products and wastes. This paper explores whether industrial ecosystems may have lifecycles that are in some way analogous to the life cycles of biological ecosystems – that is patterns and processes recognizable from recent findings in ecosystem ecology. Based on preliminary research it seems that industrial ecosystems have characteristics of self-organizing systems where organization increases as more exergy is pumped into the system. Furthermore, such ecosystems appear to develop more complex structures and processes with greater diversity and increased cycling, before reaching some maximum level after which self-organization may break down. Each of these hypotheses will be explored more fully in an attempt to decipher possible patterns and processes of industrial ecosystems.

James Kay suggests that industrial ecology must address the issues of complexity, self-organization, and uncertainty inherent to ecosystems. I suggest these characteristics can be seen in industrial ecosystems such as Kalundborg and Styria.

- Properties emerge from this "post-normal science" that can shed light on new hypotheses to understand some industrial ecosystem dynamics.
- Emergent hypotheses that reflect Kay and others with regard to strengthening the ecosystem approach to industrial ecology are now applied to Kalundborg as the exemplar of industrial ecosystems

H_1 - Quantity – Trades beget more trades

- Spatial – Kalundborg principle of the "short mental distance" between firms
- Temporal – trust over many years
- Momentum effect - acceleration from 7 exchanges in the first 20 years (1959 – 1979) to 11 exchanges in the second 20 years (1979-1999)
- Kay (2002) - as more exergy is pumped into a system, more organization emerges

H_2 - Quality – There is increasing complexity in the exchanges

- Gertler observed that the first links in Kalundborg were simple – sale of waste products (e.g. fly ash and steam) without significant pretreatment or rerouting. Later ones were more complex – outgrowth of pollution control technologies – altering processes and by-products - such as Novo sludge, scrubbed SO_2 at Statoil and Asnæs
- Kay (2002) - as ecosystems develop or mature they should develop more

complex structures and processes with greater diversity, more cycling, and more hierarchical levels to aid exergy degradation

Industrial ecosystems have a natural lifecycle

- As ownership and control become more disparate would diminish "short mental distance"
- Jacobsen & Christensen (of Kalundborg) – temporal – concerned about effects of generational change
- R.E. Ulanowicz - there is a 'window of vitality" - a minimum and maximum level between which self-organization can occur."
- Kay (2002) - The hierarchical nature of complex systems requires that they be studied from different types of perspectives and at different scales – no one is correct – need diversity of perspectives
- In total – spatial, temporal, organizational scale analysis – may reveal the lifecycle of industrial ecosystems.

From Miller **Living in the Environment** p. 80 - "the size of an ecosystem is arbitrary and is defined by the system we wish to study." Defines ecosystem "a community of different species involved in a dynamic network of biological, chemical, and physical interactions that sustain it and allow it to respond to changing conditions."

Graedel and Hardy - An increase in industrial organism diversity increases the number of interactions in which resources are shared.

Connectance values for biological& industrial food webs are similar (Hardy and Graedel)A central concept for BE food webs is connectance. Connectance is a quantitative measure, defined as the number of direct interactions in a web divided by the number of possible interactions.

- Not only important what happens *across boundaries*, but also to explore *internal ecosystem dynamics* (Kay and Schneider 1994)Also Kay 2002.

Industrial Ecology as a Management Concept for Chemical Industrial Parks

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In the 1990s a wide structural change in the sector of chemical industry took place in Germany. In the former GDR the changes began at the time of the German reunification in 1989 which raised a need to reorganize the East-German chemical industry. This led to the dissolution of big state-owned chemical companies and privatization of their vital production plants and transport and environmental infrastructure. The dissolution of large chemical corporations in western Germany began in the middle of 1990s. Here the plants with multifold products followed the global course of development by spinning off unprofitable branches of production and outsourcing functions that did not belong to the core competence of the parent company. In addition to privatization and spin-off processes the land owner companies opened their sites to new tenant companies leading to the formation of chemical industrial parks (CIPs). Currently there exist approximately 30 CIPs in Germany.

With the emergence of CIPs arose also the need for new management structures to operate the reorganized sites. All the German CIPs apply a private management model with a park managing company, i.e. a company that manages all park intern issues. These managing companies include the following main models: 1) Major user model and 2) infrastructure company model. In the major user model one dominant investor in the park is at the same time the park operator. This operator is also the owner of the land and has a status as a producer and as an infrastructure and service provider. In the infrastructure company model major investors in the park are shareholders of the operating company or the operating company is an independent firm. The infrastructure company is usually the owner of the land and has a status as an infrastructure and service provider.

Figure 1 presents a simplified material and energy flow scheme of a standard German CIP. As it can be seen the product synergies (mostly linear flows) in CIPs are well developed. Another common feature to all CIPs is that the managing company operates the environmental infrastructure of the park and offers these utilities to park tenants leading to well established utilities synergies (from linear to cyclic flows). Furthermore, the park operator provides the tenants with a range of centralized services (e.g. site security, permit management, environmental analysis, logistics etc.) resulting in a site wide service network. In addition to these synergies some by-product exchanges (cyclic flows) are documented around the biggest actors of CIPs such as cogeneration plants, waste incinerators and refineries. Since the German law does not define the organization form "industrial park" the operation of CIPs bases on various private-sector agreements including land leases and services contracts that are closed between the park manager and tenant companies. The developed synergies have brought remarkable economic benefits to the managing companies and tenants through especially "variabilization" of fixed costs and economies of scale.

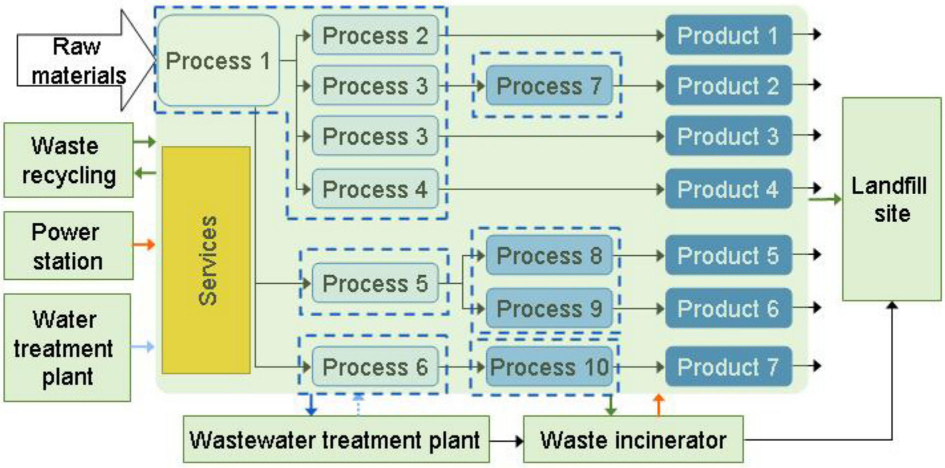

Figure 1. Simplified material and energy flow scheme of a standard CIP

In the current PhD project "Industrial Ecology as a Management Concept for Chemical Industrial Parks" CIPs are observed as industrial ecosystems in which collocated firms in a defined industrial area have different kinds of symbiotic interactions with each others. The CIPs are considered to be dynamic systems that go through the evolution stages of 1) planning and construction, 2) recruitment and 3) operating. All of these stages are characterized by specific strategic and operative management tasks. The overall research question of the study is: **How do the different management models affect the development of various synergies during the evolution stages of an industrial park?** This problem is examined empirically through case studies on the strategic and operative management levels. On these levels the following questions are posed, respectively:

- How do *the recruitment criteria (tenant portfolio) and the strategy* of a park manager influence the emergence of an industrial ecosystem?
- How can a park manager with the help of the various *management instruments* conduct the development of an industrial park into an industrial ecosystem?

The research framework is shown in Figure 2. Besides comparing the German brownfield developments with private management models a greenfield development with a public management model is included into the study.

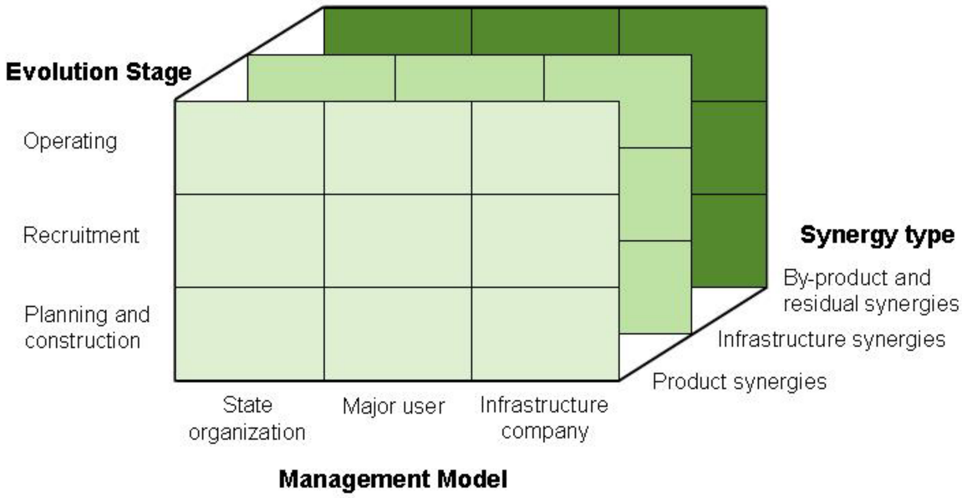

Figure 2. Research framework and basis for the comparative study

Research and decision support system of environmental evaluation of industrial symbiotic collaboration in Asian eco-industrial estates

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KeyWords: industrial symbiosis, Eco-town, zero-emission, Geographical Information System (GIS), eco-town reporting system, material exchange

Industrial Symbiosis (IS) is widely considered as one of the most effective policies and business concepts to realize sustainable developments, which are to reduce local and global environmental emission while providing feasible profits and motivations for business sectors, municipalities and citizen groups. As Kalundborg is argued as most advanced IS implementation over decades, a number of Eco-Industrial Estate (EIE) practices are planned and developed all over the world. Most of pursuing projects, unlike preceding Kalundborg case, are based more on their single stream industries or material flows.

In Japan, Eco-town projects were firstly developed in 1997 as subsidies. In the first fiscal year, four municipalities including Kawasaki City were approved as Eco-towns. Nineteen cities have been approved as Eco-towns up to March 2004. Three basic concepts of Japanese Eco-town projects include Zero Emission Concept to form a regional-resource-recycle-type economic society, promotion of industries with emphasizing environmental industries by utilizing the local know-how, and joint cooperation of local governments, citizens and industries. An Eco-town plan, which is prepared by local government recognized as a model for other local public entities and approved by the Ministry of Economy, Trade and Industry (METI) and the Ministry of the Environment (MoE), will be provided comprehensive and multi-phased supports

. The process to estimate feasibility of material exchange practices in Eco-town could be evaluated based on the application of GIS on the eco-efficiency of the system, by considering of the economic issue, including profits of business sectors, and environmental issues, such as the emission of CO_2 and the amount of waste materials to landfill.

The process to measure eco-efficiency is also discussed such as the factors of environmental values and environmental loadings. In the case of Kawasaki Eco-town, environmental value can be expressed in term of the business profits, and environmental loadings should integrate with the factors of CO_2 emission and the amount of waste materials to landfill. By assuming the profits to be constant in both situations, with or without the practices of symbiosis relationship, comparison of eco-efficiency in material exchange practices to conventional type of situation can be done quantitatively.

The evaluation and decision support system for Eco-town and Eco-Industrial Estates is to be extended toward the following symbiotic practices are to be evaluated.

(1) Collaboration among the industries in Eco-Industrial Estates

By integrating the quantitative data from eco-reporting surveys, matching of waste material exchange among industries can be designed, and the potential ways of material exchange practices can be evaluated.

(2) Collaboration between a Eco-town and neighborhood urban areas

By setting appropriate boundaries for collection networks, plausible cooperative waste reutilizations between urban sectors and industrial sectors are identified and their environmental impacts are evaluated as well as their economical feasibilities.

(3) Collaboration among Eco-towns and cities

Regional scale networking among Eco-towns and cities are also investigated for their environmental impacts and economical feasibilities.

Industrial Symbiosis Networks and Sustainability

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Regarded as the practical application of main industrial ecology principles at the regional levels, Industrial Symbiosis (IS) networks are gaining increasing interest, manifested in a growing number of programmes around the world aiming to assist their development. Despite their undisputable potential to improve resource use efficiency at the regional level, the overall sustainability contribution of IS networks are in times questionable and difficult to asses. This is a vital weakness in the field, specially given the importance of aligning emerging IS networks with sustainability objectives. In an attempt to address this weakness, in this paper we propose a framework to be used for the assessment of the the sustainability profile of IS networks. This framework considers six economic, social, and environmental goals that should be addressed in the planning for and execution of an IS network along with eight associated strategies that can be used to pursue these goals. The proposed framework is depicted schematically in Figure 1.

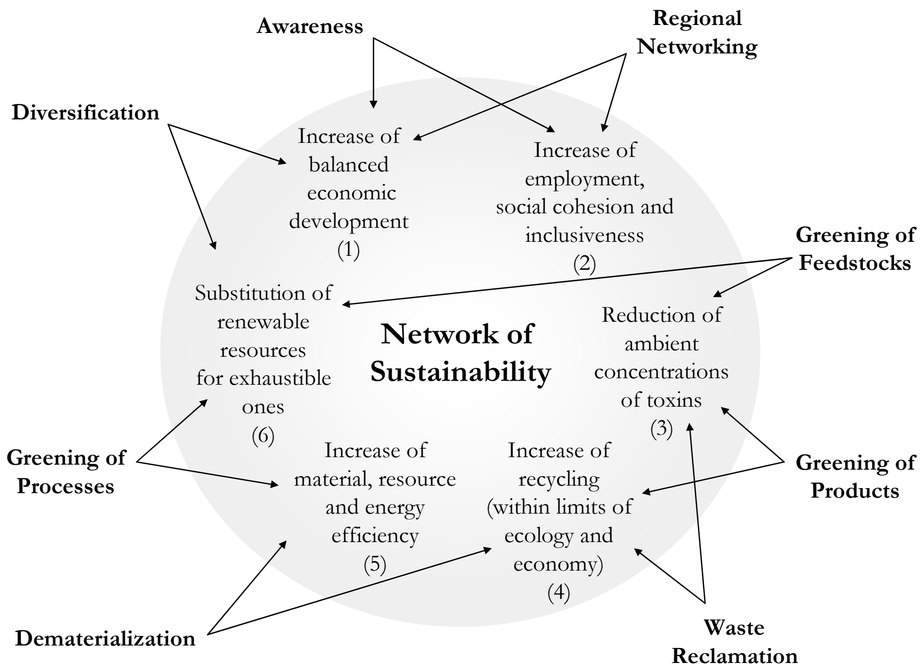

Figure 1: Schematic representation of the framework proposed to assess the sustainability profile of industrial symbiosis networks.

This framework is then applied to assess the sustainability profile of the IS network that is developing in the Swedish industrial town of Landskrona. In Landskrona more than 20 private and three public organizations have been actively participating in an IS programme coordinated by IIIEE since 2002. In addition to various organically developed inter-organisational resource exchanges in the town, additional opportunities for synergistic connections have been identified through this programme and some of these became operational. Figure 2 depicts the existing and potential syngertistic connections relevant to the activities in Landskrona.

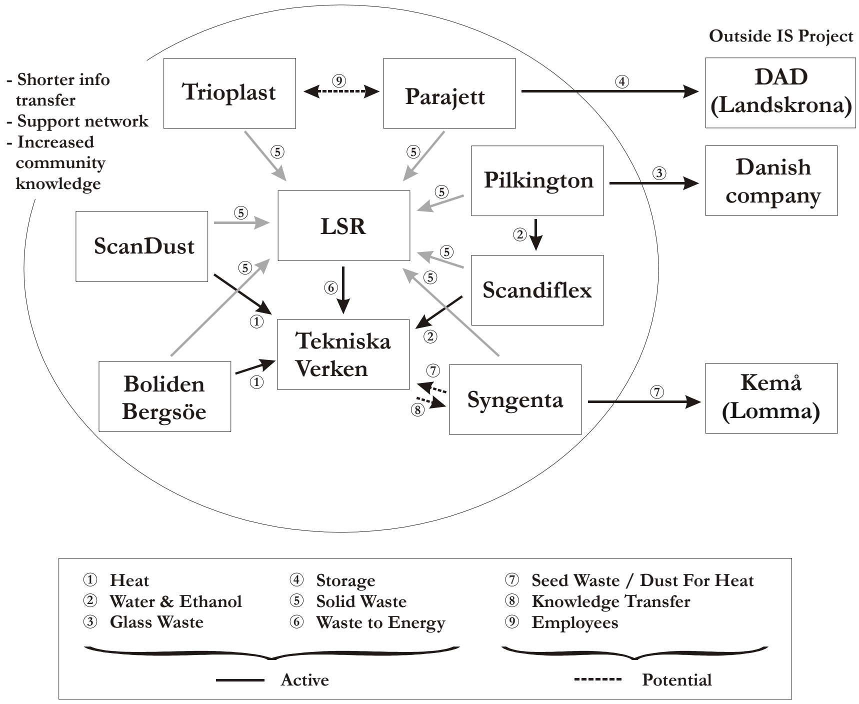

Figure 2: Existing or potential synergistic connections in Landskrona IS network.

Through the application of our proposed framework to Lanskrona IS network, we conclude that this network has various attributes that are well aligned with sustainability objectives. However, according to our framework, the network and its individual members will be required to:

- work more with the social issues;
- place more emphasis on the development and implementation of strategies and actions that will expand their focus beyond production loops and will enable them to close the consumption loops and reduce the total material throughput.

It is our recommendation that testing of this framework through its application of other IS networks and its consequent refinement should be an area of focus in IS related research. The outcome of such a work will provide valuable guidance better aligning IS networks with sustainability objectives and will thus help getting closer to a more sustainable industrial economic system.

Industrial Ecology in the Rotterdam Harbor and Industry Complex: `You need acknowledgement, vision, trust, and a long term program to make it happen'

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The INES (INdustrial EcoSystem) Mainport project (1999 – 2002) and the Rotterdam Harbor and Industry Complex (HIC) program (2003 – 2007) are long-term industrial ecology programs that continued the activities of the first INES project (1994 - 1997). All program's key objectives were to initiate and support activities within the Mainport Rotterdam that contribute to the sustainability of industrial operations and future port development. The Mainport is seen as an overarching area of activities that are identified as potential industrial ecology elaborations of: `the decoupling of economic growth and environmental pollution, the closing of loops between companies, the optimalization of energy streams, the joint use of facilities, and co-siting'. From 1998, a INES strategic decision-making platform with members of national and regional industry associations, plant managers, national and regional governmental organizations, an environmental advocacy organization and academia decide and evaluate Industrial Ecology projects in the program. All platform members saw the INES Mainport project as a strategic project that should evolve to the stage of a *sustainable industrial region*, in which all actors develop a gradually unfolding strategic vision of sustainability as basis for their activities.

The INES Mainport project is evaluated in 2003 as being in the stage of *regional efficiency*, in which the INES projectmanager cared for the knowledge dissemination, continuity, innovation, communication and the co-ordination of projects in a context that the companies decide about participation independently. The dynamics of the evolving industrial ecology concept in complex projects meant for the INES project manager a time consuming process with the need of much patience, sometimes forcing projects and anticipating set-backs. Based on persistency, also good results were achieved and implemented such as, a joint compressed air system (extended to seventeen companies in 2004), the outsourcing of utilities as the core-business of service companies, cluster management for heat exchange, co-siting at the sites owned by Huntsman and Shell, who supply all utilities to new companies on their sites, and different industrial water systems. It can be said that the INES Mainport project provided much insight in the `win-win' possibilities to manage energy and resources more efficiently.

The HIC program is radical in the way how after ten years of exploring rest heat research, the breakthrough to the utilization of rest heat (approximately 2000

MW of heat is emitted to the air) in residential and green houses (including CO_2) is nearby. The Shell plant management, an energy provider, an energy distributor, the municipality and two housing associations signed a contract with the intention to deliver rest heat to 5000 dwellings in 2006. It is concluded that the long term program provided the condition for this development.

As result of the ongoing industrial ecology programs is observed that at a conceptual level a spin-off of knowledge and willingness for co-operation has developed. Illustrations are that the industrial ecology concept is also applied in not-INES Mainport and HIC projects, that industrial air and utility companies experience a better acceptance of the `multi-utility' concept and that direct information about the INES Mainport project showed single companies better solutions in an Industrial Ecology context than optimalization within their own company.
Furthermore, the difference between the perspective of industry and government representatives became clear. The awareness and recognition of each other's perspective was utilized in for developing transparency, co-operation and trust as important elements in industrial ecology and sustainable regions activities. Ofcourse communication in such time-consuming and complex projects to all stakeholders is very important. In the HIC program is agreed that the organic growing of networks of all stakeholders and the insight in each other's position is crucial. Strong cases for strategic discussions and choises are seen as needed steps for developing a sustainable region. From the INES Mainport project was learned that the relationship with projects in practice gave added value to avoid changes of thoughts without engagement. That has been the basis for the ongoing reflexive approach in the HIC program as interaction between strategy evaluation and practical projects as pathway towards a sustainable region.

Tees Valley Industrial Symbiosis Project: A Case Study on the Implementation of Industrial Symbiosis

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The Tees Valley Industrial Symbiosis Project (TVISP) was established in January 2003 to facilitate the uptake of Industrial Symbiosis principles in the Tees Valley, a highly industrialised area in the North East of England. This paper describes the results of the first two years of operation of the project.

Industrial Symbiosis (IS) is the alignment of industry along the 'waste = food' principle found in mature natural eco-systems. The concept came to prominence through the discovery of symbiotic synergies between companies in Kalundborg, Denmark. Other Symbiotic clusters have since been discovered in Styria, Austria and the Houston Ship Canal, USA.

These examples of IS were not developed consciously, rather they developed as a result of the chance collocation of compatible industries and the economic and legislative climate in that region, eg the level of landfill and aggregate taxes, and restrictions on the landfilling of certain substances. However, such an evolutionary approach will deliver benefits very slowly as each company adapts individually to reduce its costs. More recently, many projects have been established to actively develop symbiotic clusters for example at Chaparral Steel, USA and in the UK on Humberside, West Midlands, Grangemouth and Mersey Banks.

The industry of the Tees Valley is dominated by the petrochemicals industry, largely located on three sites: the two ex-ICI complexes of Wilton and Billingham, and the Seal Sands site which has always held a variety of companies. The two ICI sites were built upon IS principles, with the ex-chief executive of ICI, John Harvey Jones, declaring in 1993: "*...our aim was to utilise every last bit of waste... each plant was in some way linked to, and supplied by, the others and the end product which had to be disposed of was very small.*" However, since the splitting and selling off of these plants in the 1990s, the number of plants on Wilton has dropped to approximately 50% of that during the ICI regime, leading to an increase in waste not being utilised as a resource - an example of how the turnover of actors can disrupt IS systems.

Other major industries include iron- and steel-making, pharmaceuticals and inorganic chemicals. The total waste arising from Teesside's industries amount to 2.5m Tpa of commercial and industrial waste and a further 0.25m Tpa of hazardous waste.

The Tees Valley IS Project (TVISP) was designed with three main strands of activity:

- Brainstorming: bringing stakeholders together in structured brainstorming sessions to develop potential synergies (a stakeholder method);

- Data Collection: collecting waste and raw material information from each participant and matching them manually (also known as input-output mapping);
- Major projects: promoting ideas for new facilities with a large capital requirement.

TVISP has undoubtedly been effective, engaging 70 companies, including almost every major manufacturer in the area, and diverting over 30 000 Tpa of waste from landfill with a further 500 000 Tpa under advanced discussion.
Of the material diverted, the majority has been:

- Plastics recycling using process waste and packaging from a variety of sources;
- Composting of a variety of biodegradable material for soil improvement in agriculture;
- Solvent recovery and recycling.

The companies receiving these materials have generally been innovative small to medium size enterprises (SMEs). Of the material under discussion, 50% involves a German specialist investing in plant on Teesside to process major waste flows including a substantial amount of hazardous material.
Of the three strands of the project, the quick wins generally arose from data collection. A larger number of more innovative synergies were generated during the brainstorming sessions, but many of these were later filtered out on technical, economic and/or risk grounds. A number of major projects were identified such as waste heat recovery for domestic heating, but generally these did not progress due to a lack of a champion to drive them forward.
The paper plots these new material flows and describes to what extent the barriers to IS identified in other cases and academic literature were addressed and/or overcome. In summary, the positive lessons to be learnt from the project are:

- The amount of material already diverted from landfill represents extremely good value for money in regard to the funding supporting the project;
- If all the ongoing negotiations are successful, the project will have succeeded in reducing the waste generated in the Tees Valley by a substantial amount;
- Economic benefits were substantial with over 20 jobs created with several times this number in the pipeline if and when the synergies under discussion come to fruition;
- The dynamic process used in TVISP led to quick wins, building up a strong sense of momentum in the project which in turn kept enthusiasm high amongst participants;
- The combination of methods led to a good mix of quick wins and more innovative ideas;

- The most interesting synergies were the interactions across sectors, in particular in the petrochemicals industry, which has historically co-operated to maximise synergies within the sector, but has seldom considered synergies with other industries.

The barriers that impeded the project were:

- Major infrastructure projects require substantial championing in addition to the facilitation that the project could resource. This has been identified as a priority for the second phase of the project;
- Major synergies require lengthy negotiation between companies due to the risks involved. The full benefits of this project are only likely to emerge in the medium to long term.

In conclusion, TVISP has been highly successful and presents a robust, proven model for other facilitators of industrial symbiosis.

Update on Industrial Symbiosis in the Kwinana Industrial Area

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The Kwinana industrial area is a coastal strip of 8 km located approximately 30 kilometres south of Perth (Western Australia). The area was established in the 1950s to accommodate the development of major resource processing and other heavy industries in Western Australia. There is a coexistence of diverse and non-competing processing industries in the Kwinana area, such as alumina, nickel, and oil refineries, chemical factories, power plants, a cement manufacturer, and fertiliser plants.

A comprehensive economic impact study illustrated the importance of the Kwinana region to the economy of Western Australia. This study also identified over hundred regional synergies in 2000 (including supply chain, by-product and utility synergies) between the key 26 operating companies in the Kwinana region, and pinpointed the potential for establishing new synergies. It was reported that the existing synergies deliver real-time economic, environmental, and social benefits to the companies involved, the surrounding communities and other operations. Since then, two major new industrial facilities have been built and commissioned by the end of 2004, which further enhance the area's industrial symbiosis. These are: a water reclamation plant that produces 6 GL/yr premium quality industrial process water from tertiary treated wastewater and diverts treated industrial effluent from coastal discharge to ocean discharge; and the world's first commercial 800,000 tonnes/yr direct reduction iron making plant (Hismelt), which not only revolutionises iron making by eliminating the need for coke and sinter plants, but also produces iron from currently discharged low grade iron ore and possibly also from iron containing industrial by-products.

Despite a growing number of regional synergies in well established heavy industrial areas, such as Kwinana, it appears that only direct reuse opportunities available through relatively well established technologies (e.g. heat exchange, water reuse, and cogeneration) have been realised. This implies that even though Kwinana is well positioned as an example of international best practice in regional synergies / industrial symbiosis, outstanding technology and engineering challenges have prevented many other opportunities from being realised.

The Centre for Sustainable Resource Processing (CSRP), established under the Australian Commonwealth Collaborative Research Centres Program, launched in 2004 a research and technical assistance project entitled 'Capturing Regional Synergies in the Kwinana Industrial Area' (hereafter referred to as the Kwinana

Synergies Project). The project aims to support the further development and implementation of profitable exchanges of by-products, water, energy, and services between Kwinana operations. The potential synergies will only come to fruition, through dedicated research and hands-on support to quantify the potential size of each of them and to identify, screen and package the technologies that could realise them.

The detailed objectives of the Kwinana Synergies Project are to:

1. Collect input/output data for principal materials, energy and water streams for companies operating in and around Kwinana, and synthesise these data into an area wide resource and process flow database.

2. Identify and assess further regional synergy opportunities in the Kwinana area that improve the overall eco-efficiency of the area.

3. Support operating companies and the Kwinana Industries Council with the development and evaluation (including trials) of promising regional synergy opportunities.

Up to 80 by-product and utility synergy opportunities have been identified to date, and it is anticipated that this number will increase over time as the project progresses. Potential synergy opportunities are identified by the resource and process flow database and brainstorm sessions during workshops. Additionally, participating companies suggest synergy opportunities during on-site visits. All identified synergy opportunities are screened based on whether or not they are within the scope of the project, to what extent they have already been evaluated and/or undertaken by the companies, and if the demand quantity meets the supply quantity. For each selected synergy project, the research team conducts an opportunity appraisal in close co-operation with the involved companies. The opportunity appraisal is a triple-bottom-line assessment that enables a comparison of the expected contribution of the potential synergy project to improvement of the eco-efficiency profile of the Kwinana region. Preliminary business plans will be developed for the projects with the highest potential success rate.

The conference presentation will give a status quo on the latest developments in the Kwinana Synergies Project and will share the lessons learnt from the emerging regional synergies in Kwinana.

Note

The Kwinana Synergies Project runs parallel with a similar project in the Gladstone industrial area (Queensland) and is supported by a foundation research project that reviews and documents current and emerging best practices in regional synergies, develops and trials a novel methodology for regional eco-efficiency opportunity assessments and assesses synergy technology needs and opportunities. This project is titled 'Enabling Tools and Technologies for Capturing Regional Synergies' and will feed into both the Kwinana and Gladstone Synergies Projects.

Acknowledgements

The research reported here is supported by the Centre for Sustainable Resource Processing, which has been established under the Australian Commonwealth Collaborative Research Centres Program. Professor van Berkel's Chair in Cleaner Production is co-sponsored by Alcoa World Alumina Australia, CSBP Limited, and Curtin University of Technology.

Keywords: Regional synergies, industrial symbiosis, Kwinana, Australia.

Eco-Industrial Development in China

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The increasing resource and environmental pressures have impeded China's efforts to quickly promote their people's life quality, while protecting their natural environment. Due to lack of resources, technologies and capital, China needs to seek a more integrated development strategy. Industrial ecology may be one solution as it aims at optimizing the use of materials and energy in products, processes, industrial sectors and economies by systemically mimicking natural systems in an industrial setting. The relevant practices and experiences in the developed world have proved that there is a degree of effectiveness and efficiency to development through the application of industrial ecology. It is even more critical to apply the principles of industrial ecology in China, where resources are scarce. However, compared with developed nations, China faces different environmental, economic and social constraints. Therefore, China has to adopt different approaches to implement the concept of industrial ecology. In this paper, we first review the current practices in eco-industrial development in China. Then the advantages and barriers to apply industrial ecology in China are analyzed and recommendations are provided.

June 13.
Technical session T2

T2 AM

Session A: **Tools in IE**

Chairmen: K. Cockerill

Location: Lindstedtsvägen 3
Room: E1.

Can the Chinese Steel Industry Learn from Past US Experiences? A Comparative Dynamic MFA Perspective

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Recent disruptions in the steel scrap markets due to economic growth in China illustrate the interdependence of the steel cycles among different world regions. Long-term forecasts for future steel production and scrap supply are relevant for policy decision-making and investments in mining, furnace technology, and waste management infrastructures. Such forecasts need to be based on an understanding of the steel cycles in the main producing and consuming countries.

The Yale Center for Industrial Ecology is conducting a research project, which aims at understanding the cycles of iron and its alloying elements on national, regional, and global levels. The project uses material flow analysis (MFA) based models, which are programmed in MATLAB, in order to simulate different long-term scenarios for future production and consumption of steel, and to identify options for improved efficiency of these cycles. The core of the model lies in the stocks in use, which provide the desired services, and which influence future scrap availability as well as future steel demand due to possible replacements of these stocks. Model applications are illustrated for the US and China.

The simulation results of the US show that the steel stocks in construction are dominant compared with the stocks in automobiles and machinery and appliances. As constructions have a relatively long lifetime compared with other use categories, scrap production follows steel production with a relatively long delay, which is relevant for long-term scrap supply. In the construction sector, the input is still about 4-5 times larger than the output; in the other sectors, input and output are almost balanced. Overall, US steel production uses about 60% scrap and 40% refined iron (mainly pig iron).

In China, raw material supply differs strongly from the US: The Chinese economy is mainly based on refined iron and new scrap. Production of old scrap (from discarded products) is still negligible, which is compensated through old scrap imports, causing disruptions on the world scrap market. The total scrap use of China constitutes about 15% of the raw materials for steel production. Simulation results show that the Chinese scrap shortage is a temporary phenomenon, which depends on the lifetime distribution of Chinese steel products.

Incorporating variability into a life cycle analysis of nutrient flows in agriculture.

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The inherent variability in agricultural systems can be difficult to capture in life cycle assessments, which often require the use of only one value to represent inputs and export factors to the system. The upstream and on-farm flows of carbon, nitrogen, and phosphorus were modeled and compared for the US corn belt. Through the use of Monte Carlo simulations, the model incorporates both natural variability (i.e. the differences in nutrient exports from a wet year to a drought) and data uncertainty. This research is set in the context of bio-based products, where the carbon uptake of plants and the aqueous emissions of nitrogen and phosphorus are important environmental factors.

Quantifying Material Flows in the US Economy,

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National material flow accounts (MFA) provide detailed information about the physical inputs and outputs associated with a nations economic activity. These flows represent the pressure that the economy puts on the environment during the extraction, use, and final disposition of commodities used in the economy. Defining the magnitude and character of these flows and how they change with time, is therefore, essential to evaluating the sustainability of a nation's economy. This paper examines the inputs and outputs to the US economy from 1975-2000. It is based on a recently completed World Resources Institute (WRI) study which represents a considerable expansion and extension of previous work presented in Resource Flows: The Material Basis of Industrial Economies, 1997, and The Weight of Nations: Material Outputs From Industrial Economies, 2000.

Detailed information on the changes in the physical material flows in the US during the twenty-six years was developed using over 160 discrete commodity inputs and over 600 output flows to produce a comprehensive database for the entire period. These flows were then combined to produce aggregated macro indicators of national consumption, additions to stock, and outputs. In addition to the aggregated data, specific flows associated with transportation and energy use, housing and construction, heavy metals and specific commodity materials, are examined to illustrate the level of detail and information contained in the accounts. The major national indicators for the US were also compared with similar indicators for the EU, as published by Eurostat, to illustrate possible useful cross-country comparisons.

Finally, existing data and methodology issues and database availability are discussed along with a brief status of current MFA activities in the US.

Ecological Benchmarking on Company Level: Measuring the Ecological Efficiency of Sites or Companies

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Life Cycle Assessment (LCA) methods that have been developed in recent years allow for the comparison of ecological advantages and disadvantages of products and services. However, how can the ecological performance of entire production sites or companies be compared? In this case, it is difficult to define a functional unit as a standard of comparison: A site or company generally produce many products, so that working out complete LCAs for each of them would mean too much of an effort. Nevertheless, being able to compare different sites or companies is quite important, as on this level many significant decisions are made about ecological positioning within markets and society.

As the result of a research project funded by the German federal state of Baden-Wuerttemberg, a system of environmental performance indicators has been developed, trying to reach the following aims: The main intention was to measure environmental efficiency on a *company level*, not a product level. To achieve this, the resulting benefits needed to be confronted with the ecological damage of a site. The indicator system should therefore allow for the comparison of different production sites as well as of the same site over time, taking into account different and changing product portfolios and vertical ranges of manufacture. The second challenge was to consider a *comprehensive ecological responsibility* that a company bears beyond the ecological impact of the specific site. And thirdly, the effort to implement and utilize the indicator system should be minimized in order to make it *suitable for practical usage*. Therefore, managers should be able to calculate the indicator quite easily, preferably by using data provided by their accounting system or which can be obtained simply. This can be difficult, especially as value-added chains have become more and more globalized while vertical ranges of manufacture have become shorter. Thus, in some industries, getting information about the entire supply chain is rendered almost impossible.

The indicator system that the Institute of Applied Sciences in Pforzheim has succeeded in developing meets all of the three above-mentioned criteria. Representing environmental impacts of companies for the time being, the focus has been laid on climate impacts, measured by the global warming potential (GWP) of green house gas (GHG) emissions. In principle, it is also possible to chose and quantify other impacts such as toxicity, acidification or ozone depletion. The generated formula, allowing for an easy calculation of the climate efficiency of a production site or a company, takes into account extended *ecological responsibility* for GHG emissions in the following ways:

Firstly, it includes the climate efficiency of *suppliers* in a coherent and easy way, alleviating the problem of allocating GHG emissions to the various products that are produced by a specific site or company: It has become possible to avoid the effort of assigning a site's production processes to its specific products and of measuring their respective GHG emissions. Additionally, methodological problems of allocating emissions to products in the cases of joint-product production are solved by introducing a simple, yet stringent allocation system. Last but not least, the organizational effort of obtaining the data of the supply chain is minimal.

Secondly, *reduction processes* for the disposal of waste can be introduced into the indicator system as well. The fundamental idea of the indicator system and the type of extended responsibility it implicitly assigns to a company, is to confront a company's revenues with its expenses, interpreted both ecologically and economically. For this purpose, modern concepts of production theory are used. This allows for the coherent handling of waste and goods both as inputs and outputs of production and reduction processes from one link to the other along the entire product life cycle: from production through usage and on to waste disposal. As can be seen, there are some similarities to the Life Cycle Assessment of products, but also significant methodological differences. In this way, the indicator system can in principle be used to evaluate the ecological efficiency of every company within the *entire economy*, both production and reduction companies, in a coherent and easy way.

However, there is still another quite interesting aspect to the indicator system and its basic concept of revenues and expenses: It is also imaginable to apply it to the *evaluation of products or services*. In this case, the focus of attention is the user of a product or service. The benefit (revenue) of the user (e.g. mobility: driving from point A to point B) is compared to the direct GHG emissions during consumption (the combustion of gasoline during driving) as well as the indirect emissions caused by the expenses incurred with the benefit: the emissions along the supply and reduction chains of the products needed to create the benefit (the car and the gasoline). Thus, the entire direct and indirect expenses incurred by the benefit are considered.

All in all, the indicator system is able to assess the climate efficiency of companies or of specific sites. It can in principle be applied to the entire economy, i.e. both production and reduction companies. The indicator can be introduced and calculated quite easily, especially as problems concerning the allocation of emissions to specific products are alleviated and, to allow for the extended ecological responsibility of a company, it is only necessary to get the efficiency indicator from its preliminary suppliers within the supply chain as well as the waste disposal companies directly behind the company itself within the reduction chain. Last but not least, in addition to the evaluation of companies, it is also feasible to use the indicator system to assess the ecological efficiency of products: from production through consumption and on to reduction.

Integrating Waste Input-Output Analysis with MFA

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This paper is concerned with integration of waste input-output (WIO) model [1] with MFA/SFA. The WIO model is a closed model of goods production, waste generation, waste treatment, and waste recycling, the empirical application of which is facilitated by the associated accounting system (WIO table) that represents the flow of goods and waste among different sectors of the economy including waste treatment.

Waste is a mixture of a large number of substances with a large variety of its carrying forms (goods). For instance, lead (Pb) may occur, among others, in discarded car batteries in the form of electrode, in discarded CRTs in the form contained in glass, and in discarded appliances in the form of solder. From the point of view of waste and environment management, it is of great importance to be able to trace the flow of substances and goods that carry them over life cycles in the economy.

Tracing of the flow of substances within the framework of input-output modeling requires a proper consideration of the mass balance between input and output including waste generation: that portion of material input that does not physically enter output becomes waste. WIO in its current form is not able to trace the flow of substances in the economy because it does not consider the mass balance between input and output, while it does consider the mass balance of each good and waste. In short, tracing of the flow of substances requires consideration of the column-wise mass balance in addition to that of row-wise balance, which is automatic in input-output analysis (IOA).

MFA/SFA has been widely used to trace the flow of substances among different sectors of the economy. As far as its modeling is concerned, MFA/SFA is based on conventional IOA [2]. The fact that IOA in its conventional form is short of providing a closed loop solution of goods production and waste treatment may impose certain restrictions on the analytical applicability of MFA/SFA. In particular, effects on the recovery of specific substances of employing alternative waste treatment and recycling technologies may be difficult to consider based on MFA/SFA, notwithstanding its superb ability to depict the flow of substances.

By integrating WIO model with MFA/SFA, a closed loop analytical model of MFA/SFA is obtained. It is known that reordering of IO coefficients matrix can reveal a certain triangular structure that represents hierarchical degrees of fabrication among inputs [3]. It is shown that this triangular nature of IO matrix is of fundamental importance for deriving analytical model of MFA/SFA. In particular, goods are divided into two groups depending on degrees of fabrication. The first group refers to those that are directly obtained from natural resources and do not use any other input as its component; metal elements such as Pb are a typical example. The second group of goods refers to products that are made of a mixture of inputs of the first group such as batteries, CRTs and appliances. The net input (input that enters output) coefficients of materials can then be represented as follows, where the upper partitioned matrix refers to inputs from the second group and the lower one refers to those from the first group.

$$\widetilde{A}_{MM} = \begin{pmatrix} \widetilde{A}_{\beta\beta} & 0 \\ \widetilde{A}_{\alpha,\beta} & 0 \end{pmatrix}$$

The net input coefficients here are measured in physical units such that its column elements add up to unity. The Leontief inverse of this matrix is then shown to give the material composition of any good with regard to inputs from the first group. Applying this to physical WIO, one can obtain MFA/SFA of any input from the first group. Because the whole system is imbedded within the WIO model, evaluation of alternative waste management scenarios on MFA/SFA such as mentioned above is straightforward.

Empirical applicability of the model is illustrated for a case study with regard to metals (iron, ferroalloy, copper, zinc, lead, and aluminum) and electric appliances.

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A regional environmental impact modeling framework for Australia

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Environmental impact assessment or reporting methods such as the ecological footprint are often criticised because of their finite scope and boundary settings. In the case of an urban water provider for example, ecological footprints should capture not only effects caused by the water treatment process, but also upstream effects caused by the production of chemicals purchased by the treatment plant, by producing the concrete for the respective chemical factory buildings, by the supply of raw minerals to the concrete factory, the machines used to mine these minerals, the steel to produce the mining equipment, and so on. Furthermore, downstream effect of water usage should be accounted for, such as land, freshwater or sea contaminated by heavy metals released from households with the wastewater stream.
The interaction between downstream ecological processes and upstream economic activities can in principle be investigated using an integrated framework, where an economic input-output model serves as the conceptual centre, and generic fate models of ecological processes are linked to its outputs. Since ecological processes act on a geographical scale that is much smaller than that of the Australian economy, a crucial requirement for the combination of these economic and ecological model components is that the input-output model has to be regionalised.

A collaboration between Sydney Water Corporation, an urban water provider, and the Universities of Sydney and New South Wales has developed an integrated framework that links downstream pollutant fate models with a detailed regional upstream input-output model. Thus, industrial and ecological effects of economic activity can be quantified more accurately, and used to formulate appropriate policies, to benchmark companies, and to report and communicate sustainability issues to industry stakeholders and communities.

Ecological Footprint Analysis as an Approach for Assessing Products' Environmental Performance

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Life cycle assessment (LCA) has long been adopted for assessing product's environmental performance. However, LCA suffers from a subjective judgment that must be made in an environmental impact assessment when applying a weighting scheme. Correspondingly, its applications are restricted, particularly in policy-making. Ecological footprint analysis, which coverts the impact of consumption activities into the earth's limited land areas, does not involve a weighting procedure and can be applied as an alternative to LCA. Nevertheless, traditional ecological footprint analysis concentrates mainly on consumption activities, which fall into five major categories: food, housing, transportation, consumer products and services. A database that consists of various conversion factors is required to evaluate products' environmental performance.

Although this study largely focuses on developing a method that utilizes ecological footprint analysis to evaluate products' environmental performance, conversion factors that are required to convert products' environmental impacts (especially pollution) into the footprints (land areas) must first be determined. Here, this task was tackled by adopting the concepts of "the carrying capacity of polluted land" for assessing soil contamination, i.e., defined as the area of land to be abandoned because of pollution and "the purification capacity of vegetation" to assess air and water pollution, which is defined as the area of land planted with vegetation that needed to absorb air and water pollution. The concepts of Environmental Burden (EB) and Potency Factors (PF) were applied to assess and aggregate the footprints (areas) of the different chemicals that have similar environmental impacts. The proposed method has been used to convert some environmental impacts into ecological footprints. These impacts include global warming, atmospheric acidification, formation of photochemical ozone (smog), eutrophication and contamination of soil by heavy metals.

Environmental impacts of a lead acid battery, obtained from commercial LCA software (i.e. SimaPro) were assessed to estimate the ecological footprint and thus test the developed conversion factors. The factors for global warming, atmospheric acidification, photochemical ozone (smog), eutrophication and the contamination of soil by heavy metals are 3.22ha, 28.55ha, 1.01ha, 0.0003ha and 0.05ha, respectively. Results of this study are obviously preliminary, and the

conversion factors for ozone depletion, carcinogens, toxicity, acidity, waste, energy consumption, and other issues are still under development. After the conversion factors have all been determined, the environmental impact of a cellular phone will be addressed as a case study in terms of ecological footprints.

Keyword: Ecological footprint assessment, environmental impact, conversion factors, product evaluation, environmental performance

Session B
IE Management/Operations Research

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Room: D3.

Life Cycle Assessment Optimization Model for Cogeneration Systems Applications in Commercial Buildings

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The purpose of this paper is to present a model that can be used for energy system selection and performance analysis of natural gas-fired cogeneration systems and grid-based energy systems in commercial buildings. The framework of the study is composed of three main stages: an energy simulation model, a life cycle assessment (LCA) model, and an optimization model. Cogeneration models that have been previously developed in literature are available in three main areas: simple design-point models, which have been applied for quickly predicting plant performance and providing data for preliminary economic analysis; part-load performance models, which have been developed to predict plant performance at part-load conditions; optimization models that use operation research techniques to optimize the operation of utility plants to minimize operating cost or to maximize revenue (O'Brien 2000). The available modeling options in literature lack modeling of the design and operation of energy systems based on their environmental impacts but focus their objectives on economic implications. The LCA optimization model that is developed in this study uses environmental indicators as decision variables for the selection of energy systems and optimization of the operational strategies that integrate cogeneration systems with district utility energy systems in commercial building applications. Such an approach provides policy-officials and decision-makers with a tool that could be used in sustainable planning when designing optimum energy systems and operational strategies that favor lower primary resource consumption and emissions and maximize process efficiencies.

The LCA optimization model will be useful for: (a) selecting and sizing cogeneration systems for certain applications; (b) designing operational strategies that integrate the thermodynamic characteristics of energy systems with their primary energy consumption and emissions; (c) analyzing the effects of the various thermal and electrical energy use in buildings (due to seasonal or regional factors) on the performance of energy systems; and (d) predicting the life cycle impact resulting from selecting and operating specific energy systems for certain applications.

The scope of this study is limited to the application of the energy systems that are investigated in commercial buildings. Cogeneration systems that are investigated in this study include solid oxide fuel cell (SOFC), microturbine, and internal combustion engines (ICE). Grid-based energy systems included in this study are U.S. average electric generation power plant and natural gas-fired combined cycle power plant (NGCC). Natural gas-fired boilers are considered for thermal energy supply and absorption and electric chillers are considered to meet the cooling demand of the building.

The first stage of the framework is energy simulation, which is used to generate the building's hourly cooling, heating, and electrical energy demand. Seasonal variation in energy use data is presented for spring, summer, and winter months.

The second stage of the framework is an LCA model of the energy systems. LCA is the compilation of process inputs and outputs and the evaluation of the potential environmental impacts of a product system throughout its life cycle. The LCA model is developed following the International Organization for Standardization (ISO) framework (ANSI/ISO 1997). The life cycle stages that are covered in the LCA model include raw material acquisition (exploration/production, conversion/combustion), transportation/transmission, and use. Functional units are the hourly, daily, monthly, and annual electrical and thermal energy use of the hypothetical building under study. The environmental impact indicators chosen to quantify the potential contribution from the product's inventory flow are primary energy consumption, global warming potential (GWP), tropospheric ozone precursor potential (TOPP), and acidification potential (AP). The emission results obtained from the LCA model are further used in two steps: firstly, emission results are used as decision variables in the optimization model. Secondly, after the optimization results are acquired, emission data resulting from the optimum energy systems and operational strategies are used in the assessment of the life cycle impact of energy generation and operation in the building.

The third stage of this study is to develop an optimization model to determine the optimum cogeneration system and operational strategy. In order to determine if a cogeneration system is technically and economically feasible, several parameters must be investigated to evaluate the selection, sizing, and operational strategies of a cogeneration system. Cogeneration systems can be operated in various ways depending on the type of energy demand and energy use in a building. The two critical parameters that are investigated to evaluate the feasibility of using cogeneration systems are (a) building's electrical and thermal energy use, and (b) electrical and thermal efficiency ratios of cogeneration systems. Cogeneration systems can be sized to meet the peak electric or thermal load, depending on the electrical and thermal efficiency ratios of the cogeneration systems and on the cogeneration plant configurations. Cogeneration systems can be operated to meet the thermal energy demand of the building, referred to as thermal load following (TLF). Another mode of operation is meeting the electrical energy demand of the building, referred to as electrical load following (ELF). A hybrid strategy utilizes the best features of the electrical and thermal load following strategies. The hybrid strategy calls for the plant to be operated to achieve maximum savings during electric or thermal peak demand periods. The environmental factors primary energy consumption, GWP, TOPP, and AP, are used in the objective function of the optimization model. Depending on the objective function, the optimization model can be solved to minimize an individual parameter or a combination of: primary resource use and emission impacts as well as maximize system efficiency or minimize life cycle cost. The life cycle assessment optimization model can be used to evaluate the selection of alternative cogeneration systems, size those systems, and determine the preferred operational strategy based on the desired set of criteria.

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Multi-Criteria Based Evaluation of Reverse Logistics Systems

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Recycling of materials aiming at the highest possible purity and utility level is of prime importance regarding the concept of industrial ecology (Gradel & Allenby, 1995). In this context, regulation of treatment of discarded electrical and electronic products was one of the targets of the Fifth Environmental Action Programme of the European Union. Because of the resulting adoption and national implementation of the European Union's directive on waste electrical and electronic equipment (WEEE) (European Parliament and Council, 2003), changes in the field of electronic scrap treatment are expected. For Original Equipment Manufacturers (OEMs) this will result in minor organisational changes and the bearing of treatment expenses. However, disassembly companies are currently concerned about major structural and functional changes in their operating area. Amongst others, concentration and centralisation tendencies are feared. In context with these changes, negative impacts on the treatment of WEEE may appear, e.g. ruin of small and medium sized enterprises (SMEs), limited competition, loss of jobs for unskilled or handicapped people, increase of transports and thus increase of emissions as well as decline of transparency of costs and material flows (Chryssos, 2000; Müller, 2003; Urbanek & Schneider, 2002; Klatt, 2001).

To prevent centralisation tendencies, there is a need to derive recommendations for preservation, redesign and further development of the existing decentralised WEEE treatment system. In this context, empirical studies of small and medium sized disassembly companies were carried out, analysing critical factors of success (Walther & Spengler, 2004). Additionally, economic evaluations of disassembly networks were performed, deriving indications for cost reductions (Walther & Spengler, 2003). The results of these analyses demonstrated that a collaboration of SMEs in networks as well as support of economic, social, ecological, and also political stakeholders will be necessary in the future to achieve persistence of decentralised treatment structures.

Therefore, these stakeholders (e.g. sustainable oriented OEMs awarding disassembly contracts) are to be convinced that decentralised WEEE treatment structures provide advantages in comparison to central systems. In this context, the aim of this contribution is to compare central and decentralised treatment alternatives taking into account not only economic but also ecological, social and technical objectives.

For such cases, where various (and often opposed) objectives are to be considered, methods for Multi-Criteria Decision Making (MCDM) are applied (Zimmermann & Gutsche, 1991). MCDM allows decision makers to simultaneously consider quantitative cost and non-cost related as well as

qualitative criteria. Also, it allows realistic modelling, traceability and transparency of decision processes and provides the decision maker degrees of freedom for formulation of objectives and preferences (Zimmermann & Gutsche, 1991).
In our contribution, we first determine appropriate alternatives of WEEE treatment systems. Secondly, evaluation criteria are defined. While economic criteria (fixed and variable costs) can easily be added to one single value, ecological as well as social and technical criteria have to be structured in a hierarchical way and weights are to be assigned to every single criterion. By discussion of criteria and weighting with stakeholders, and also by structuring them, the evaluation process becomes transparent and traceable.

Subsequently, a characterisation of alternatives is done using data of comprehensive empirical studies, of input-output material flow modelling and of an economic evaluation of material flows and processes. Based on this data and relevant criteria, MCDM methods are used for evaluation of different alternative treatment systems. Since preferences of decision makers vary, variations in the weighting of the criteria allow scenario and sensitivity analyses.
Based on this evaluation, recommendations can be derived for political decision makers, as well as for ecological and social stakeholders regarding advisability of support of decentralised treatment systems. Additionally, recommendations can be given for OEMs (often having sustainability goals as second instance after economic critiera) whether and under which conditions a contracting of or collaboration with SMEs in recycling of WEEE is feasible. For the small and medium sized disassembly companies, weak points to be improved, but also strengths to be commercialised can be deduced.

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Modelling Decision Making in Disaggregated Analyses of Industrial Networks

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The systems under study in Industrial Ecology are typically highly integrated networks for the supply and utilisation of products and services. When considering these networks, it is useful to distinguish between two levels of analysis, namely aggregated and disaggregated approaches. The former considers the network as a whole, and focuses on aggregated flows (e.g. of material, energy and capital). It can be argued that such a "global" perspective is consistent with the level of analysis required by governments or strategic planners who may be interested in optimising systems as a whole. Under these circumstances, some of the nodes in the network may be disadvantaged (e.g. financially or in terms of the constraints placed on their operations), while others may benefit. Such global models of networks may assist policy makers and planners to design appropriate instruments (e.g. regulations, taxes, incentives, subsidies, etc.) to promote the achievement of the global optimum. However, it should be recognised that the network contains parties who will act in their own interests. The pursuit of own interests may lead to suboptimal configuration and operation of the network – a situation which may be exacerbated by an imperfect or inappropriate policy or legislative environment. In order to understand what is likely to manifest and how this might differ from the global optimum or perceived ideal, it is necessary to analyse the network from a disaggregated perspective, i.e. considering the operating environment and corresponding behaviour of each node in the network. It has been argued that even for policy, an aggregated perspective of industry is inadequate and that a disaggregated approach to analysis is required to develop the necessary understanding of the "values, knowledge and incentives faced by various actors in both the demand and supply sectors" (Axtell et al., 2002). Such disaggregated approaches to analysis are referred to as "agent-based" (e.g. Deffuant, 2001; Axtell et al., 2002; Bousquet and Le Page, 2004; Monticino et al., 2004).

Industrial networks can be considered to be complex systems. The elements of complex systems are typically mutually co-determining, i.e. the behaviour of the various subsystems, and the interactions between them, influence and are influenced by each other. This results a dynamic system (i.e. one that can change over time) which has emergent properties (i.e. the combined activity of the elements of the system lead to particular patterns or outcomes which can be observed when considering the system as whole). "Agents" are particular subsystems which exhibit autonomous behaviour. These need not necessarily be individuals, but can be collections of individuals or entities (e.g. firms, villages, industrial sectors, etc.). An agent-based approach to the analysis of such complex systems is a "bottom-up" approach which focuses on the behaviour of these various subsystems and their interactions in order to reveal the dynamic and emergent properties of the system as a whole. Computer based simulations of multi-agents, also called multi-agent simulation (MAS) (Bousquet and Le Page, 2004), allow the modelling of individual agent behaviour at a disaggregated level and shows the state of the system resulting from the actions of the agents, the interactions between agents and their interactions with broader environment (e.g. the biophysical environment).

One of the key challenges for MAS is to model the decision making of the agents. It is not uncommon to assume that agents display rational behaviour, i.e. they maximise some objective function subject to the constraints they face. Such optimisation may include mathematical approaches (e.g. linear programming), single objective optimisation (e.g. maximisation of utility within a microeconomic framework) or even multi-objective approaches to optimisation (Bousquet and Le Page, 2004). The assumption of rationality is clearly a simplification of real life decision making which would be influenced by cognitive, emotional, social and cultural factors (e.g. Fischhoff and Small, 2000). The idea of "bounded rationality" (Simon, 1976) takes into account the cognitive limitations of decision makers and the state of their knowledge when faced with decisions. This is one of the founding tenants of behavioural economics where the focus is on understanding how people actually behave and make decisions.

Despite the advances in computer software and hardware, the development of credible agent-based simulation models is a substantial undertaking. However, it is recognised that agent-orientated analysis of networks to provide a disaggregated perspective that accounts for the effects of distributed decision making and the implications of mutual co-determination is essential. The development of agent-based models using simple behavioural rules for agents could assist in this analysis. For this, approaches based on multiple criteria decision analysis (MCDA) and heuristic approaches based on behavioural economics show potential. This paper explores the use of both of these approaches in agent-based models and demonstrates some initial attempts at such agent-based modelling in the context of a network for the utilisation of biomass for energy provision in South Africa. Some perspectives are also provided on the decision contexts in which it would be essential to use an agent-based or disaggregated approach, rather than a global approach, for the analysis of the biomass energy network.

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Environmental Management System in practice. Assisting Decision-makers to achieve performance

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Environmental management systems (EMS) have become a common and formal part of organizational operations over the past 10 years. A major concern of both firms and the public is how EMSs influence environmental performance outcomes. The intent of EMSs is continuous improvement across all environmental impact categories, yet the limited transparency of EMS goals and outcomes does not immediately indicate that continuous improvement is achieved.

We consider this question from perspectives both internal and external to the firm. An in-depth case study method investigated nine multinational corporations to examine their EMS structure and information systems. Results indicate many common EMS characteristics regardless of firm type, such as policies, goals, audits, and management review. EMS coverage is consistent with current regulatory requirements, particularly compliance with emissions reporting requirements. Broader aspects of environmental performance get less attention, such as extended product responsibility or risks of potential problems. Environmental management information systems follow the emphasis on regulatory requirements. Table 1 lists the most commonly available environmental information and that most requested by management based on our study. Results reveal little communication of key environmental performance information outside of EHS personnel and required reports. This limited communication hinders decision-makers in making the major technological changes necessary to bring about improvements in environmental performance.

External to a firm, policy makers and the general public have only limited information to compare facilities. We analyze the environmental performance of U.S. automobiles assembly facilities with regard to their ISO 14001 EMS certification. Across several environmental performance variables – toxic releases, criteria air pollutants, hazardous waste generation, and compliance records – no significant differences exist in the environmental performance of the facilities, regardless of their time of certification and length of certification. Merely the presence of an EMS is not sufficient to determine the improvements in environmental performance, although often used as an indicator of environmental performance efforts.

The results of both analyses lead to five elements to broaden development of EMS structures to achieve performance improvement:

1. Quantifiable goals for both short- and long-term performance.
2. Risk assessment of emerging environmental issues that may impact operations and products
3. Process maps to facilitate understanding of inputs and outputs
4. Useful method of collecting and disseminating environmental data
5. Collaboration of environmental professionals both within the organization and outside

These elements are practiced by some firms to various degrees and are chosen to emphasize decision-making tools within an organization. From an industrial ecology perspective, such elements are necessary for EMS to be used effectively by organizations.

Table 1. Most commonly available and requested information in Corporate Environmental Management Systems

Environmental Information	**Most commonly available**	**Most commonly requested**
Injury & Illness Incident Statistics	1	**1**
Air Emissions Management	2	**6**
Key Performance Indicators	3	**9**
Non-Conformance Statistics	4	23
Chemical Inventory/Management	5	**7**
EHS Auditing	6	**3**
Notice of Violation Tracking	7	**10**
Waste Management	8	**2**
Computer Based Training for Environmental	9	21
MSDS's - Incoming from vendors	10	**4**
Spill Tracking and Notification	11	**5**
Computer Based Training for Health & Safety	12	18
EHS Documents/Knowledge Base	13	26
Energy Consumption/ Energy Management	14	11
ISO 14001 Management System	15	15
MSDS's - On the Web for Customers	16	12
Pollution Prevention	17	13
Toxic Release Inventory	18	17
MSDS Creation - Outbound for Customers	19	20
Regulatory Tracking Calendar	20	24
Wastewater Management	21	14
EHS Project Management	22	19
Product Liability/Product Stewardship	23	16
Regulatory Interpretation Library	24	**8**
Stormwater Management	25	25
Toxicology Information	26	27
EHS Cost Analysis	27	22
Voluntary Program Participant Requirements	28	28

Resource Efficiency in the Context of Plant Layout Planning

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This paper demonstrates the use of a metric of resource efficiency as a basis for plant layout planning. Consequently, the term resource efficiency is discussed within the paper before a practically applicable methodological approach in presented and employed for a case study.
The definition of resource efficiency from an applicability point of view is complex since various parameters must be considered and representative ones selected. Especially for environmental resources, in which the virtues of competition do not apply in most cases, no competitive markets exist which could guide resources to their maximised utility, just as the discussions for public goods and external costs show. Therefore, the idea is to understand waste not as material to be discarded, but as a potential future resource. Thus, the material properties determine the value of a resource. Furthermore, questions concerning the consideration of recovery (i.e. higher resource efficiency for simpler recovery) and functionality are briefly addressed. The determination of plausible ratios between the different resources is important in order to counterbalance them and to illustrate the trade-offs.

Multi Objective Pinch Analysis (MOPA) is presented as a systematic analysis tool for the techno-economic assessment of plants and production systems [Geldermann et al. (2004), Treitz et al. (2004)]. Firstly, a process model must be developed based on the specific process data and requirements. This model can be used to support the screening of technologies for selecting various alternative technology combinations. This screening is backed by the BAT catalogue and the analysis of emerging technologies. Based on the process model characteristic figures are calculated reflecting the technical, ecological and economic impacts of all available technology combinations. Next, resource efficiency as the overall objective for the assessment is broken down into a multiple objective optimisation problem for energy-, water- and solvent-process streams and implemented in MATLAB using the Optimisation Toolbox. The target values for these resources are identified using pinch analysis and the weighting parameters for the resources are chosen according to the methodology presented in the first part of the paper.

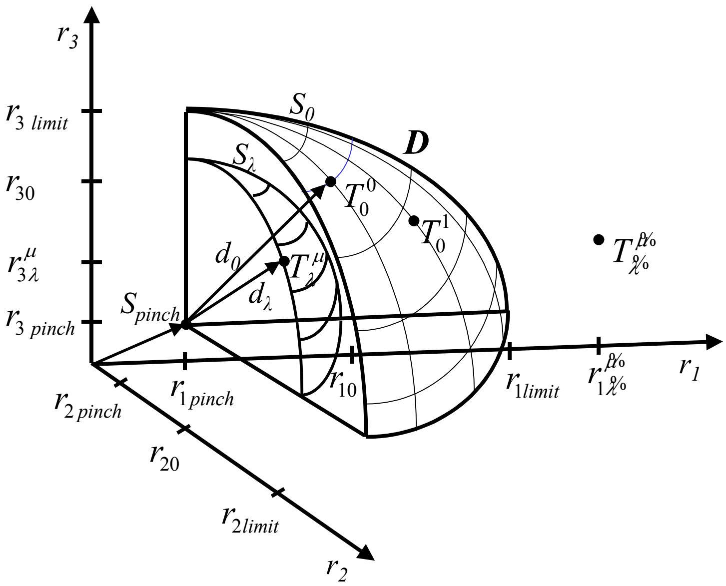

Figure 1: Domain of considered process improvements

Given the current consumption, savings potentials can be calculated overall or by individual component. Additionally, further criteria such as investment, operating costs, and quality attributes extend the dimension of the given problem for the subsequent process design. The obtained value represents the target for the subsequent design step and the basis for the developed metric. This metric is a measure for the overall or individual resource savings potential and acts as an input for a multi-criteria analysis. The multi-criteria analysis is driven by the trade-offs between investments and operating costs, while continuously looking for an economically feasible solution. The ultimately realisable savings are defined by the implemented technology combination based on a new process design. By incorporating selective measures addressing the target values, technology combinations for a possible implementation can be selected.

Finally, case studies from Chile and China are employed to demonstrate the application of the methodology. In these, a special focus is placed on wastewater management of the considered system, but also issues concerning energy and solvent consumption are addressed. In order to illustrate the process requirements different parameters are described in detail and characteristic figures are derived to describe the process layout. These data are used for the optimisation module of MOPA. In conclusion, implications for the process design are derived based on a multi-criteria approach.

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System Dynamic Modelling within Sustainability Constraints

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The complexities of the ecological and social systems and their interrelationships have been a source confusion and frustration for industrial sustainability practitioners. In response, a vast range of sustainability related ideas, tools, concepts and approaches have been developed and to keep the analysis effort at manageable levels sustainability practitioners have learnt to apply strict system boundaries in terms of the topic of study, the geographic area, the time frame, the impact categories, etc. A drawback of this approach is that some ideas, issues and impacts may be excluded from the study, not because they are judged irrelevant but since no one is looking in their direction. 'Backcasting from Sustainability Principles' is a planning methodology that offers a theoretical solution to this dilemma, namely, to include everything in the study – disregarding geographic, temporal or other boundaries - that may stop us from achieving success as defined by 'Basic Sustainability Principles' or sustainability constraints[1,2]. Previous studies have shown that 'Backcasting from Sustainability Principles' can be applied for systematic planning towards sustainability in both public and business organisations, for different societal problem areas and for the selection and design tools and concepts relevant for sustainable development [3,4,5]. We are currently entering a whole new research field, in which we, from the same overriding sustainability perspective, analyse and design various tools and concepts like product development [6,7], lifecycle thinking [2] and industrial ecology [8].

In this study we are asking ourselves whether 'Systems Dynamic Modelling' can be combined with 'Backcasting from Sustainability Principles' to support strategic planning towards sustainability. From the perspective of a 'Backcasting Practitioner', 'Systems Dynamic Modelling' is a set of tools that help gaining insight into the detailed functioning of a given system, but lacks the ability to support strategic planning towards sustainability – unless complemented with a satisfactory goal definition. 'Backcasting from Sustainability Principles', in the eyes of a 'Systems Modeller', is the planning step of a learning loop that also includes action implementation and follow-up. Since no dynamic modelling takes place this methodology typically produce laundry lists of isolated problems and solutions, thereby missing potentially important feedback loops, delays, hidden problems and suitable intervention points in the system.

We suggest a new integrated approach that starts with an initial analysis of the problem at hand, utilizing 'Backcasting from Sustainability Principles'. This creates laundry lists of critical present-day flows and practices, and of solutions and visions, i.e. a frame for continued analysis. After that, system dynamic tools are applied to study the interrelationships between the listed items, which create more robust analyses both of the problems at hand, and the possible solutions. Furthermore, it is helpful to make choices as regards the best road (out of several) forward towards sustainability, within the overall frame.

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Variant Calculation in Material Flow Networks

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Material flow networks are a widespread methodology of operational environmental protection. They are used to describe, calculate and evaluate material flows and their environmental strains in a process-oriented way. Variant calculation involves the analysis of product-mutations as well as the comparison of engineering alternatives.
This paper investigates variant calculation as a possible field of application for material flow networks. It defines "variant calculation in material flow networks" and reveals several tasks of operational planning as main business applications of this approach. Furthermore the paper presents ideas to meet requirements of a broad computer support for those applications.
The approach enables companies to plan product-mutations and technological variances in a process-oriented and detailed manner. Precise information on the environmental impacts of every alternative and the operation as a whole are additional benefits. However it is not only the operational planning that profits. For instance adaptable models make user-related simulations or sensitivity analysis possible. Thus the suggested enhancements increase the flexibility of computer-supported material flow networks in general.

Session C.
Corporate Sustainability

Chairmen: J. Korhonen

Location: Lindstedtsvägen 17
Room: D1.

Historical accountability and cumulative impacts: the treatment of time in corporate sustainability reporting

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The definition of sustainable development contains a clear reference to intertemporal equity: "the needs of future generations". As a consequence, in order to live up to its name, corporate sustainability reporting (CSR) should consider temporal aspects, and these should be dealt with in a scientifically rigorous and consistent way.

A large number of *sustainability indicators* have been chosen in existing CSR schemes. The environmental indicators in these schemes relate to impacts that have particular lifetimes. In turn, the ecosystems affected by these impacts exhibit particular dynamics, and may take varying amounts of time to recover or adapt.

Impact lifetimes and ecosystem recovery times span a wide range of periods, up to at least several centuries. To complicate matters, impacts can be caused by a range of environmental pressures that can be short- and long-term, and ecosystems can be more or less resilient to these pressures.
Generally, corporations have different histories of environmental pressures. In order to achieve fairness between companies and consistency in reporting and benchmarking, CSR should ideally be designed to take into account the differences in time scales of both impacts and the recovery of ecosystems or other aspects of the environment.
In assessing sustainability, historical accountability and impact lifetimes can in principle be captured by considering impacts as cumulative rather than instantaneous. In terms of the pressure-state-response model for environmental assessment, long-term, on-going (cumulative) impacts are best described by *state* rather than *pressure* indicators. Water availability/stress (state) and water use (pressure) are examples of these indicator types. State indicators also have the advantage that they are more closely related to the actual impact, or damage. Some state indicators for environmental issues (such as climate change and air quality) can only be measured on relatively large spatial scales, respectively global or regional. Corporate (and sometimes national) contributions to these states cannot be measured directly, but must be derived from the corresponding pressure indicators (in this case, emissions of greenhouse gases or other air pollutants).
As a result, most national and CSR schemes feature pressure indicators that are accounted for in a 'snapshot-like' manner. The accounting period (usually annually) is often much shorter than impact lifetimes and respective recovery

times. As a consequence, the environmental impact of corporations is not fully captured, and in turn, comparisons and benchmarking are likely to be inconsistent and unfair.

In principle, all pressure indicators could be linked to state indicators by a temporal analysis. However, sometimes a scientific model of the respective link is missing altogether, or if existing, involves uncertainty. For example, it is possible but difficult to link national or corporate greenhouse gas emissions to an appropriate state indicator for climate change, such as atmospheric greenhouse gas concentrations, net radiative forcing, temperature change or sea level rise.

The idea of pressure and state indicators refers only to impacts. As mentioned previously, a true description of sustainability would take into account the time for ecosystem recovery from these impacts. At present, very few ecological studies have come up with a quantitative and predictive pressures-state-response link that is applicable beyond their respective (mostly small) ecosystem. This paucity of knowledge is due to the inherent complexity of the ecological world. Therefore, in this article, we restrict our argument to incorporating the temporal profile of the pressure-state link into CSR. In principle, this argument holds equally for incorporating the temporal profile of the state-response link.

We examine how temporal aspects have been and could be incorporated into environmental indicators within CSR, and give a review of some current indicators and reporting schemes. While our main focus is on corporate reporting, temporal issues have rarely been examined for companies, so that we frequently draw on examples from regional or national reporting schemes. Three generic types of temporal issues are described in order to highlight problems of reporting approaches described. We analyses in more detail some attempts to incorporate time into environmental reporting, and discuss problems that still have to be overcome.

Triple Bottom Line Accounting for Australia

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Triple Bottom Line accounting is widely advanced as a way in which firms and institutions can realise broader societal objectives in addition to increasing shareholder value. In our analysis of the Australian economy, we integrate financial input-output tables that describe the inter-dependencies between economic sectors, with national social and environmental accounts to construct numerate 'triple bottom line' accounts for 135 discrete economic sectors. The accounts are portrayed against the numeraire of 'one dollar of final demand'. Thus for a sector of the economy, financial aspects of performance can be expressed for example as dollars of export earnings per dollar of final demand. Social aspects such as employment can be portrayed as minutes of employment generated per dollar. Greenhouse issues can be portrayed as kilograms of carbon dioxide emitted per dollar.

Since these indicators of 'triple bottom line' performance are referenced against financial units and are consistent with the System of National Accounts, they can be applied to financial accounts of a firm, a service or a product, and allow a robust triple bottom line account to be developed across a range of scales. The critical advantage of this approach is that it represents a nation wide life cycle analysis without boundaries. It includes both the direct or immediate effects as well as the indirect or diffuse effects associated with a large and distant chain of supply paths. The incorporation of all the indirect or upstream effects therefore removes any problems associated with a choice of boundary, and imports and exports are also included. Both products and firms can therefore be assessed properly in sustainable chain management terms. Thus a firm that uses a key intermediate input that requires a large amount of water for example, cannot hide the environmental implications since they are revealed in the analysis of the full production chain. This revelation can also underpin the change and improvement process when firms acknowledge both the direct and indirect effects, and improve their selection of key inputs on a wider range of criteria, rather than just on price alone.

This study for a Federal Government agency has recently been released nationally and has attracted both positive and negative comments. Ethical investment groups, environmental consultants and non-government organizations have generally viewed the study positively. Some industry groups and financial services organisations have been critical particularly highlighting the tension between obligatory financial reporting at the firm boundary, but being able to report on environmental indicators over the full production chain.

Production and Communication of Corporate Sustainability ReportsSoftware Tool for Single Source Cross Media and Multiple Requirement Sustainability Reporting

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Corporate sustainability reporting describes a development path towards a concept of balanced reporting (DTTI, IISD and SustainAbility 1993; UNEP and SustainAbility 1994), communicating the three pillars of environmental, social, and economic performance and its mutual interrelations to interested parties, what in business terms is called the triple bottom line approach (Clarke 2001; Raar 2002). While the early sustainability reports in the late 1990s have been available primarily on print media and are prepared as “one size fits all” documents, today, as practice matures and reporters as well as report users are going to make use of the internet (Shephard et al. 2001; Weil and Winter-Watson 2002; Scott and Jackson 2002, Isenmann 2004), the field is evidently in a phase of transition, entering a new stage of sophisticated digital reporting (SustainAbility and UNEP 1999, Wheeler and Elkington 2001; GRI 2004).
As a result of this development, **production** of such reports needs to be streamlined along the whole reporting workflow, intended to reduce costs and save resources, but to increase quality (Isenmann and Marx Gómez 2004). Further, **communication** on sustainability issues becomes more interactive, tailored to target groups and dialogue-oriented (OECD 1999; WBCSD 2002; Brosowski and Lenz 2004). All in all, sustainability (online) reporting is going to become part of companies’ daily affairs, at least to a certain extent (Marshall and Brown 2003), and thus most communication vehicles are accessible on the WWW (Rikhardsson et al. 2002): reports, brochures, leaflets, newsletters, press releases, slides, presentations, audio sequences, video clips etc. could be downloaded or are available online respectively, prepared for being pulled or automatically disseminated via e-mail or other current push technologies (Isenmann and Lenz 2001).

- From a **reporters` perspective**, streamlined **production** of sustainability reports becomes of increasing relevance, and thus an emerging issue of management’s priority. Such an enterprise however is not as simple a process as it may look like at first glance, as it is a multifaceted effort, affecting at least stakeholder relations, communication strategy, and image profile as well as organisation, management systems, staff, and ICT-capabilities, even for companies with experience in reporting and already using the internet for business applications. Among other difficulties companies are struggling, there are at least three challenges that need to be managed:

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  - integration of different issues into reports while extracting information from heterogeneous data sources,
  - provision of reports on various media, preferably in an automated manner,
  - and fine tuning reports according to users' needs and preferences and exactly meeting the vast of emerging reporting requirements (Leipziger 2003), including norms (EMAS 2002), standards (ISO 2003), guidelines (GRI 2003), and codes of conduct (OECD 2000) etc.

- From a **report user`s point of view**, issues of **communication** are crucial. For example, increasing user control, opportunities to select report contents and design, involving key target groups, learning their issues and concerns, and customising reports to heterogeneous information needs while meeting different reporting requirements drive reporting reputation and subsequently influence its success, perhaps whether users actually pay attention to sustainability reports, how readers assess reliability and value of these documents, and to what extent stakeholders are willing to make use of such communication vehicles for decision making.

- Further, from a **governmental perspective** or for any other standard-setting body, one of the early stated goals in the field could be achieved, i.e. improvement of performance indicators, normalisation of metrics, standards for reporting, aggregation of metrics (micro-macro-links), and weighting of metrics (National Academy of Engineering, National Research Council 1999).

Today, reporting on sustainability issues merely through one size fits all hard copies or simple electronic duplicates without any added value may hardly fulfil stakeholder expectations and future requirements. Companies have to realise that the early "honeymoon period" (DTTI, IISD and SustainAbility 1993, 9) in which sustainability reports sometimes may have received media response, public attention, and perhaps sound awards just for existing rather than for what was disclosed in them and how it was communicated is now over, definitely.
Despite the considerable progress companies have made in recent years however, current reporting practice shows significant room for improvements (Isenmann and Lenz 2002; Rikhardsson et al. 2002; Andrew 2003), particularly in terms of efficient production and high quality communication. Hence, a **software tool** is proposed that provides single source cross media and multiple requirement sustainability reporting. This tool elevates reporters and report users to a position reaping the full range of media-specific capabilities of the internet, to the benefit of managers, accountants, employees, members of the financial community,

standard setting institutions or organizations focused on benchmarking, rating and ranking. The software development is carried out by the Department of Business Information Systems and Operations Research (BiOR), Kaiserslautern University of Technology, Germany, and the Institute for Technical and Business Information Systems, Otto-von-Guericke-Universität Magdeburg, Germany. Further, this joint project is embedded in an overall process of the scientific community of environmental informatics, with the goal to harmonise document structures for advanced environmental and sustainability reporting.

The software development is regarded as the cutting edge approach in the rapidly developing field of advanced environmental and sustainability reporting using the internet. For example, in "The 2001 Benchmark Survey of the State of Global Environmental and Social Reporting" carried out by the CSR Network (Line et al. 2002), internet-based reporting and a more balanced reporting approach are seen as the top reporting priorities. Such a forward-looking approach offers a variety of added value creating features compared with early environmental and sustainability reporting stages. For example, it provides relevant contents (environmental, economic, social issues and mutual interrelations) that comprise the core themes for corporate sustainability, different media (print media, internet, CD-ROM etc.), it uses corresponding distributing principles (push, pull), it enables different views on the report contents, and it offers various presentation styles (media-specific, target group tailored).

Implementation of Corporate Social Responsibility (CSR) in Sustainable Management Systems of Enterprises

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Definitions of corporate social responsibility describe CSR as a concept whereby companies integrate social (and environmental) concerns in their business operations and in their interactions with their stakeholders on a voluntary basis (European Commission 2001). CSR seems to be even more, linking economical, ecological and social responsibility to a triple-bottom-line-model of enterprises which is quite similar to the well-established three-column-model of sustainability. Both models attempt to resolve the ambitious and challenging task of integrating social, ecological and economical aspects.

An interdisciplinary research group at Darmstadt University of Technology (Industrial Material Cycles, Business Studies, Sociology) financed by the Centre for Interdisciplinary Technology Research (ZIT) has started in 2004 a research project on the question how social responsibility can be communicated and implemented for the actors in enterprises on different operational levels. Regarding the international widespread debate on CSR definition and CSR tools, it seems to be important to structure the CSR debate according to traditional business processes. In the lecture in Stockholm will be given the first results of a systematic critical organizational discourse based analysis of annual business reports, environmental reports, sustainability reports and social responsibility reports by the German stock index (DAX) enterprises.

Today Global Players actually communicate CSR in form of a rising amount of CSR reports who are somehow replacing traditional environmental reports of the last decade (see figure 1). In addition to that the rating and benchmarking of global players on their “CSR behaviour” by international financial and economic agencies will be considered. These agencies are mostly using their own indicators and questionnaires for measuring and assessment of CSR in enterprises. For this reason the interdisciplinary research study addresses the transparency and plausability of social responsible management, how it is postulated in the guidelines of good corporate governance. The corporate governance structure specifies the distribution of rights and responsibilities among different participants in the corporation, such as, the board, managers, shareholders and other stakeholders, and spells out the rules and procedures for making decisions on corporate affairs. (OECD April 1999).

The first result of the of the interdisciplinary study of reports by DAX enterprises will be presented in terms of a structure of the CSR debate according to traditional business processes and the background question how CSR can be implemented in these processes.

The second result will be describing and structuring the CSR indicators of these reports. One immersing evaluation point will be the institutional and legal background of used CSR indicators (e.g. GRI Guidelines, rating, benchmarking, CSD) and their quantitative and qualitative character. Also there will be answered the question whether there is a link to social sustainability indicators on the macro-economic level.

Another result of the conjoint study will be presented in a structure model of internal strategic/governmental and operational level of enterprises and their actual function for implementation of SCR.

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Evaluating the Progress of Automakers Toward Sustainable Plastics

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The use of plastics globally continues to rise, including in the manufacture of automobiles. U.S. consumption of plastics in family vehicles now stands at over 4.3 billion pounds per year with the percent of plastics in vehicles having increased from 4.9% of vehicle weight in 1977 to 7.5% of vehicle weight in 2003. Automotive plastics use is on the order of 5- 7% of overall plastics consumption globally.

Although some automakers are beginning to evaluate the safety and sustainability of plastic auto parts, they have a long way to go. Automakers continue to rely on petrochemical-based plastics, which use and release toxic chemicals that are harmful to human health and the environment and are extremely difficult to recycle.

To help consumers understand the commitment of automakers to environmentally friendly plastics, we evaluated six leading automakers on their efforts to use sustainable plastics. What are their goals for sustainable plastics? How are they measuring progress toward meeting those goals? And how far along the path of environmentally sustainable plastics have they gone?

We define environmentally sustainable plastics as:

- having no toxic, persistent chemicals associated with the life cycle of the material,
- being capable of either a) closed-loop recycling (recycled into the same product) or b) degrading into healthy nutrients for the soil, and
- being manufactured from renewable raw materials.

This research effort evaluated the six largest automakers selling into the American market: DaimlerChrysler, Ford, General Motors (GM), Honda, Nissan, and Toyota. The automakers were evaluated based upon information provided in their corporate sustainability or environmental reports and corporate web pages. Specifically, they were evaluated based upon:

- their vision for sustainable materials,
- the measurable goals they set to achieve sustainable plastics, and
- the actions they have taken to transform their use of plastics.

Our evaluation found that most automakers are fairing poorly on the path toward sustainable plastics. While automakers could improve their grades by doing a better job of reporting their activities, the level of commitment to taking real action to use sustainable plastics will also need to improve significantly among the six automakers evaluated. Assuming that the data provided in their environmental reports and on their webpages are good indicators of the automakers sustainable plastics goals and activities, all of them have a lot of work to do.

We also found a lack of *global* environmental commitment among the automakers. Rather than committing to achieve sustainable plastics globally, most companies are committing to sustainable plastics only in nations where there are legislative requirements, such as in Japan and the European Union. This lack of global environmental commitment reflects the environmental double standards that corporations often impose, especially with products, on nations without strong consumer and environmental laws.

While progress toward sustainable plastics is slow and happening at different rates in different regions of the world, there are positive examples of change in the industry. Collectively, the best visions, goals, and actions among the six automakers represent a clear first step toward materials that sustain human health and natural ecosystems and away from plastics with negative end-of-life values and toxic life cycles.

The best examples from the auto sector show that automakers have the capacity to design for environmentally sound plastics. If these six automakers moved quickly to adopt the leading goals and to implement the leading activities over the next three years, the auto sector would make significant strides toward sustainable plastics.

When Results Count; Applying Industrial Ecology to Leverage the Profitability, Stability and Reputation of Global Corporations

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Topic Area: *Environmental Management and Sustainable Manufacturing*

Every Corporate Environmental Manager faces the daunting challenge of demonstrating the value of their business solutions to corporate executives, business managers and operating personnel. No matter whether the Environmental Manager is striving to achieve regulatory compliance or a legacy of corporate stewardship, their efforts will ultimately be judged by corporate leaders that continuously appraise the value of environmental programs against the backdrop of traditional financial and business metrics. In order to win in this competitive environment, the Corporate Environmental Manager must adapt their global, regional and local solutions to meet the same "model of success" employed by the more traditional business disciplines (e.g. finance, manufacturing, engineering, sales, etc.). This paper provides Corporate Environmental Managers, Academic Leaders and Global Consultants with Manager with a framework of business strategies, protocols, and tools (including order of implementation) for transforming Industrial Ecology into a "Peer Business Discipline" that more effectively meets the test of organizational, market and executive leaders.

The presentation will bridge the gap between the academic foundations of Industrial Ecology and its fundamental application within the framework of a corporate environment. It will apply the lessons gleaned from designing, implementing, and proving the value of Industrial Ecology/Environmental Solutions for major corporations facing a diverse array of business and regulatory challenges. These examples will not only address the strategic implications of IE/ES solutions but how they tend influence the day to day business operations of local manufacturing sites, operating personnel and business reputations in the eyes of local constituencies (e.g. customers, regulatory agencies, communities, and advocacy groups).

The presentation will be structured in the general following format:

1. <u>Executive Summary</u>: This section will provide the audience with the specific and concise understanding of why the success of Corporate based Industrial

Ecology/ Environmental Management solutions will ultimately be framed within the contextual framework of the metrics that define success in a competitive business environment. This includes the careful consideration of the explicit and implicit factors that work to influence a decision maker's judgment in a corporate setting. This includes both formal and informal factors of corporate culture including corporate tradition, key performance indicators, global perception of risk, operational experience and trust, creating and defending the business case, market influence and drivers, regulatory risk and consequences, and global value chain trends.

2. Building and Defending The Business Case: What does it take, what is necessary and how do you sell the business case for implementing Industrial Ecology solutions to corporate decision makers that operate in a competitive environment. Focusing on the various levels of business operations, from manufacturing processes at the plant level to the global impacts of corporate reputation management, the ability to craft the business case in terms of the metrics that define organizational success will be evaluated. Integrated within this function will be the factors of corporate history, industry standards, corporate culture, market forces, strategic objectives, financial metrics, customer requirements, regulatory threats, business risk, and the ever present influence of power brokers, thought leaders and program gatekeepers.
3. Total Environmental Solutions: The ability to provide a total solution to a business problem is as important for the field of Industrial Ecology as it is for any of the traditional business, engineering and human relationship disciplines. In most circumstances, we find business solutions tailored to address a relatively narrow framework of circumstances (time, operation, location, constituency, etc.). While this linear approach to problem solving often proves successful at solving the specific problem, it typically sets into motion changes that reverberate across global operations and at every level of the organizational hierarchy. The configural consequences of these solutions often result in creating new, unintended problems for the organization. By taking a configural approach to problem solving (Total Environmental Solutions) the Industrial Ecologist helps maximize the economic benefit of the solution to key performance metrics while limiting the potential for negative consequences across the global value chain.
4. Best Management Practices: We often hear the term best management practices but rarely appreciate the rational for why they are considered best for a given situation. When applying an industrial ecology solution, is it more important to create a stand alone management system or to integrate it within a traditional management system. The tension between these choices will be discussed and highlighted with real world examples. Approaches to integrating best management practices within the framework of traditional management systems, so each enhances the performance of the other, will also be discussed in conjunction with strategy formulation, operational

alignment, performance recognition and communication methodologies. The tools of Progressive Environmental Roadmaps, Performance Report Cards, Corporate Citizenship, Sustainable Compliance and Global Relationship Building will be discussed.

5. Inventing The Future Of Industrial Ecology: In the end, the ability to transform the academic applications and industrial solutions of Industrial Ecology into a Peer Business Discipline is of critical importance to the people that look to it for credible answers in an increasingly complex world. To this end, I will provide a general framework on what is needed to move a new discipline like Industrial Ecology up the value chain so it gains the same degree of respect, credibility and effectiveness as solutions provided by any other traditional business discipline. The ability to build the perceived value of Industrial Ecology in the eyes of corporate, government and academic decision makers will have a profound impact on the future success of the discipline and the people that seek to apply its solutions.

Session D.
Sustainable Manufacturing

Chairmen: E. Hertwich

Location: Lindstedtsvägen 5
Room: D2.

Measuring the Environmental Load of Manufacturing Processes

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This paper provides an update on the progress being made on an NSF-funded project to analyze the environmental loads associated with eight different manufacturing processes: machining, sand casting, die casting, electrical discharge machining, abrasive water-jet machining, injection molding, grinding, and advanced composites autoclave processing. The goal of this project is to develop representative environmental models of each process, paying particular attention is issues including energy use, material use, and emissions. These models can be used to better understand individual processes, such that future process improvements can focus on areas of greatest environmental concern. More importantly, this collection of process models will serve as a means to compare the environmental performance of alternative manufacturing processes, product designs, and process plans. This comparison of processes based on environmental aspects will be increasingly important in trying to move manufacturing towards sustainability.

This paper will primarily focus on comparing the environmental impacts from machining and sand casting [1, 2]. Additional results from comparisons with die casting, electrical discharge machining, and abrasive water-jet machining will also be included. This paper will also present two alternative views of the role of manufacturing process equipment: one as a service necessary to produce a product, and one as a product in and of itself. The results from these two views provide interesting and sometimes dramatic results. For example, Figure 1 shows the annual emissions resulting from the operation of a typical production machine tool (22 kW spindle, cutting 57% of the time, 2 shifts, auxiliary equipment, electricity from US grid), as measured in annual SUV equivalents.

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[2] Dalquist, S. and T. Gutowski. "Life Cycle Analysis of Conventional Manufacturing Techniques: Sand Casting," ASME International Mechanical Engineering Congress and RD&D Expo, Anaheim, California, USA, November 13-19, 2004.

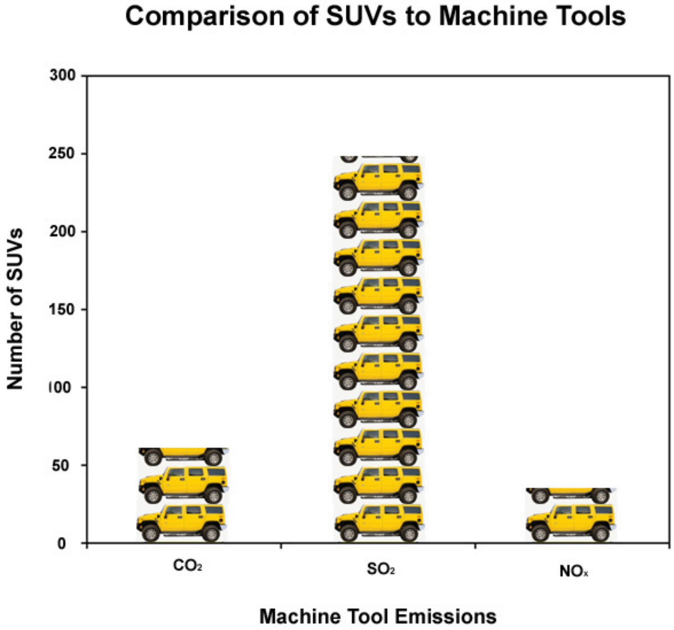

Figure 1: Annual CO_2, SO_2, and NO_X emissions from a production machine tool, as measured in annual SUV equivalents.

Light-weighting Cars Using Magnesium: Is There an Environmental Advantage?

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Light-weighting of automobiles has been a key issue for reasons of meeting stringent requirements on greenhouse gas (GHG) emissions. For instance, reducing the weight of a car by 100 kg can save emissions from fuel by an estimated 2600 kg of CO2 equivalent over a driving distance of 200,000 km (the life of a car). Weight reduction in cars is achieved by substituting the heavier steel components with components made from materials that are lighter, such as aluminium, magnesium and plastics. Of these, the metallic based components are receiving attention due to their relative ease in recycling than plastics given the additional requirements on recycling of end of life vehicles. In this respect, aluminium alloys are widely used and accepted by the industry. However, magnesium is lighter than aluminium and has superior casting properties that make it attractive, though it has a few inherent problems too, such as corrosion. To this end, successful research in magnesium alloying and casting technologies has ameliorated its negative properties and has substantially improved its application potential.

Nevertheless, the comparative environmental burden created in the production of magnesium can be higher than that of both aluminium and steel. This is further compounded by the relative difficulty in readily recycling and using magnesium to make components. This can be critical since, using secondary magnesium (or aluminium) would be much more environmentally friendly having an approximate GHG emission of around 10% of that of an equivalent amount of primary magnesium (or aluminium). Therefore, it is important that these and other factors in manufacturing are considered to assess magnesium's environmental performance. In fact, a whole of lifecycle assessment would reveal the net impact, rather than the emission savings due to reduced use of fuel (due to lower weight of magnesium) at the automotive use stage.

This study reports on such an assessment for two automotive components, namely converter housing and engine block using lifecycle analysis. These components substantially differ in their weight (converter housing is much smaller and lighter) and functions in a car and represent a spread of complexities in their design, manufacture (casting) and assembly. The environmental impact is computed in terms of GHG for emissions at each stage of the component's lifecycle. The stages include primary ingot production, casting and finishing of the component, use in automobiles and final recycling. At each stage of production, the impact of adopting alternative technology pathways is taken into account as summarised below:

- Impact of producing primary ingots considers using an electrolytic process (in Australia) and thermal reduction process (known as the Pidgeon process, it is widely used in China).
- There have been recent advances in technology that can substantially reduce the emissions in casting. These include use of alternative cover gases (other than sulphur hexafluoride or SF6 that has an impact potential of around 22,000 kg CO2 equivalent per kg), improvement in yield and increased use of secondary magnesium.

The comparative environmental performance of magnesium components (i.e. converter housing and engine block) is determined using functionally equivalent components made from competing metals. The metals considered are: steel (Australia), aluminium (Europe and USA) and magnesium (Australia and China). For each of the metals, the break-even distances in the use of a medium-sized car where the net emissions become comparable is calculated. This shows the comparative position (in terms of driving distance) of each metal in the portfolio and break-even points where the GHG performance of one or of one other becomes better. For example, comparing the GHG performance of engine blocks made from magnesium (Australia) and aluminium (USA), the break-even distance is 90,000 km in favour of the former. The results further indicate substantial improvements in environmental performance when technology improvements are made, such as the use of cover gas with much less GHG impact than SF6. In effect, the study reveals a comparable environmental performance of magnesium against other competing metals used in light-weighting cars.

Techno-economic Assessment of the Biotechnological Production of Bulk Chemicals from Renewable Resources until 2030

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In public and scientific debates, most attention related to biotechnology has so far been paid to genetically modified (GM) food, human genomics and pharmaceuticals synthesized by genetic engineering. However, biotechnology is about to open new perspectives for the manufacture of chemical bulk materials and chemical intermediates from renewable raw materials such as glucose, molasses and lignocellulosics, for example by means of fermentation. In the context of the European project "BREW", the developments in this field in the next 20-30 years are considered. In order to further the research efforts and public discussion, this study aims at evaluating the medium and long term potential of biotechnology to produce certain bulk chemicals and chemical intermediates from renewables as an alternative route of production to petrochemical processes, while accounting for an expected technological progress in industrial biotechnology. In this paper we present a prospective assessment for the period until 2030.

The methods used to address this aim include the analysis of material flows, energy use and emissions as well as the estimation of production costs for complex bio-based production chains. These are compared to conventional products, which have a comparable functionality but have been produced via petrochemical production routes. For the biotechnological production processes a generic approach was developed to circumvent problems related to data confidentiality and to ensure a comparable level of ambition. Bulk materials and chemical intermediates analysed include carboxylic acids such as acetic acid, alcohols such as *1,3*-propanediol and proteins such as lysine.

This presentation will provide results on material flows, energy use and CO_2 emissions for key biotechnological products, which are assessed for two system boundaries: 'cradle to factory gate' and 'cradle to grave'. Together with the estimated future production costs these results provide new insight into the potential of the considered substances and processes to substitute in the medium and long-term functionally equivalent products based on petrochemical production processes.

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Sustainable Production for a Green Future

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This paper discusses the practices of sustainable production, eco-supply chain and eco-logistics. The concept of sustainable production emerged in 1992 at the United Nations Conference on Environment and Development [1]. Lowell Centre for Sustainable Production defines sustainable production as the creation of goods and services using processes and systems that are non-polluting; conserving of energy and natural resources; economically viable; safe and healthful for employees, communities and consumers; and socially and creatively rewarding for all working people [2]. They developed a framework of indicators of sustainable production and a methodology to operationalise the framework. Boer and Jovane [3] argued that the mutation of the economic, social and technological environments call for continuous changes of products and related processes. They developed a new model for sustainable production and suggested that networks for both virtual and physical factories are needed and integration of which would lead to self-innovating extended factory, capable of responding to changes required by the sustainable production paradigm.

In this study, we concentrate on issues dealing with delivery of parts and raw materials from suppliers (which is concerned with inbound eco-logistics), design of products (which is concerned with eco-friendliness of materials and parts to be used and the environmentally friendliness of manufacturing processes), manufacturing of components (which is concerned with green technologies to be used and internal eco-logistics), and delivery of finished products to customers (which is concerned with outbound eco-logistics). Green manufacturing is seen as a sub-set of sustainable production. Eco-supply chains and eco-logistics support sustainable production.

The level of “eco-friendliness” of a supply chain is becoming increasingly important to the customers in order to choose the correct suppliers and be able to shed the correct light of sustainability to the end-market. This enables the creation of international competitiveness at the global level. Eco-logistics is a system in the supply chain where enterprises, i.e. suppliers and customers are collaboratively using environmentally friendly materials in production and transportation, which aims to minimise hazardous waste from the logistical operations. When these practices are realised, the supply chain can be identified as an eco-supply chain. Nagel [4] investigated how Lucent Technologies supply line can merge with initiatives, which reduce the environmental load of a telecommunications product during its life cycle. This study revealed that 70% of its suppliers lacked formal environmental policies. As a result, Lucent developed a new approach called environmental supply-line engineering and researched the possibility of incorporating it into its product realisation processes to improve environmental performance. This approach centred on eco-supplier development and its interactions with eco-design, the end of a product life and technological innovations. On the other hand, van Hoek [5] looked at the challenges for research on green steps to take and green supply chains to make in practice, as a step up to lowering the ecological footprints of supply chains.

A study carried out by Florida [6] found evidence that there is some USA manufacturing enterprises, which practise zero emission strategy in manufacturing, and majority of the respondents practise reduced emission strategy. The President and CEO of Mitsubishi Electric Cooperation - Nomakuchi [7] integrates the strategy of reducing environmental burden with full consideration for environment at every level of operations, i.e. through the promotion of eco-factories, eco-products and eco-logistics, into the corporate strategy. Sharp contributes to the realisation of a sustainable society by 'the super green initiatives' [8]. Sharp is also introducing low-pollution vehicles, reducing packaging materials and using cushioning materials made from cardboard rather than plastics [8]. The practice of green manufacturing is not limited to the electronic and white good industries. Automotive industry is another key user of green manufacturing practices, e.g. the production of hybrid (gasoline-electric) cars - Lexus RX400h, Toyota Prius and Honda Insight. O'Brien [9] suggested that manufacturing bears a particular responsibility for achieving international standards for sustainability and public consciousness to support sustainability should start from the design stage. Hence, those innovations in design and new product development reinforce this finding.

It must be noted that the shift of manufacturing operations to the eastern world to reduce cost implies that less environmental ethical approach is used by the western enterprises. This approach will result in exploitation of the eastern world's resources and hence will increase the exposure of its local environments to pollution, unsustainable life-style, inferior working environment, and ill-health. Therefore, future research in operations management and its related fields should consider a more sustainable method of production. Simply 'greening' one part of the world and shifting the 'dirty work' to another part of the world is not sustainable enough. Also, previous studies appear to disregard distinctions between the levels of eco-friendliness at specific stages of logistical operations in the supply chain. For example, enterprises might claim that they are practising eco-logistics, but in fact those practices are at a very minimum level. The potential impact of such illusion could be insignificant to stakeholders and customers. It was also found that the cases on sustainable production seem to depend on the culture of the countries, enterprises and individual; and the type of products and industries. It will be interesting to find out whether there are other factors that affect the extent of sustainable production put in practice, both positively and negatively. To conclude, it can be suggested that sustainable production has to be directed from two-way, i.e. from production and from consumption. A balance between these is critical to ensure sustainable future.

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A Study of Benign Manufacturing of Electronics, Recycling and Disposal Trades

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The management of defunct consumer electronic products is a huge and growing problem across state, national, and international boundaries. Electronic products increasingly pervade all levels of society and the multifaceted issues of costs, reliability, recycling, hazardous materials, landfill and incinerator sites, and the parameters of effective legislation are understood to different extents by various communities and levels of governments. This multidisciplinary project investigates the case of cell phones to demonstrate an approach for manufacturing environmentally benign electronic products. Our approach moves the global debate beyond the current focus on the lead (Pb) content of electronics. For example, brominated fire retardants in electronics have emerged as a major concern. Our study reviews questions such as: What are the impediments to manufacturing "environmentally benign" electronic products that escape environmental regulatory classification as "hazardous waste" at their end of useful lives? Would these environmentally benign products perform satisfactorily according to established standards and at reasonable costs? Would these new electronic products be recyclable? Would the products be disposable in domestic landfills or could they be incinerated? In what ways can current regulatory initiatives, both local and international, hasten the development and acceptance of environmentally benign products?

A chemical analysis of leachate generated by phones is being conducted to identify constituents that meet or exceed regulatory standards for hazardous waste classification. Secondly, cost and performance differentials are being evaluated between environmentally benign alternative component materials that can potentially replace the hazardous constituents in currently marketed products. A program has been established to answer these questions and to ensure that the results are readily translated into results that are usable by policy-makers. This paper provides preliminary results from our project, which is charting a path toward legislation and public engagement for managing electronic waste through a strategy that best uses the product of scientific research in materials science, engineering, economics, and environmental health.

The Feasibility and Environmental Consequences of Scale Change in Office Paper Production

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The pursuit of sustainability in the paper industry is increasingly important. It is the third most environmentally damaging industrial sector and despite the promise of electronic technologies, demand for office paper is rising. Numerous studies of the environmental impact of the paper industry have been performed. They show that the major environmental impacts are: the emission of methane during paper decomposition in landfill, the emission of carbon dioxide due to the energy used in pulp and paper drying processes and the pollution of water following the pulping and bleaching processes.

The approaches to improving the environmental performance of the paper industry that have been explored to date are: the use of clean technologies to restrict post-process emissions in particular the black liquor which arises from pulping; the use of renewable energy sources, particularly through burning waste fibres; the recycling used paper as a substitute for virgin fibre. These have lead to significant improvement, but the industry sees them as only sufficient to be ``on the way to sustainability". True sustainability in office paper is likely to be achieved only by a more radical change in production systems. One possibility is to change the structure of the supply chain by use of different scales of production process.

As yet, no studies have been conducted on the impact of production scale on the environmental performance of office paper. This paper explores the link between scale and sustainability in the supply of office paper by considering five technologies that economically provide office paper. The five technologies are: standard paper-making in large plants; standard recycling in regional plants; paper-making using agricultural crops in local mini-mills; recycling office paper within the office; replacing paper with an electronic equivalent. These technologies range in scale (measured by output at a given location) from 100,000 tonnes per year down to 20 kg per year.

To compare these different scales of production, the relative environmental impact and operational challenges of each scale are estimated based on published impact assessments. The results show that regional recycling would be environmentally preferable to large scale production if it had access to renewable fuel sources. The environmental benefit of local agricultural fibre based mini-mills is limited unless forests are particularly valued. Office based paper recycling is highly preferable to large scale production but requires a widespread change in printing technology. Electronic paper may, in the long run, be environmentally preferable to large scale production if the technology replaces printers and displays as well as paper.

The paper concludes that while there may be an environmental case for scale change, this case depends on making complex changes to the industrial ecology of office paper.

Green Chemical Process Design in the United States

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This paper will describe a general framework for incorporating green engineering design principles into chemical process designs. The challenges of green chemical process design can be broadly grouped into three categories, labeled as assessment, improvement and integration. Assessment tools help define what constitutes a green process or a green product, and provide frameworks for performing optimization. Once a set of tools is available for assessing environmental impacts and costs, engineers can apply traditional analysis and design methods to improve mass efficiency, energy efficiency and environmental performance. Some new design tools specifically focused on environmental improvement are emerging; on balance, however, the tools for improving environmental performance will likely be the same as the tools that engineers have worked for decades to improve products and processes. Finally, tools are emerging that will allow engineers to evaluate how well their processes and products integrate into supply chains.

Assessment, improvement and integration tools have been broadly applied in the U.S. chemicals industry and this presentation will describe a variety of case studies.

Session E.

Agriculture in IE

Chairmen: S. Wirsenius

Location: Lindstedtsvägen 3
Room: E2.

Major Societal Transition towards Food Sustainability Inevitable?

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Introduction

In order to significantly reduce global environmental change, rather than some gradual improvement, a stepwise change is required (Vellinga et al., 1998; Vellinga & Herb, 1999; Weaver et al., 2000b), a so-called "societal transition" or "industrial transformation". In fact, the production of 1) food, 2) energy and 3) water have been identified as three main targets for stepwise "transition" (Vellinga et al., 1998). Moreover, these three main activities are not independent of one another, since food production appropriates a major share of freshwater and energy produced. Furthermore, crops are produced, transported, processed and turned into food products in ever larger volumes, with ever increasing impacts on the environment (Hoffman, 2001; Millstone & Lang, 2003; Tilman et al., 2002). Therefore, a transition is particularly necessary in the food area (Aiking & Vellinga, 2000; Green et al., 1999).

The protein issue: Pigs or peas?

Within the realm of food, meat takes a unique place (Beardsworth & Keil, 1997). On average, 6 kg of plant protein is required to yield 1 kg of meat protein (Pimentel & Pimentel, 2003; Smil, 2000). Due to this inherently inefficient conversion, meat is responsible for a disproportionate share of environmental pressure. While the world population doubled during the second half of the 20th century, its appetite for meat quadrupled, requiring 40-50% of the world grain harvest to be fed to livestock (Evans, 1998). When striving for sustainable ways of food production and consumption, therefore, the protein chain is an excellent starting point. In theory, a promising solution may be offered by partial replacement of meat proteins with products based on plant proteins (so-called Novel Protein Foods, NPFs) in the human diet (Weaver et al., 2000a). Against this background, we developed the PROFETAS programme (Protein Foods, Environment, Technology And Society), which aims to assess to what extent a significant shift from meat to plant proteins in the Western style diet is: 1. environmentally more sustainable than present trends, 2. technologically feasible, 3. socially desirable. In PROFETAS two dozen researchers developed a transdisciplinary (political, social, economic, technological, environmental, ecological, chemical, etc.) approach to the design and evaluation of alternative protein production options and their impacts, with a predominant role for consumer preferences. The final goal was to translate the results into options for policymakers from both national and international government and industry.

Some PROFETAS results

Life cycle assessment shows that a transition from meat to plant protein might result in a 3-fold lower requirement of agricultural land and freshwater to start with. World-wide, however, there is potential for a 30-40 fold reduction in water use, and eutrophication. The geographic location of these and other environmental benefits will, however, depend very much on the actual selection of crops to be used as raw materials. Crop growth modelling applied to pea growth suggests that in the EU additional high pea crop yields with low resource input may be anticipated in Scandinavia. The same model can be used for other arable crops. It can serve a wide range of purposes, such as comparing resource use efficiency of crops in terms of biomass, seed and protein production (Aiking et al., in press).

A desk study on crop options shows that, in Europe, potential raw materials might include pea, lucerne and grasses. Lupin and rapeseed are less well suited. Outside Europe at least soy should be added. However, the feasibility to be a suitable source for NPFs is not the only important selection criterion. Since just 20-40% of the seeds is protein, extra waste from the non-protein fraction (up to 80% of the crop) would largely offset the potential 4-6 fold environmental gain from replacing indirect (meat) with direct plant protein consumption. Therefore, useful application of the non-protein fraction is indispensable to a protein transition, and should influence crop selection. As a general result, oil crops (such as soy or rapeseed) seem preferable over starchy crops (such as pea) with regard to applicability of non-protein fractions in biofuel production. In this respect, it became evident that combining sustainable production of protein and energy in one crop will simultaneously mitigate agricultural resource depletion, agricultural pollution, as well as climate change.

Many actors are involved, all of which will perceive their own barriers and opportunities. In PROFETAS (Aiking et al., in press), at least four barriers to such a transition towards decoupling protein production from concomitant environmental impacts have been identified: 1) social forces opposing change are strong, because meat has a high status, 2) economic forces opposing change are strong, because established interests in the meat chain are powerful, 3) technological know-how on novel (plant) protein foods is lacking, and 4) for centuries the meat chain has been optimised for exhaustive use of all by-products, potentially offsetting a large part of the theoretical environmental gain. Consequently, important actors include consumers, retailers, food processors, farmers, NGOs and policymakers. Interestingly, opportunities and obstacles for a transition turn out to be strongly different depending on the level (from local to global). In Asia, for example, incentives, crops and consumer taste are different. Therefore, regional approaches to a protein transition are called for.

Even in developed countries, only a minority of the consumers is prepared to avoid meat and if they do, health issues are a much stronger underlying motivation than environmental issues (Beardsworth & Bryman, 2004). In contrast, in developing countries, in particular, the proportion of meat in the diet is rising rapidly (Bruinsma, 2002). Our economic analysis indicates that if only the “rich” consumers switch to consume more NPFs to partly replace meat, the meat production and emissions will hardly be reduced because of increasing demand of meat of “low income” and “middle income” consumers in developing countries. For more detailed information, please consult our website (PROFETAS, 2004).

Conclusions

Concerning activities with major environmental impacts, such as food production, there is an increasing tendency to regard them as requiring a “transition” on a global scale, with a concomitant long-term view, and looking at all aspects associated with sustainability, i.e. ecology, economy and society (Aiking & De Boer, 2004). As a consequence of rapidly rising environmental pressures, the “protein transition” studied in PROFETAS seems inevitable. In addition, we came to the conclusion that transitions rarely go alone. The water transition, the energy (biomass) transition and the protein transition (towards more sustainable production and consumption of water, energy and protein, respectively), are strongly coupled. Meat produces 40-fold more eutrophication, and requires 40-fold more freshwater than plant protein. Moreover, using the non-protein fraction of biomass for energy production, and the proteins to replace meat production, is a highly efficient combination. A clear case of “win-win-win” results.

Integrating Farming and Wastewater Management – an Environmental Systems Analysis of Barley Production Using Human Urine

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Introduction

Source-separation of human urine is a promising technique for improving wastewater systems. By closing the nutrient cycle, nitrogen and phosphorus can be used as resources in agriculture, while at the same time the eutrophication from treated wastewater is reduced. When using an organic fertiliser such as human urine, the farmer needs to take different considerations into account besides its plant nutrient value, e.g. when and how to spread the urine. Decisions made by the farmer might thus influence the environmental outcome for the whole system, something that emphasizes the need for in-depth studies from an agricultural perspective.

The main objective of this study was to evaluate the environmental consequences when human urine replaced mineral fertilisers in barley production. Life Cycle Assessment methodology was used to compare two scenarios: conventional barley production using only mineral fertilisers and production using a combination of source-separated human urine and mineral fertilisers. The functional unit (FU) was 1 kg of barley harvested.

Systems description

In the *reference scenario*, conventional barley production in accordance with present practice in the region surrounding lake Mälaren was assessed. In the *urine-spreading scenario*, the greater part of the mineral fertiliser was replaced by human urine. Both the immediate effects from soil compaction and its future effects were accounted for in the yield obtained in the urine-spreading scenario as a reduction of the yield in the year under study.

The urine was assumed to be collected from detached single households with individual concrete storage tanks. The urine separation system was further assumed to be a supplementary function added to an already existing conventional system with a wastewater treatment plant operating regardless of the urine separation system, treating the other wastewater fractions from the households. The reduced need for treatment, distribution and pumping of drinking water and wastewater was accounted for, as well as the reduced amount of precipitation chemicals required.

A change-orientated perspective was used, focusing on changes occurring when the urine-spreading scenario was introduced compared to the reference scenario.

All main changes in the urine-spreading scenario compared to the reference scenario were considered, including production of the capital goods differing between the two scenarios.

Results

The use of fossil fuel was similar in the two scenarios, while the use of electricity differed. The electricity saved in the urine-spreading scenario emerged from a smaller quantity of drinking water produced, as well as a reduced need for pumping and treating wastewater. The emissions of greenhouse gases from the two scenarios were of the same magnitude, although slightly higher from the reference scenario. Production of mineral fertilisers contributed most to global warming in the reference scenario. The potential contribution to eutrophication was considerably higher for the reference scenario than for the urine-spreading scenario. The difference between the scenarios was explained by the reduced emissions of nitrogen from the wastewater treatment plant when urine was separated. However, the urine-spreading scenario contributed most to acidification, expressed as a maximum scenario, through its higher emissions of NO_X and NH_3. The emissions of NH_3 in particular differed between the scenarios, due to losses during storage and spreading of urine.

The potential effects of a large-scale regional change from conventional wheat production according to the reference scenario to the urine-spreading scenario were examined. In a normalisation, these changes were compared to figures on the total impact for Sweden. Urine from approximately one million users of separating toilets was assumed to be spread on arable land. The most noticeable change appeared in a lower discharge of nitrogen (-0.9%) and phosphorus (-0.4%) to water and substitution of nitrogen and phosphorus fertilisers (-1% and –3% respectively). The change was relatively small compared with the total nutrient load, even in a regional context, mainly because urine-separation was compared to conventional wastewater treatment with efficient removal of nitrogen and phosphorus. The increase of NH_3 emitted in the urine-spreading scenario was 0.3% above the present emission figure for Sweden.

Discussion

An optimal fertiliser strategy regarding e.g. substitution of mineral fertiliser, spreading time and application technique was demonstrated as being important for many environmental aspects. As the handling of urine at farm level is critical for many environmental aspects, a good strategy for using human urine in practical farming needs to be an integrated part in the design of urine-separating systems.

Whether a urine-separating system, where urine is used as fertiliser, is more energy-efficient than a conventional system depends to a large extent on the design of the system. By using a change-orientated perspective in this study, major changes in the construction of capital goods were taken into account, without considering the construction phase as a whole. Production of capital goods contributed noticeably to the primary energy used in the urine-spreading scenario. The calculated lifetime for the capital goods and choice of material is therefore important. The long distance sometimes required for transporting the urine has been pointed out as a weakness for source-separating systems without further concentration of the urine mixture. The assumptions used in this study allowed transportation 42.5 km (one way) in the urine-spreading scenario, before the primary energy use in the urine-spreading scenario exceeded that in the reference scenario. Concentration of urine as an additional process in order to reduce the energy use required for transportation should therefore be compared to the construction of capital goods required for this concentration.

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Dietary Trends and Land use

TheImpact of ChangingFood ConsumptionPatterns on Agricultural Land Resources
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1. Introduction

An adequately nourished population is essential for sustainable development. Today, widespread poverty is the main reason that a large share of the world population fails to meet its food needs. Five factors make food security an important issue for the coming decades: (i) the growth of the world population, (ii) technological changes in agriculture, (iii) a shift from local self sufficiency towards a global commodity market, (iv) the growing number of malnourished people, and (v) dietary changes toward more affluent food consumption patterns, the focus of this study.

Two factors cause a change in total food demand, the number of people that have to be fed, and food consumption patterns people favor. Over time, traditional societies have learned what will provide an adequate diet by methods of trial and error. This knowledge has formed the basis for a wide variety of food consumption patterns, repeated arrangements in consumption by a population determined by types and quantities of specific foods, and combinations into dishes and meals. Tradition, cultural heritage, and religious rules are important factors for these patterns. Sometimes large consumption changes take place in a short period of time. In many countries since 1961, increasing affluence has gone along with increasing consumption of affluent foods like meat, sugar, and alcoholic beverages.

The production of food requires vast amounts of land. Sofar, changes in agriculture have been sufficient to meet demand growth. In some countries, the physiological yield limits are almost reached, however. A continuation of demand increase, therefore, implies huge challenges on the availability of land resources.

The specific aims of this study are to examine the range of per capita land requirements for food patterns that not only fulfil basic physiological needs, but also satisfy social and cultural demands. The study calculates inter-generational and regional differences in consumption, and identifies those parts of the food packages that have the largest claims on land areas. Results are used to discuss future food security on a global scale.

2. Methods

A foregoing study on land requirements for food consumption patterns has developed a method to calculate land requirements for individual foods (m^2 year kg^{-1}). This study uses the data on land requirements to assess the relationship between per capita requirements and food consumption patterns. This is done for three scale levels: (i) a basic food consumption level, providing sufficient nutritional energy, (ii) a subsistence level, providing nutritional energy and nutrients, and (iii) a cultural level, containing the actual consumption patterns. The study calculates the gap between land requirements for basic and subsistence levels, and requirements for actual food consumption patterns. In order to evaluate effects of temporal changes in consumption on land requirements, it includes inter-generational differences.

3. Results and discussion

Figure 1 shows that land requirements for food patterns on the subsistence level are three times larger than for patterns on the basic level. The study finds large differences among consumption categories. In The Netherlands, the categories of fats and meat show the largest requirements: 580 m^2 (30% of the total) and 570 m^2 (29% of the total) respectively. Dairy and eggs require 320 m^2 (17% of the total). The area for beverages is 220 m^2 (12% of the total), and is heavily dominated by one item: 60% is needed for coffee. Although the consumption of basic foods (staples, such as cereals and potatoes; sugar; vegetables and fruits) is a factor of four larger than for meat, the land required is only 220 m^2 (12% of the total).

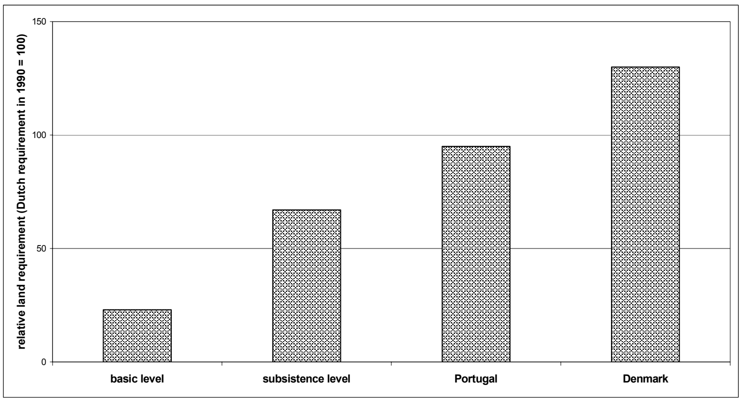

Figure 1 Relative land requirements for two hypothetical food consumption patterns, the basic and subsistence level, and for two existing European patterns related to the smallest and largest land requirements, the Portuguese and the Danish.(land requirement for the Dutch per capita food consumption in 1990 = 100)

Per capita land requirements differ among countries. Even in Europe, the study observes large differences among land requirements for food consumption patterns. Figure 1 shows results for European extremes expressed in relative units. In absolute units, Portugal has the smallest per capita land requirement (1810 m^2), Denmark the largest (2480 m^2). Large consumption of beer, coffee, fats, pork, and butter causes this large Danish land use. Despite the existence of a physiological limit for food consumption, the study finds a difference of a factor of six between the land requirement for a hypothetical diet based on wheat and the requirement for an affluent diet.

Patterns can change rapidly over time, leading to other claims on the land. Figure 2 shows that in The Netherlands in the period 1950-1990 larger demand for more affluent foods led to a 40% rise of per capita land requirements. Although food consumption patterns changed, figure 2 also shows that based on actual yields, in reality per capita land requirements decreased.

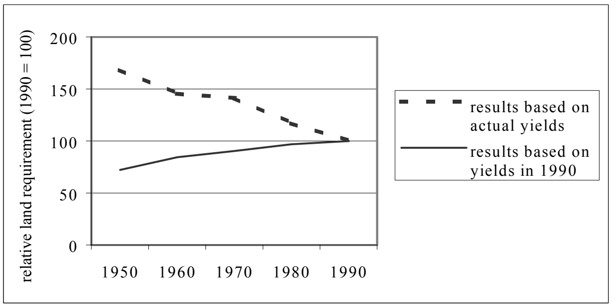

Figure 2
Development of Dutch land requirements for food between 1950-1990. Calculations were made using yields in 1990 as input data An indication of actual requirements is given by correcting these results for lower yields in the period considered

4. Conclusions

Studies on food security based on comparison of food energy supply with nutritional energy requirements show that future generations can be fed. However, these studies do not take into account foods low in nutrient density, important on a cultural scale level (e.g. coffee), or large quantities of specific foods. This study takes physical as well as cultural requirements into account and shows large differences among land needs for various food consumption patterns. The study observes that a trend toward more affluent patterns will bring with it a need for more land and cause competition with other claims. Today, average food intakes in many developing countries are lower than requirements on the subsistence level. In these countries, rising incomes will not only increase food intake but also cause a shift of consumption patterns toward the affluent menus in western countries. As a result, per capita land requirements might rise substantially.

Life Cycle Assessment of Electricity Generation from Sugar-Cane Biomass

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Sugar cane, grown widely in developing countries, is known to be one of the most productive species in terms of its conversion of solar energy to chemical potential energy. Owing to events taking place at the international level, the sugar cane industry is at a cross roads. It has to undergo changes to ensure its sustainability and competitiveness in the context of the globalisation of the economy. In the past, the sugar industry depended on sugar alone for its commercial viability. But along with the imperative of harnessing energy from renewable sources to drive development on the continent, the opportunity of generating energy co-products from this industry is becoming increasingly attractive. Several options exist as shown in Figure 1, ranging from co-generation of electricity via bagasse combustion and/or gasification, possibly augmented by cane-trash utilization as fuel, via composting which could lead to increased crop productivity, to the production of ethanol from molasses or whole cane, or in the future even from the bagasse via cellulose hydrolysis processes. Biogas production from the wastes completes this picture.

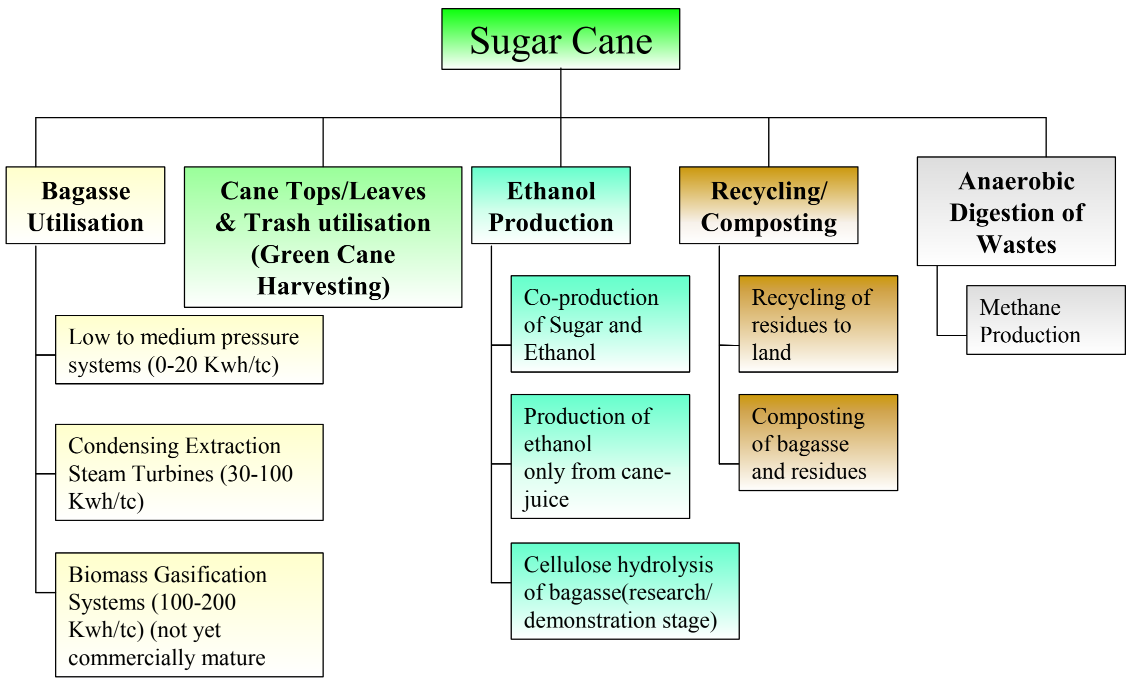

Figure 1: Options for Energy By-Products from Sugar Cane

Comparing these options, even from a point of net productivity only, is a complex task, and it becomes more complex when economic and environmental issues have to be taken into account as well. Agricultural, environmental and energy policy-making in countries with sugar industries will have to increasingly engage with this potential of better utilisation of crops. The Life cycle Assessment tool(LCA) is a suitable one for assessing the various potential practices, as they are designed to deal with the above-mentioned complexity.

This paper presents the findings of a life-cycle assessment (LCA) of electricity generated from the combustion of sugar-cane bagasse in Mauritian sugar mills. The study arose from the identification of the need for environmental information and methodologies for comparing energy alternatives on environmental grounds to provide guidance to a developing renewable energy market in Mauritius to substantiate ‘green energy’ claims.
The aim of the study was to apply an established model to the assessment of bagasse-derived electricity to determine if bagasse-derived electricity provides any environmental benefits over the existing dominant source of electricity in Mauritius (electricity derived from fuel oil or coal), and to provide recommendations for an appropriate model for future LCA studies of energy systems. The paper draws some generic conclusions regarding policy and strategy related to possible future electricity generation from this industry:

The system analysed in this study is the production of exported electricity from sugar mills from the combustion of sugarcane bagasse. The unit operations that make up the system are the growing and harvesting of sugarcane, the transport of the harvested cane to sugar mills, the production of bagasse as a by-product from the sugar milling process, and the combustion of bagasse to generate heat and electricity. The functional unit of the study is the generation of 1GWh of electricity exported to the state electricity grid from Mauritian sugar mills. The system is limited geographically to the state of Mauritius and is intended to be representative of current agricultural techniques practiced and current manufacturing processes used by Mauritian sugar mills.

The LCA study generated characterised results for the impact categories: water use, greenhouse gas emissions, acidification, summer smog, eutrophication, solid waste and non-renewable energy input. The characterised data for 1GWh of bagasse-derived electricity was compared with data for 1GWh of coal-derived electricity, using the same set of characterisation factors. The results of this comparison indicate that bagasse-derived electricity provides potential environmental benefits in some areas but not in others. Bagasse-derived electricity performs well in the areas of greenhouse gas emissions, acidification, solid waste generation and non-renewable energy inputs, but performs poorly in relation to water consumption and eutrophication.

Sustainable use of food processing wastes livestock feed or bio-energy

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Introduction

The food processing industry produces large quantities of waste products. In the Netherlands the agricultural waste-streams account for two thirds of the total industrial waste-streams. Presently these waste-streams are in use as feed for livestock. In the Netherlands about 70 % of the livestock feed originates from waste-streams generated by the food processing industry. Comparable values are found on a global scale. This livestock is more or less upgrading a waste-stream from not suitable for human consumption into a highly valued food commodity (meat). This implies that residues from food processing industry form the basis for the production of important proteins in the human diet.
In principle, these residues can also be used for other non-food purposes for instance as feedstock for bio-energy production. The amount of energy that can be obtained from these residues is substantial. It is estimated that in the Netherlands potentially 190 PJ can be obtained from these residues, on a global scale values of over 12 EJ are mentioned.
However, the use of these residues as an energy source will affect the food system, since an important source for livestock feed disappears.
This paper focuses on the question: what are the consequences of using residues for energy generation instead of using them for livestock feed. It studies the adaptations required in the food system to compensate for the loss of residues. Three different systems are recognised: the present one where residues are used for livestock feed (figure 1) and energy is obtained from energy crops (wood), and two systems were residues are used for energy generation. The loss of livestock feed is compensated for by growing extra protein crops (in combination with a change to a vegetarian lifestyle (figure 2)) or by the growing of extra feed crops (figure 3).

Figure 1

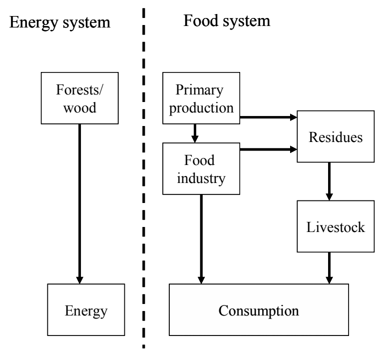


Figure 2

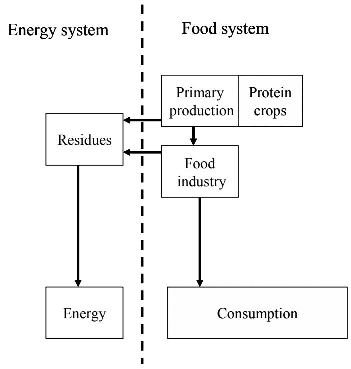
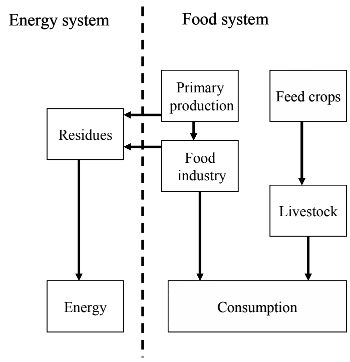


Figure 3



Figures: Schematical presentation of the three systems studied: Energy Crops system (fig 1), Vegetarian System (fig 2), Feed Crops System (fig 3)

Method

For all three systems the magnitude of the various flows is quantified through answering the following questions:

1. What is the magnitude of available residues in kg/person.
2. How much meat can be produced on basis of these residues
3. How much beans/pulses compensate for the animal protein in the menu
4. How much wheat compensates for the residues as livestock feed
5. How much energy can be gained from the residues considered
6. How much wood from biomass plantations compensates for energy in residues.
7. Finally how much acreage is needed for producing the beans, the wheat and the wood in the various systems.

Results

Table 1 shows the acreage required for the production of proteins and energy in the three systems studied. No acreage is attributed to the agricultural residues since it is assumed that they are 'unwanted' by-products of the food industry. This implies that in the Vegetarian System (fig 2) and the Feed Crops System (fig 3) no land is attributed to energy and that in the Energy Crop System (fig 1) no land is attributed to the meat production. The production of 36 kg beans in the Vegetarian System requires 120 m^2. In the Energy Crops System 80 m^2 is needed for the production of 2.2 GJ energy (121 kg wood), and the production of 120 kg wheat in the Fodder Crops System requires 170 m^2.

Table 1 Comparison of the acreage required for producing proteins {33 kg pork (on residues or 120 kg wheat as fodder) or 36 kg beans} and 2.2 GJ energy (on residues or 121 kg wood) in the three different food-energy production systems.

Energy crops (fig 1)		Vegetarian (fig 2)		Feed crops (fig 3)	
	m^2		m^2		m^2
33 kg pork	0	36 kg beans	120	120 kg wheat	170
121 kg wood	80	2.2 GJ energy	0	2.2 GJ energy	0
Total	80	Total	120	Total	170

The large differences that occur between the systems are striking. The Energy Crops System and the Fodder Crops System produce the same commodities (energy and pork) but the Fodder Crops System requires nearly 100 m^2 more to do so. The Vegetarian system also requires a larger acreage than the Energy Crops System (120 m^2). It should be noted that values mentioned concern values per person per year. 33 kg pork is over 70% of the annual meat consumption per person. And 120 m^2 seems a small amount of land but multiplying it with the number of inhabitants results is vast amounts of land needed.

Conclusion

The analysis above allows some general conclusions on use of agricultural residues for energy generation. When residues have a value as livestock feed, use of these residues as energy source results tremendous trade-offs to the food system. These trade-offs are due to the fact that loss of livestock feed need to be compensated for to maintain a healthy diet for the human population. The loss in the food system is far larger (120-170 m^2) than the gain in the energy system (80 m^2).

Perennial Crops are Most Efficient in Biomass Production – A Comparison of the Efficiency and Multiple Land Use Options of Perennial and Annual Biomass Crops.

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Introduction and aim

The EU has set high targets for the use of biomass in future Europe that would, if this biomass were to be produced within Europe, require several million hectares for energy crop production. Because of the high land demand for energy crop production, but also because of the potential competition of biomass production with other land uses, like food production or nature protection areas, biomass production should be efficient in terms of land use and the generation of ecological benefits. Aim of this presentation is to perform a quantitative comparison of the nitrogen, energy, water and land use efficiencies of energy crops and to discuss their ecological benefits in multiple land use systems.

Approach and results

In terms of efficiency biomass production should be optimized for those sources that are either limited, like land and water, or have potential negative environmental impacts, like nitrogen and energy use. Here we pay special attention to nitrogen use efficiency. It is important with regard to environmental sound production of biomass because nitrogen application on the one hand is essential for high yields, but also has several severe environmental impacts like nitrate emissions to surface and ground water and emissions of greenhouse gases (nitrous oxide) on the other hand. Together with nitrogen use efficiency (kg N input per t biomass) the efficiencies of water (l water consumed per t biomass), energy (GJ input per t biomass) and land use (GJ harvestable bioenergy per ha) will be shown and quantified for perennial and annual crops by the example of the biomass grass miscanthus and the cereal triticale. The results show that the resource use efficiency of crops significantly depends from the site conditions and the input (e.g. nitrogen fertilizer) level. Optimum input levels in terms of efficiencies for one factor, e.g. nitrogen, are not always optimum levels for the efficiency of other factors, e.g. land. An example for the impact of energy input on the energy use efficiency of biomass production is given in figure 1 for the crops triticale and miscanthus. Compared to the annual crop triticale, miscanthus is twice as efficient in terms of water, nitrogen and land use. The reasons for the different performances of energy crops will be discussed.

Land use efficiency of biomass production can mean a high amount of energy produced per ha, but also the fulfillment of different functions on the same area. In so called multiple land use systems the production of energy crops can be combined with functions that deliver products or services other than biomass like the remediation of soils, enhancement of biodiversity, cleaning of waste water etc. In a review more than 30 functions that can be combined with biomass production were found. These functions are grouped into 8 categories (see table 1).

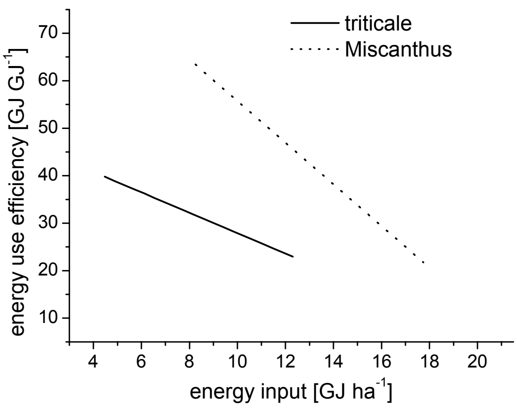

Figure 1: Energy use efficiency (in GJ per GJ) for the biomass production with miscanthus and triticale

Category of land use functions	*Examples*
Nature conservation and management on local and regional level	Enhancing Biodiversity
Nature conservation on global level	Carbon sequestration
Extraction of abiotic renewable resources	Extracting of drinking water
Waste treatment and disposal	Municipal Wastewater cleaning
Protection	Buffering areas of nature protection against influence of intensively used areas
Recreation facilitation	Green and structural elements in settlement areas
Agro-forestry	Production of fruits and medical plants
Infrastructural improvements	Visual and acoustic protection along streets, railways and settlements

Table 1: categories of land use functions for the combination with biomass production in multiple land use systems

An analysis of the combination options of different crops with these functions has shown that not all crops are combinable with every function and that the amount of products being delivered by a function depends on the kind of energy crop combined. Carbon sequestration, for example, requires long-term soil rest. This can, to a certain extend, be practiced with conservation tillage practices in annual crop production systems, but the amount of carbon sequestered is generally higher under perennial crops that require no soil tillage over decades. In this presentation the combination ability of different biomass crops with land use functions will be discussed.

Conclusions

The overall conclusion of the presentation is that, for several reasons, perennial crops are (a) more efficient biomass producers and (b) more suitable for sustainable multiple land use systems.

Global Patterns in Socio-Economic Biomass Metabolism. A New Estimate.

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The amount of biomass humans extract globally is of considerable ecological as well as socio-economic importance. In using biomass, humans compete with all other organisms for this important resource. Biomass harvests can have significant ecological impacts, among others endangerment of biodiversity and changes in ecological carbon (or other material) stocks and flows. As food and feed, biomass is indispensible for the sustenance of humans and their domesticated animals. In subsistence economies biomass is an important, often almost the only source of energy. But also in industrial societies biomass constitutes an important element of the energy system and contributes up to a quarter of total primary energy supply

Despite it's socio-economic significance, there is considerable uncertainty in data on global socio-economic biomass metabolism. While some important fluxes are recorded each year in FAO databases (http://www.fao.org), only more or less crude estimates exist for a considerable fraction of the yearly flows, e.g., the contribution of biomass to energy supply in rural areas, above all in subsistence communities in developing countries, grazing by domesticated animals, etc. Only recently, biomass flows in the global food system have been evaluated in a combined statistical-modelling approach by Wirsenius (2000), but at present no comprehensive analysis is available.

This paper presents a new, comprehensive estimate of global biomass extraction and use on the level of individual countries respectively world regions. Our estimate is consistent with the international standard methodology for material and energy flow accounting (MEFA) and builds on international statistical database such as FAOSTAT or the IEA database. Flows not covered or underestimated by international statistics, such as biomass grazed by livestock or wood harvest, are quantified by using demand-driven modelling approaches and regional estimates. Particularly biomass flows in rural areas in developing countries are only weakly covered by official statistics and often based on very crude estimates. We have improved these figures by modelling these flows referring to a number of detailed MEFA studies at a local and regional level in developing countries.

The paper will discuss global patterns of biomass use and identify important socio-economic and natural factors determining the overall size and structure of biomass metabolism. It will discuss the relation between land use, population density, economic development and socio-economic biomass flows. Special attention will be given to environmental pressures related to biomass extraction, above all to socio-economic interference with energy flows of ecosystems (i.e. patterns of human appropriation of net primary production).

T2 PM

Session A: **Tools in IE**

Chairmen: R. Ramaswamy

Location: Lindstedtsvägen 3
Room: E1.

A Dynamic "Toolbox" for Modeling Physical and Social Systems Related to Water Flows

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Vince Tidwell, and Len Malczynski, Sandia National Laboratories, Albuquerque, NM, USA

In the growing body of knowledge about energy and material flows, water continues to be an under assessed "material." Without water, there is no energy to flow and water is used in vast quantities in myriad industrial processes. Water is also a very social material. It is essential to human life and its management is subject to disparate political, social, and cultural systems. As parts of the world already face dire water shortages, better understanding how this material flows throughout various systems is increasingly important. Industrial ecologists fully recognize the need to integrate physical and social processes in order to achieve sustainability. Toward that end, Sandia National Laboratories has established a multidisciplinary team to use a system dynamics approach to model both physical and social attributes of any water use/water management application.

This multi-year project is developing a generic resource-planning "toolbox"—a collection of process modules and constitutive relations that an analyst can "swap" in and out to model the physical and social systems important to a specific issue. For water, the technical challenge lies in integrating disparate systems of hydrology, ecology, climate, demographics, economics, policy, culture and law. The research team includes experts from all pertinent disciplines. After one year, this team has developed an initial framework for the "toolbox" within a system dynamics platform.

System dynamics provides a mathematical framework for integrating the natural and social processes and utilizes an interactive interface for engaging decision-makers and the public. System dynamics is based on the concept of a spatially aggregated and temporally dynamic commodity balance. These models focus on capturing the feedback and time delays between interacting subsystems. A key value is that they can reveal complex relationships that are often non-intuitive among the physical and/or social systems.

Additionally, system dynamics suggests that omitting variables that researchers know are important, but that are not well represented with numeric data, is less scientific than estimating values to represent key relationships (Sterman, 2000). Unique among computer-based models, this effort includes social parameters that are crucial in water-related decisions, but difficult to integrate into a mathematical model. Using heuristic information, the toolbox can integrate qualitative data, such as cultural values or non-price driven behavior.

Relevant to decision-making processes, a system dynamics model can conduct simulations in a matter of seconds to minutes. Users can generate "what if" scenarios and see the implications of various combinations of actions and what is driving the outcome. This "toolbox" approach will allow decision-makers to identify key variables within their system of interest and to readily see relationships among those variables. This may be especially valuable in regions or industries that lack extensive or accurate data related to water use. The graphical interface also makes the "toolbox" a potentially powerful public education resource, which is key to addressing social or cultural barriers to improved water management.

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In-Use Stocks of Metals: A Status Report

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The past decade has seen a large number of substance flow studies for metals, on spatial levels from factories to the planet. One universal aspect of these studies is that flows into use (inputs) exceed those into waste management (outputs); the difference represents additions to in-use stock. Historical records of input flows and data or estimates of output flows can thus provide estimates of standing stock. That stock can be estimated independently by identifying the principal reservoirs in which the stock resides (e.g., buildings, automobiles, etc.) and multiplying the number of each of those reservoirs in the geographical area of interest by the typical metal contents of the reservoirs. Standing stock studies for copper, zinc, and other metals are reviewed for consistency, and best estimate per capita stocks are derived for developed and developing countries. The results illustrate (and begin to explain) discrepancies among individual studies, and indicate where additional analyses are needed. Because the amount of materials available for recycling in future years depends upon the amount now embedded in products providing services, and on the lifetimes of those products, improving the accuracy of estimates of in-use stocks and in-service lifetimes will become increasingly important.

Urban Ecology: Applying Material Flow Analysis to Great Mendoza Area.

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At present, 47% of the world population lives in big urban centers, with an increasing trend, rating 55% during the second half of the XXI century. Moreover, this proportion is even bigger in Latin American countries reaching today 70% of urbanization. This increasing urbanization has a multifold dimension, on one side there is not only a population shift from rural areas to urban, but also middle size cities are loosing their population towards big urban centers and mega cities (more than 10 millions). It is expected that the amount of megacities in the world will increase from 15 (today) to 25 in year 2020.

On the other side many cities follows a chaotic development pattern, so new models are required to explain this phenomena and to help plan the growing need of services This urgent need has pushed an increased the interest to find new analysis and simulation tools for the urban development. Recently Material Flow Analysis (MFA) has become a fast growing field of research with increasing policy relevance. MFA is also recently used for the analysis of the metabolism of cities, regions, and national or supranational economies. MFA refers to the analysis of the throughput of process chains comprising the extraction or harvest, chemical transformation, manufacturing, consumption, recycling, and disposal of materials.
It is based on accounts in physical units (usually in terms of tons) quantifying the inputs and outputs of those processes. The subjects of the accounting are chemically defined substances (e.g. carbon or carbon dioxide) on the one hand and natural or technical compounds or ‘bulk’ materials (e.g. coal, wood) on the other hand. These studies are based on the methodological principle of mass balancing, whose accounting may be directed to selected substances and materials or to total material input, output and throughput.

In this paper we will concentrate our attention to the overall characterization of the metabolic performance of the city of Mendoza, Argentina, in order to understand the volume, structure and quality of the throughput and to assess the status and trend with regard to its sustainability. This project intent, precisely, to contribute to the development of planning and management tools, and it should help to evaluate new scenarios of urban growth, and particularly to study the greenhouse gases emissions trends.
The overall main goal of this study is to develop a spatio-temporal – dynamic-model of urban area, combined two methodologies, a top-down model, as the

MFA mentioned above; and a bottom-up approach using agent models (like cellular automata or genetic algorithms) based on a geographical information system (GIS). Top-down models provides an overall understanding of the city performance, but bottom-up approaches give more insight and detail of the geographical differences which may help to identify the main drivers or patterns of consumption and sustainability options.

Material Flow Analysis in China

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The tool of material flow analysis (MFA) was used in recent years in China's circular economic development. Four case studies on different levels, one on national level and three on regional level, were presented in the paper, which were carried out by DESE, Tsinghua University.

First, MFA China from 1990 to 2000 was illustrated, using the standardized MFA methodology widely applied before. Some aggregate indicators were presented to make further analysis. Results showed that the materials inputted to the Chinese economy increased by an annual rate of 4.04%, while the outputted materials also increased, by an annual rate of 6.12%. Because of the huge population, China had very low material consumption per capita. Compared with other countries, the material utilization efficiency in China was very low. The average resource productivity (RP) of China was only 2.16% of that of Japan. To achieve the modernization aim, China must improve its RP for 33 times.

The second case study is MFA Jiangsu — province level. The background of MFA Jiangsu is the planning of establishing a recycling-based industry of Jiangsu Province, an eastern province in China. On the basis of collecting large quantity of data, MFA was used to analyze the material input, pollution output and material recycling of industry system of Jiangsu. The analysis revealed that industry system of Jiangsu Province was a linear economy with the characteristic of single directional material flow of "resources-products-wastes". Moreover, four different economic growth styles were discussed by scenario analysis. The results also showed that current style was not a sustainable one. Therefore, it is very important to establish a recycling-based industry, and the weak-decoupling growth style is a feasible way to reach the destination.

The third case study is MFA Guiyang — city level. Guiyang is a pilot city of circular economy development in China. In order to lay the foundation of the planning for the circular economy development in Guiyang, MFA was used to analyze the economic growth style in Guiyang. The method was based on the framework of Eurostat guideline, with some amendments according to the characteristic of regional MFA and the data condition of Guiyang. The panorama of material flows in Guiyang in 2000, the amount, structure, intensity and per capita of direct material input (DMI) from 1978 to 2002 and those of waste of production (WP) from 1996 to 2002 were given. The results showed that the nowadays economic growth in Guiyang had a strong characteristic of linear economy style--high resource input and high pollution discharge.

Finally, MFA Yima —county level— was discussed. Yima is a small county in the middle China's Henan Province. The economy of Yima mainly depends on the coal extraction. DMI, DMC and WP during the period from 1995 to 2003 were calculated. The material flow intensity and material flow per capita were calculated subsequently. In the studied 9 years, the GDP grew rapidly by 96%, while the population rose slowly by 11%. In the case of Yima, the DMI fell a little, which showed a decouple trend between economic growth and resource use. However, the rapidly risen DMC showed an opposite trend. The WP also grew, indicating that the economic growth haven't decoupled from pollution discharge yet. DMI and DMC should be used together to judge the decouple trend, so the economic growth style of Yima is still a linear economy of high resource input and high pollution discharge.

According to the MFA results, both China and the three regions studied above have strong characteristics of linear economy, and the economic growth haven't decoupled from resource input and pollution discharge yet. Such traditional way of economic growth must be abandoned, and circular economy is the best choice of the sustainable development.

Moreover, all the four case studies were carried out in China, where statistical data, especially the regional imports and exports data are relatively sparse. These studies provided experiences to the development in the research field of MFA. The four different cases are of different levels. In a word, the regional MFA is more difficult to be carried out than the national MFA, because of the lack of the regional imports and exports data, according to the current statistical system. Among regional MFAs, the higher the level is, the more difficult the task will be. The main reason also lies in the regional imports and exports data. Nowadays, it is nearly impossible to get full set of data on the province level, while it is realistic to collect enough data on the county level. However, with the establishment of statistical system under the framework of SEEA or Green GDP in the future, it brings promise of resolving the problems mentioned above.

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An Integrated LCA-LCC Model for Evaluating Concrete Infrastructure Sustainability

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Cement, the key binding material in concrete, is vital to human infrastructure and the economy. We rely on its durability and versatility to build our roads, bridges, buildings and water and sewage systems. Despite its important role in our built environment, its production contributes a significant amount of carbon dioxide (CO_2), a greenhouse gas, to the atmosphere; approximately 5% of total anthropogenic emissions[1], and is one of the top two industry producers of CO_2.[2] Global flows of concrete amount to approximately 2 tonnes per person on the planet[3], and in the Unites States amounts to flows greater than 1,600 million metric tonnes (Mt) each year. Of total U.S. consumption, approximately 31% is used to build and rehabilitate highways and roads[4]. Despite this investment, an estimated one-third of U.S. roadways are in poor or mediocre condition, burdening the public with construction related impacts such as congestion and vehicle damage.[5, 6]

Long-term environmental and economic impacts of infrastructure design and material selection are modeled as part of a five-year NSF MUSES[7] project whose goal is to enhance the life cycle management of concrete infrastructure by developing a holistic approach for modeling. In the first phase of this research, an integrated life cycle assessment (LCA) and life cycle cost (LCC) model was developed to simulate construction and rehabilitation processes and traffic flow over the full service life of a bridge deck. This model is applied to two alternative concrete bridge deck designs: one a conventional steel reinforced concrete (SRC) deck with mechanical steel expansion joints, and the other an SRC deck with engineered cementitious composite (ECC) link slabs. Figure 1 shows the LCA-LCC model integration framework. This dynamic LCA-LCC model includes over 100 user-defined parameters and incorporates a traffic congestion model, the Kentucky Transportation Center's KyUCP model; and two

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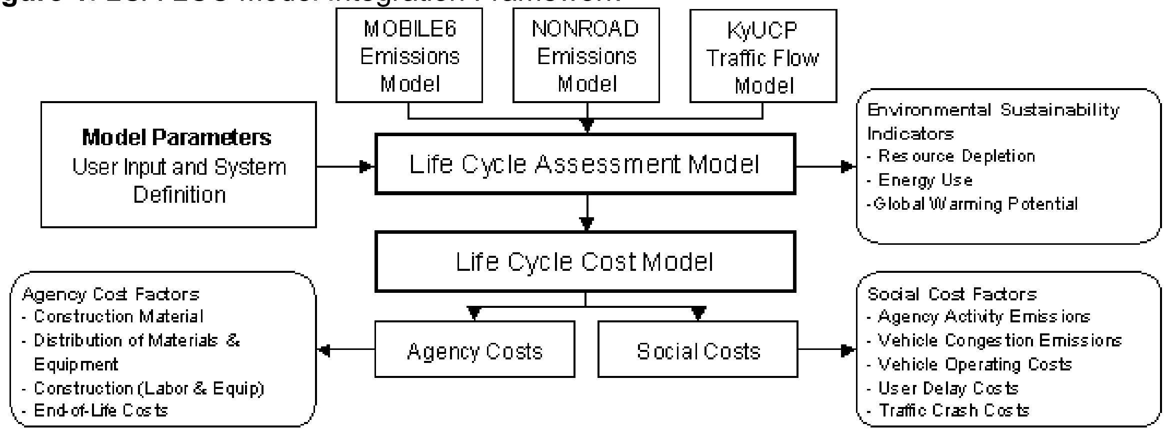
[7] Materials Use: Science, Engineering, and the Society (MUSES) is part of the National Science Foundation's Biocomplexity in the Environment Program.

emissions models, the U.S. Environmental Protection Agency's (USEPA) MOBILE6.2 emissions model for assessing vehicle emissions, and USEPA's NONROAD emissions and fuel use model to evaluate construction equipment impacts. The integrated model accounts for changes in vehicle and equipment emissions, and changes in traffic flow rate patterns over the bridge deck lifetime.

Figure 1. LCA-LCC Model Integration Framework

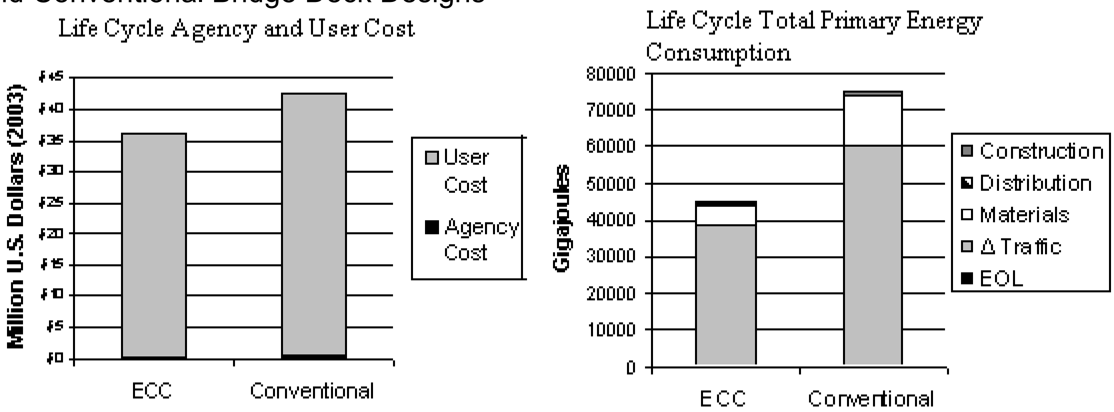


Results from the LCA model provide a set of environmental sustainability indicators that also serve as key inputs to the LCC model. The LCC model accounts for both agency and social costs. Agency costs consist of material, construction, and end-of-life costs. Social costs are comprised of emissions damage costs from agency activities, vehicle congestion, user delay, vehicle crash, and vehicle operating costs.

The two design alternatives are evaluated over a 60-year time horizon: the ECC link slab system is modeled with a 60-year service life, while the conventional joint system requires two bridge decks each lasting 30-years. Over this time period the ECC link slab system shows significant benefits in environmental performance relative to the conventional joint system, despite that ECC material is more energy intensive than conventional concrete on a per-volume basis. Results show that the ECC link slab system consumes 40% less total primary energy, produces 39% less carbon dioxide, and consumes an average of 38% less of key natural resources such as coal, limestone, and water. Construction related traffic dominates model results. For a 0% traffic growth scenario, construction related traffic energy (shown as Δ Traffic in Figure 2) comprises 80% of total primary energy consumed by the conventional system and 85% of total primary energy consumed by the ECC system. Construction related traffic also dominates results for the majority of air emissions including; hydrocarbons, carbon monoxide, methane, and greenhouse gas emissions.

As with the LCA model, the LCC model shows that user-related costs such as time lost to motorists and commercial trucks due to construction related congestion dominate the total life cycle costs calculated in the model. In fact user costs, led primarily by the costs of delays from construction-related traffic congestion, account for 99% of costs in the ECC design system and 98% of costs in the conventional design system. Overall, however, the ECC system has an approximate cost advantage of 15% over the conventional system.

Figure 2. Lifecycle Energy Use and Cost for the ECC Link Slab and Conventional Bridge Deck Designs



Session B:
Social Dimension/ Side of IE

Chairmen: M. Cohen

Location: Lindstedtsvägen 5
Room: D2

EIP Champions Focus on Developing Social Relationships via Two Distinct Models

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During the past twenty years, Industrial Ecology (IE) has emerged in response to a global call for sustainable development to counteract environmental pollution from industrial wastes. Missing from the IE dialogue is research about the individuals who champion the creation of Eco Industrial Parks (EIPs). Based on a qualitative study of two champions associated with Kalundborg industrial symbiosis in Denmark and Londonderry EIP in New Hampshire, USA, two distinctive models of operation emerged. The research methods of ethnography and grounded theory allowed a theoretical understanding of the champions' experience. The systematic analysis resulted in data that revealed the champions focus on developing social relationships and not technological connections. The two cultural models represent an adaptive-processing style and an expert-linear approach. The adaptive-process model stresses inter-personal relationships to assess available resources and develop an effective strategy based on understanding the local context; and the linear-expert model links a predictive approach with a formal setting that targets top managers. Both approaches or a combination of the two models are effective. The emphasis of the findings is on the role of people and the social relationships necessary in implementing EIPs—factors often disregarded in the industrial ecology discourse.

Scientific profile and unique features of identity: Industrial Ecology reviewed from a philosophical perspective

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The paper is an attempt of a philosophical appraisal to Industrial Ecology, seen as a new academic branch and emerging scientific field that stresses to perform industrial economy and crucial technologies on different levels towards a more sustainable future, preferably by learning from nature's economy and natural ecosystems' behaviour (Ayres 1994; Graedel 2000; Isenmann 2003). Sometimes, this new field is even announced as the "science of sustainability" (Allenby 1999; IEEE 2000; Ehrenfeld 2004).

Since its inception and throughout its early stages some decades ago (Frosch 1992; Erkman 1997), industrial ecology has rapidly developed to an intellectual area which now constitutes a scientific community with an emerging body of theory (Korhonen 2004) and a growing school of thought (Graedel and Allenby 1995; Ayres and Ayres 1996; 2002), perhaps in its own right (Bourg 2003). Today, Industrial Ecology frames a professional academic culture (Huber 2000; Ehrenfeld 2000; 2001) with political and social implications and growing impacts on governmental agendas, business applications in a number of industry sectors, and higher educational programmes.

We think it may be the right time to stimulate discussion and fire debate on the field's disciplinary contours from a philosophical perspective - that is to bring Industrial Ecology's constitutive characteristics to the surface. Regarding its scientific profile, special emphasis is given to basic underlying assumptions, which are analysed within four fundamental categories:

- The role of human
- The function of nature
- The relationship between human and nature, and
- The meaning of economy and technology.

The contents of these categories are regarded as the core elements as "the heart" of Industrial Ecology's scientific profile and contribute to give the field its unique identity. The interpretations typical for Industrial Ecology indicates in these categories on the one hand a fundamental change and paradigm shift, especially in comparison with orthodox schools of economics and engineering.

On the other hand, Industrial Ecology is a response originated in the internal dialogue that there is an increasing need to elucidate core principles and values of the field (Allen 2001). In this respect, a philosophical appraisal sharpens Industrial Ecology's scientific profile. Further, approaching the research agenda from a philosophical perspective contributes to an ongoing vital methodological discourse (Lifset 1998; Allenby 1998; Boons and Roome 2001). The epistemology and methodology of the field has to answer questions such as:

- Where to set the boundaries and where to position the emerging discipline?
- What are appropriate research instruments, and
- How to deal with normative notions und underlying moral concepts?

These questions contribute to realign the discipline systematically with its (methodological) roots (Bey 2001), and will probably motivate transformations within a field, where a meta-disciplinary approach (Graedel 2000) becomes of greater importance.

Intellectual assumptions, theoretical basis, and central tenets of Industrial Ecology are to be found in the philosophical categories mentioned above. The architecture and body of theory seems to be significantly affected by them. Recognising these issues has an impact on Industrial Ecology's current and future standing too, for example related to the development of meta-disciplinary co-operation between disciplines such as engineering sciences and political sciences.

Moreover, society and academia have to consider, if it is possible to approach the normative concept of sustainability solely based on positive science or if other resources are needed to be taken into account, which gives a reason to discuss the role of ethics.

The way of how these issues are discussed and dealt with will likely influence reputation and shape conceptual success of the field. Recognition of its theoretical basis might also contribute to determine whether Industrial Ecology draws academic attention, how practitioners assess reliability and value of concepts, tools and instruments, and to what extent stakeholders are willing to make use of terminology typical for Industrial Ecology.

Shedding more light onto (still) underlying assumptions of the concept of Industrial Ecology could help the field's intellectual and institutional development, especially when trying to find a place within the scientific communities. Greater clarity in these issues seems to be needed to maintain any substantial meaning in contrast to other fields. Clearer definition what Industrial Ecology should be and what not, evidently becomes crucial as more and more communities position themselves as disciplines focused on sustainability and claim to provide relevance for approaching this ambitious goal.

The Social Side of Industrial Symbiosis: Using Social Network Analysis to Understand How Social Relationships Influence the Development of Symbiotic Linkages

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Industrial symbiosis describes the interdependence of geographically proximate but distinct firms for accessing and recycling resources. It requires a transformation not only in the physical connections among firms, but also in the way firms operate internally and how they interact with other firms, communities and ecosystems where they are located. High levels of communication, trust and social interaction are regarded as important features in locations where industrial symbiosis has successfully evolved. However, the specific roles played by social forces have not been well-studied. This research draws on the field of social network analysis, which characterizes and quantifies relationships among actors in a system, in this case, firms and their managers. It analyzes the correlations between social network (informal, professional and business) ties among the managers and the development of industrial symbiosis linkages among the firms. Intensive interviews were conducted with the managers in a variety of firms in three Puerto Rican towns – Arecibo, Barceloneta and Manatí – where several industrial symbiosis linkages were previously uncovered, including both by-product synergies and utility sharing arrangements. The analysis uncovered a social hierarchy among the interviewees, and correlations between particular social ties and symbiosis linkages. Knowledge of the role played by different types of social ties can elucidate opportunities for harnessing the power of interpersonal relationships in nurturing eco-industrial developments.

Creating Social System Change for Industrial Ecology: Companies as Agents of Change

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While there have been recent calls for increased attention to the social "side" of industrial ecology (Cohen-Rosenthal, 2000; Ehrenfeld, 2000; Hoffman, 2003), there remains little work that elaborates the mechanisms of simultaneous social and technological change to attain the goals of industrial ecology. Using the tools of industrial ecology we have gained an increasingly sophisticated understanding of desired and possible end states in which industrial pollution is greatly reduced, but we do not necessarily understand how companies can proceed from their current situations to these desired end states. In other words, we know the "what" but not the "how" of the solutions we seek (Andrews, 2001).

To redress this, some scholars have called for increased attention in the industrial ecology literature to the human influences on change, whether at the level of individual cognition, individual decision-making, organizational cultures and structures, or broader societal institutions (Andrews, 2001; Hoffman, 2003). These approaches should not threaten the field's historical focus on material and energy flow analysis, but should complement them by drawing attention to the interactions between physical and social systems, with a resulting return to the holistic roots of the field (Allenby & Richards, 1994; Ayres & Simonis, 1994; Graedel & Allenby, 1995). Further, examining the mechanisms by which organizations change social systems does not demand that scholars of industrial ecology revise the normative basis of the field, an issue that is hotly contested (Allenby, 1999; Bey, 2001; Boons & Roome, 2001).

Our focus on social system change starts from the empirical observation that some organizations are more successful than others a making change on both technical and social aspects of environmental issues (Smith, 2003). Why are some companies able to effectively change the "rules of the game" when they act on such issues, while others are not? For example, British Petroleum CEO John Browne announced in 1997 that his company considered global climate change a serious issue and voluntarily pledged to reduce its greenhouse gas emissions. Through these actions, BP both responded to and influenced a change in public, NGO, government and international opinion such that the company has had a disproportionate voice in influencing government policy and has offset critical challenges from activist and media scrutiny (Hoffman, 2000). Beyond changing BP's social and cultural standing, these actions precipitated a major shift in corporate positions on global climate change such that Royal Dutch Shell followed BP in making a $500 million commitment to solar energy and other renewable energy sources and quitting the Global Climate Coalition (GCC), an industry group opposed to curbing greenhouse gas emissions. With these two major defections, the GCC soon collapsed (Hoffman, 2000).

This is an example of a firm taking action that reshapes the broader field of organizations in which it operates (Scott, 1995), and shifts the broadly accepted norms of business practice, forcing others to follow. While the role of reshaping rules and norms has traditionally been attributed to government (Fligstein, 1990; DiMaggio, 1991) or social movement organizations (Benford & Snow, 2000), organizational scholars are increasingly attending to how corporations strategically and purposively perpetuate change (Lawrence, 1999; Fligstein, 2001). Could Exxon have taken the same actions as BP had? And, if it had, would it have precipitated similar change? In this paper, we use insights from organizational theory to explain why some companies, and not others, are able to initiate change within a field. We identify the particular types of capital that put a company in a position to act, and the particular skills that actually enable it to take action.

In order to make the kind of social system change demanded by industrial ecology, a company must possess the economic, social and cultural capital that enables it to influence others within a field of organizations. Capital "represents a power over the field (at a given moment)" (Bourdieu, 1985: 724). But more than merely analogous to power, capital draws attention to a variety of modes of influence an organization may possess, the relative value of these different modes, and their interaction with each other. In the paper, we identify the particular types of economic, social and cultural capital companies should hold in order to be in a position to influence others in the field to establish new types of relationships and new norms congruent with the ends of industrial ecology.

Finally, whether and how a company can actually act from such a position depends on internally developed skills. We propose that four broad classes of skills are critical in moving companies from having the opportunity to act to having the capacity to act: scanning and sensing the environment; framing the issue; gaining commitment; and attaching new practices to existing ones. In the paper, we integrate and build on a number of organizational theories to elaborate these classes of skills.

Insights from organizational theory can enrich research on industrial ecology by introducing ways to understand a company's capacity to act and bring about change at the level of social systems. The mechanisms by which individual companies move from one set of relationships and one set of business norms to quite different sets are not elaborated in much of the literature on industrial ecology. Starting from the simple observation that not all companies are equally able to change the rules of the game in the fields in which they operate, we identify the types of economic, social and cultural capital that are valued in creating change, and the particular set of skills a company must possess in order to actually implement the change. This is a first step in identifying how individual companies can bring about the simultaneous social and technological changes demanded by industrial ecology.

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Linking Material and Energy Use to Time Use. An Integrated Assessment of Social Metabolism for the UK 1950-2000

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Social metabolism refers to the idea that societies intentionally organise a permanent flow of matter and energy in order to reproduce physically. While case studies using the concept of social metabolism have focused on the interface between society and nature little has been said about the make up of society itself. This is, however, understandably difficult since sociology does not offer straightforward operationalizations of 'the social' ready for being linked to the biophysical accounts of flows of matter and energy. In this contribution, it is suggested that time use accounting has a certain potential to inform us about the social side of metabolism. If we can measure how the members of a society spend their time, we have the elements of a certain sort of account of how that society works. I we repeat these measurements, at different stages in the history of a society, then we will have the basis for a developmental account of social and economic change. It is the daily activities of members of a society that shape (and in turn are shaped by) economic structure. Changes in the aggregates of time use can be used at the societal level to explain changes in social structure.

Our time use accounting starts with total available time in a social system which constitutes a limited resource (a budget). Part of total available time is allocated to what people need to reproduce themselves (including sleeping, eating, and personal care). Another fraction is allocated to non-working members of population including children in childcare and school as well as elderly people in retirement. According to a certain socio-political compromise these groups might change over time. The remaining time is either allocated to household chores or working time to earn a salary. Working time for a salary is directly reflected in labour statistics.

In a first step, the time use evidence is linked to information on energy use, both in a biophysical and an economic reading to understand qualitative changes in the activity patterns of a society. This is done at the societal level but also at the level of the productive sector of the economy to allow for discussing social structure, the level of capitalization of the economy, and technological performance.
Secondly, different labour activities and sets of labour/energy mixes are linked to metabolic flows to enhance our understanding on how metabolism is organised within the labour process. Thereby, we distinguish different intentional structures of the labour process such as extractive, transformative and eco-regulatory labour processes. While these activities all are directly linked to metabolic flows, increasingly labour is deployed to maintain the materially non-productive part of

social activities (parts of the service sector activities which, however, affect material flows greatly).

The above assumptions are tested using data for the UK economy for the period from 1950 to 2000. This empirical data allows for comparing phases of rapid growth (the 1950ies to the first oil crises) with periods of stabilized throughput.

Session C:
Spatial Dimension of IE

Chairmen: R. Isenmann

Location: Lindstedtsvägen 5
Room: D3

Spatial Estimation and Visualization of RMFA with GIS mapping

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As regards material flow balance in Japan, the annual total material input has averaged 2.0 billion tons (Japanese Ministry of the Environment, 1995), 1.1 billion tons of which have been designated for construction and infrastructure. Approximately one-billion tons of material are accumulated as structure or infrastructure every year. Such construction materials are stocked as structures in some years, but overage and unnecessary structures can cause new material flow to be wasted. In the near future, a huge amount of overage stock built during a period of rapid growth in Japan will cause the new material flow to become waste. In the future, the materials balance may change as a result of (1) the increase in waste generation due to the increase in overage structures, and (2) the decrease in civil engineering projects, such as road construction, that use the greatest share of recycled material in the construction industry. In order to avoid becoming a society dependent on recycling, we should focus on "upstream" countermeasures, which are more important for the long-term, rather than "downstream" countermeasures, which are effective only in the short-term.

In our former studies, Material Flow Analysis, MFA, was applied to a city, and changes in material flow for the near future were estimated. The results of this MFA were displayed with Material Flow Account figures, and by TMR / capita and DMI / capita indexes. However, the initial large-scale results of this analysis were of limited benefit to local planners.

On a local level, we found that to display material flow “spatially” and “successively” was helpful for all concerned. Local and future material balance was easier to consider with area-specific MFA mapping. Visualizing material flow was an effective way to convey and reflect the concept of MFA into local policy. We considered ways to express the questions of “Where and When do material stocks cause flow? ” and “How much flow volume will occur? ”.

To better visualize material flow, we created an Over-flow Potential Map, or OPM. In the course of estimating City-scale material flow using GIS analysis, many map layers must be calculated, for example: an In-flow map layer, an Out-flow map layer and a Stocked material map layer. An OPM is produced by taking the (recycled In-flow layer) away from the (Outflow layer). OPMs can show the volume and variety of over-flow construction materials (such as wood, iron, concrete), even for small areas on GIS maps.

Using this map, for example, policy decision makers can simulate the local effects of possible changes in policy, such as the removal of restrictions related to recycling and material flow. In this study, Kitakyushu City (Japan), Wakayama City (Japan) and Manchester City (UK) was selected for a case study. Good quality spatial dataset was available in Kitakyushu City, spatial and time-series dataset was built up in some small areas at Wakayama City and Manchester City.

The legacy of urban and industrial material flows: reducing their impact on the use of land.

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The legacy of urbanisation and industrialisation remains over time and space in the oceans and in the outer atmosphere, in river sediments and on flood plains, in waste dumps, in disused and contaminated land and in the built environment. Perhaps the most lasting legacy is on the usage of land, that most finite of resources. The unprecedented growth in material use which commenced with the industrial revolution still continues unabated and the chemical fluxes and waste flows associated with industrialisation and urbanisation effect both the biosphere and human health.

Geographical Information Systems (GIS) and Remote Sensing (RS) by aerial photography and satellite imagery are now being used to provide for a clearer understanding of accumulations of materials able to substitute the mining of construction aggregates. Ongoing work in Kitakyushu City, Japan and Manchester, North West England in characterising the quantitative and temporal arisings of recyclable construction and demolition waste will assist in closing a material loop and in the more efficient use of land won resources. Regional sustainability is enhanced through the active participation of stakeholders such as planners and regulators.

Required Effort and Relevance of Results of Site-Dependent Acidification in LCIA

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Introduction

Conventional life cycle impact assessment (LCIA) methods do not take into account the location of origin of emissions when calculating impact. Hauschild and Potting (2004) show in several examples how site-dependent LCIA can overcome the lack of accordance between the potential environmental impacts as calculated by life cycle impact assessment and the expected occurrence of actual impacts. However, opponents of site-dependent LCIA argue that the collection of the required spatial information too much burdens inventory analysis, whereas the results of the LCA hardly improve. We therefore quantified the effort to collect the additional spatial data and determined the difference between site-generic and site-dependent LCIA results.

Approach

Three existing LCA studies were selected for an additional analysis: linoleum [2], stone wool [5], and water piping systems [1]. For each case study, the additional data required for site-dependent LCIA of acidification is collected, and the time needed to collect all these data is kept up. The additional data consists of the location where each process takes place (location data) and – where necessary – disaggregating processes into the underlying basic processes (basic data). Next, LCIA is performed with help of the site-dependent acidification factors of the EDIP2003 methodology [3, 4], once by using a site-generic approach, once by using a site-dependent approach. Besides site-dependent factors for European countries, Hauschild and Potting [3] also provide site-generic factors for unlocalizable emissions and for emissions taking place outside of Europe.

Results and discussion

Table 1 lists for each case study the time required to get all the data needed for site-dependent LCIA of acidification. We estimated from this the extra time if site-dependent acidification would have been taken into account right from the start of the LCA. This time is obviously less than the time for our additional analysis, since the performer then already has most of the required data at his disposal.

Table 1 : Time spent by the performer to do the original LCA, and time needed for additional data collection required for site-dependent acidification.

	initial time spent on LCA (by performer)	effort for additional analysis	estimated effort right from the start
linoleum	480 h	84 h	46 h
stone wool	167 h	49 h	11 h
water piping systems	300 h	39 h	10 h

The hours listed in Table 1 reflect the time needed for disaggregation (basic data) and localization (location data) of acidifying emissions. Finding the location hardly took time, because often the report revealed this information. Most time was spent on disaggregating inventory data. Though all reports were rather complete, difficulties occurred because the LCA studies were not fully reproducible. That is, the reports do not contain all information required to redo the impact calculations (sometimes because of confidential processes). This lack of reproducibility is not in line with the ISO recommendations for comparative assertion disclosed to the public. It also makes all kinds of additional analyses on existing LCA studies difficult, not only recalculating the acidifying impact with site-dependent factors.

Figure 1 shows the results of site-dependent acidifying impact assessment. Compared to site-generic acidification, the relative importance of processes changes for site-dependent acidification. Figure 2 exemplifies this for the water piping case. This effect is especially important when the goal of the LCA is to improve the most acidifying processes.

Figure 1 shows that a large portion of the acidification of the linoleum case study originates from emissions located in countries outside of Europe. The lack of compatible site-dependent acidification factors for countries outside of Europe limits a site-dependent treatment of emissions originating from these countries. Site-dependent acidification is therefore presently only feasible when the majority of the emissions take place in European countries.

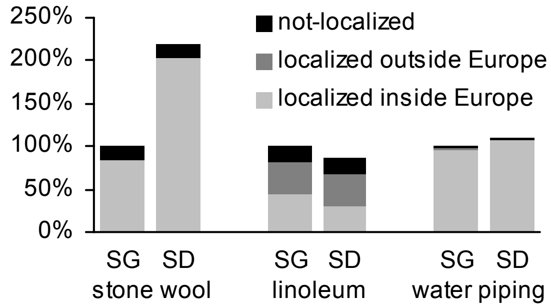

Figure 1: Site-generic (SG) and site-dependent (SD) acidification for each case study. SG is normalized to 100%.

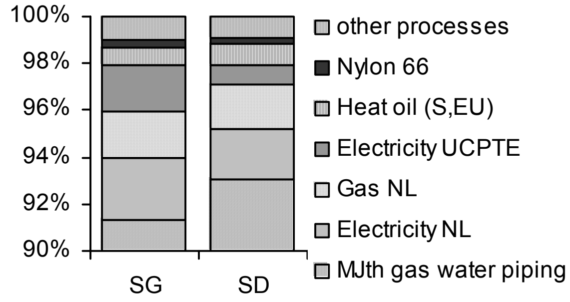

Figure 2: Site-generic (SG) and site-dependent (SD) acidification of water piping systems. Importance of processes.

Conclusion

It was easy to find the location data needed for site-dependent LCIA of the three case studies. However, the necessary disaggregating of processes into basic data took quite some time. Despite ISO recommendations, the three case studies were not fully reproducible, which further hampered easy recalculation of acidification. Due to lack of compatible factors for countries outside Europe, site-dependent calculation of the acidification in LCIA is as to yet only feasible for European emissions.

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Incorporating Spatial and Temporal Resolution in the Life Cycle Inventory of Residential Buildings using Hierarchical Modules and GIS

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Parallel and serial processes occurring in different locations are required to extract raw materials, produce components, and assemble products which are then transported varying distances, sometimes worldwide. Long lifetime products may be in service for decades, are rarely time stable, and may require periodic maintenance, repair, or modification. Continuous and intermittent activities occurring throughout a product life cycle consume resources and result in environmental discharges and waste. The resulting ecological and human health damages are delayed and occur at a distance. For example, substances released into the environment have varying residence times and time-lags are experienced between fate, exposure, effect, and damage.

Conventional life cycle assessment (LCA) generally aggregates environmental inventories over space and time. Impact category indicators and valuation schemes are often used to assess the environmental significance of a product system based on its aggregate life cycle inventory. However, the impact potential of a particular extraction or discharge depends on the time, location, and background conditions of its occurrence. By aggregating life cycle inventories and impacts, conventional LCA isolates the analysis from its context. In contrast, environmental decision-making is contextual. Decisions regarding the design, use, and retirement of product systems involve spatial and temporal tradeoffs. The ability to incorporate spatial and temporal resolution into environmental LCA would enable explicit differentiation between impacts at different location and points in time.

A number of approaches for performing LCA with temporal and spatial differentiation have been proposed and implemented. In particular, procedures for building dynamic LCA models and incorporating fate, exposure, and effect models have been developed. Spatial and temporal resolution will likely require a change in the way life cycle inventory data is reported. In particular, more detail about resource consumption, environmental discharges, and waste will be required and information about background conditions may be needed. To aid decision-making, inventory data must be representative of the product system's geographical, temporal, and technological characteristics. Furthermore, the variability and uncertainty inherent in life cycle inventory must be captured.

We review current approaches for incorporating spatial and temporal resolution in life cycle inventory and impact assessment. In particular, inventory requirements for each approach are discussed. We then develop a framework for compiling and reporting inventory data. To illustrate the proposed framework, we incorporate spatial and temporal information in life cycle inventories of several residential building subsystems. The subsystems are modeled and spatial-temporal LCI databases created using hierarchical nested modules linked to a geographic information system (GIS). Hierarchical modules improve transparency, incorporate uncertainty, and allow easy incorporation of additional subsystems. GIS provides a means to tabulate, analyze, and present LCI data based on where extractions and discharges occur. Incorporating spatial and temporal resolution in life cycle inventory data is the first step in contextualizing life cycle assessment and enabling better decision.

Material Cycles in Asia: How to Cope with International and Domestic Recycling

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Recently, the international trade in various secondary resources (i.e., residues and end-of-life products) has been expanding. For example, Japan exports end-of-life products and wastes such as home appliances, plastics, and metals to other Asian countries, especially to China.

The secondary resources exported from Japan include both residues from manufacturing processes and end-of-life products or materials. Residues include ferrous and other metal scrap, paper and plastic. On the other hand, Japan has instituted several recycling laws on packaging and end-of-life home appliances, vehicles, and other products since the late 1990s, which recover the post-consumption-type waste and implicitly intend to promote domestic recycling. In fact, the export of end-of-life products or materials has an indirect relationship with those Japanese recycling laws, because a part of recovered and pre-treated materials under those laws are not recycled domestically but exported to other countries.

The great demand in China and the difference of prices between countries drive this transboundary shipment, although Japan has enacted various recycling laws that were implicitly intended to promote domestic recycling. In China, the imported secondary resources are recycled, usually by means of primitive and low-cost hand labor.

Such international material cycles should be evaluated from the viewpoint of preventing environmental pollution as well as that of ensuring efficient resources utilization. Especially, electric and electronic waste, so-called E-waste is important target for domestic and international material cycles from the viewpoint of environmental preservation. However, there is little information on the actual recycling and utilization of these resources after their export from Japan. Hence, it is not easy to judge whether such international trade is environmentally sound globally and nationally or to determine how best to deal with it.

In this presentation, we first present an overview of material cycles in Asia mainly for plastic waste, E-waste and end-of-life vehicles, focusing on the recycling loop between Japan and China. In order to clarify the actual material flow, we try to identify those flows both by material and product types, using the trade statistics and field studies.

Second, we discuss the factors and tasks for these transboundary shipments of secondary resources. Factors include the regulations and economic values of secondary resources both in exporting and importing countries. The task in the research field is to clarify both benefits and drawbacks for international and domestic recycling as quantitatively as possible. Then we will understand what kind of material cycle, especially on which regional scale, would be both environmentally sound and economically rational.

Qualitative Growth in Tourism: a Quantitative Comparison Between Different Planning Options

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Since the 1950s, tourism has strongly increased and has become a mass phenomenon. In 2000, about 700 million tourist arrivals were counted worldwide. In accordance to this development the importance of tourism as an economic sector increased dramatically on national, but also on regional levels. In Switzerland tourism is considered one of the most important economic sectors accounting for 3.4 % of the gross domestic product (GDP) and 5.2 % of all full-time job equivalents in 1998 (Gaillard et al., 2003). When mass tourism in the mountain area of Switzerland started in the early 1960s, it was particularly valuable for remote and impoverished regions prone to emigration. However, increasing tourism and related infrastructure also caused a profound discussion about tourism including negative impacts on the environment, the regional identity and the power structures of the regions. Research programs addressed the problem (Messerli, 1989) and the concept of qualitative growth in tourism was considered the most favorable option (Krippendorf, 1986). This option encourages economic development within the boundary condition of a region's tourism carrying capacity (O'Reilly,1986). The planning concept of *carrying capacity* tries to prevent tourist regions from collapse due to environmental breakdown or overcrowding with consequent loss of attractiveness by identifying its limits of growth. The measurement of such limits can be related to the use of scarce resources such as land (on regional scale) or energy (on global scale). Qualitative growth implies that economic development is linked to a growing efficiency in resource consumption (e.g. measured in annual resource use per unit of regional GDP. This does not necessarily mean "less tourists" but may foster structural changes in tourism.

Resource efficiency or decoupling of resource consumption and economic growth are key concepts in Industrial Ecology and a number of analytic tools have been introduced for empirical investigation mostly based on Material Flow Accounting or Input Output Analysis. Yet, most studies focus on national or even gobal scale (e.g. Adriaanse et al 1997, Hubacek and Giljum 2003). On regional scale, analyses of resource efficiency are hindered by data availability (e.g. estimation of a regional GDP) as well as lacks of conceptualization (e.g. definition of appropriate system boundaries) (see e.g. Hendrics et al. 2000, Hug and Baccini 2002). Yet, the regional scale is most appropriate for many policy issues like sustainable tourism. Identifying a region's carrying capacity or its development options is site specific and requires local knowledge. A top-down definition of qualitative growth, in contrast, must remain general and can only be adopted as a guiding concept. It will be of little help for regional planners in their attempts to develop tailor made concepts and convince policy makers to move into new directions.

In this paper, we introduce a method to operationalize the concept of qualitative growth on regional scale and use it to evaluate different development options. This method is primarily based on a regional input output analysis which is combined with analyses of resource consumption (in physical units). For the investigation of qualitative growth in tourism we focus on land use as a key resource which is related to tourist activities. Yet, the consumption of other resources such as energy or biomass could easily be included into the model. Economic development is measured in changes of factor income. The key indicator for resource efficiency is therefore: land use (square meter) per factor income (Swiss Francs). Qualitative growth in tourism is defined as an increase of factor income from tourism which is higher than the corresponding growth of land use.

Case study region is the tourist resort Davos in Switzerland. Our data base was created in the research project ALPSCAPE (2001-2005) funded by the Swiss National Science Foundation. It includes a regional Input-Output-Table, geo-coded data on land use and buildings as well as data on tourist activities (consumer bags etc.). Three different development options are considered: a) the advance of high-class tourism, b) the decrease in seasonal fluctuation and c) the rise of accommodation capacity within the developed area. Parameter variation is used to estimate the potential of each option and scenario analysis allows us to compare these options.

Our calculations reveal that qualitative growth is most sensitive to the structure of tourist demand (e.g. luxury tourists versus hikers) and the seasonal fluctuation. Parameters which can be influenced by regional planning such as settlement density, in contrast, have little influence on resource efficiency. It is, however, essential to combine different strategies in development like a decrease in seasonal fluctuation with an increase of tourist activities creating a high factor income (like hotel guests). A continuation of the current trend for second homes in tourist resorts seems to be the worst development option. To prevent it from happening, regional planners have to be further empowered to influence the development of the settlement area.

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Session D:
Sustainable Manufacturing

Chairmen: R. Van Berkel

Location: Lindstedtsvägen 17
Room: D1

Modelling and Estimating the Down-cycling and its Cost in the Turnover of Aluminium.

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A challenge within the field of industrial ecology is to analyse and develop methods for management of the materials quality in material flows and cycles. Recycling of metals does not involve degrading of the metal properties similar to for instance paper recycling in which the fibers are irreversibly damaged and shortened. The recycling of metals though, often involves a down-cycling of the recycled material, that is, it is recycled one-way into specific alloys tolerant to higher levels of impurities and alloying elements. The recycled metal thus is utilised in specific qualities and accumulates in specific applications and uses. This limitation will possibly lower the total utility or value of the metal in question.

A model has been built to evaluate the cost of down-cycling in the aluminium system.
In the model, the aluminium system is divided into production, use, and recycling of major alloy groups, for which the material flows, costs, and demand are tracked. For different, externally given, rates of down-cycling of different recycled flows, the total specific value of the aluminium stock is estimated. The model is applied to the Swedish aluminium system.

The result shows that, while the expansion and structure of the aluminium system limit the costs of down-cycling today, the scenarios for possible future structural and volume changes suggest that the cost of down-cycling can increase considerably, effectively lowering the value of societal aluminium stock.

Design of Microfiltration Compatible Metalworking Fluids for Recycling

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Metalworking fluids (MWFs) are industrial lubricants and coolants widely used in the machine tool industry, and their use represents a significant fraction of the cost associated with metals manufacturing processes. However, MWFs are highly susceptible to microbial contamination that leads to potential health risks for workers [1]. This microbial growth, along with the accumulation of particulate, tramp oil, and hard water ions, deteriorates performance and necessitates frequent and costly disposals. The disposal of MWFs presents a significant environmental burden, while more stringent regulations regarding this disposal are under consideration in the U.S. in the context of the proposed Metal Products and Machinery rule [2]. With increasing recognition of these facts, interest is also increasing to develop novel recycling approaches that have the potential to reduce cost, health risks, and environmental impacts of MWFs by increasing their lifespan and by controlling microbial growth in a more environmentally benign manner.

Microfiltration (MF) is a membrane-based technology capable of removing contaminants (i.e., microorganisms, particulates, and tramp oils) from MWFs and maintaining high quality of the fluids over extended periods. It has been shown that microfiltration can serve as a high-performance recycling technology with the potential to simultaneously address the cost, health and environmental issues associated with the use of MWF in manufacturing. Currently, the economic and technical feasibility of microfiltration recycling is only clearly demonstrated for MWFs that do not contain oil [3,4]. For oil-containing MWF microemulsions (semi-synthetics), which make up the greatest proportion of MWF in use today in the U.S., the economic feasibility is currently questionable due to flow-rate limitations through MF membranes. This research overcomes the economic barrier by re-designing conventional semi-synthetic MWF formulations.

The approach adopted here is to first develop a mechanistic model of flux decline based on physicochemical parameters of fluids, with model parameters estimated by existing flow-rate data. The model is then mathematically optimized using these estimated parameters, leading to guidance for the re-formulation of the semi-synthetic MWF with much higher flow-rate. As a last step, the MWF is validated to assure its manufacturing performance.

In this research, the model developed in [5] is extended to quantitatively describe the relationship between MWF parameters (i.e., surfactant and oil concentration), emulsion characteristics (i.e., particle size and stability), and membrane fouling characteristics. Specifically, MF pore constriction is mathematically modeled as a balance between surfactant adsorption and desorption, and pore blockages are modeled in the context of queuing theory and microemulsion coalescence kinetics. Optimization of this model yields general guidelines for optimizing different semi-synthetic MWF surfactant systems. It is found that a “microfiltration compatible” MWF favors a surfactant package with both weak adsorption and high emulsion stability. Since these are contradictory characteristics, the model is used to resolve the inherent trade-off by varying surfactant package composition and concentration.

Based on these guidelines, we perform a re-design of a commercially available petroleum-based MWF and designed several novel vegetable-based MWFs. For the commercially available petroleum-based MWF, the surfactant package consists of anionic sodium petroleum sulfonate (SPS) and nonionic diisopropanolamine. In the re-design of this MWF, water soluble twin-headed anionic surfactant alkyldiphenyl oxide disulfonate is used to replace the SPS to enhance droplet repulsion and reduce adsorption. Once this surfactant package is selected, the design model is applied to quantitatively investigate the effect of oil:surfactant ratio and anionic:nonionic ratio on microfiltration flux. As shown in Figure 1, there exists a specific anionic:nonionic ratio and oil:surfactant ratio with the overall effect of maximizing MF flow-rate. In this case, we see an 8-fold flow-rate improvement without loss of manufacturing performance.

Since vegetable-based MWFs offer 1) a renewable alternative to petroleum with increased potential for biodegradation at end of life, 2) improved machining performance [6], and 3) reduced life-cycle greenhouse gas emission [7], semi-synthetic MWF formulations based on vegetable oils (i.e., Canola oil, soybean oil, and TMP ester) are also developed. As shown in Figure 2, the optimized vegetable oil based MWFs have a flow-rate that is 3-times higher than the benchmark petroleum MWF. While this flow-rate is still lower than the optimized petroleum-based MWF, there are other synergistic benefits. For instance, since these MWFs are robust to destabilization during microfiltration, they are also much more stable in the manufacturing environment where we expect them to last for months if not years. Also, these fluids are shown to be low-foaming and resistant to hard water ion accumulation up to 800 ppm (as $CaCO_3$). Based on these results, we conclude that the redesigned fluids, in conjunction with microfiltration recycling, can be employed in manufacturing operations to achieve simultaneous economic, environmental, and human health improvement.

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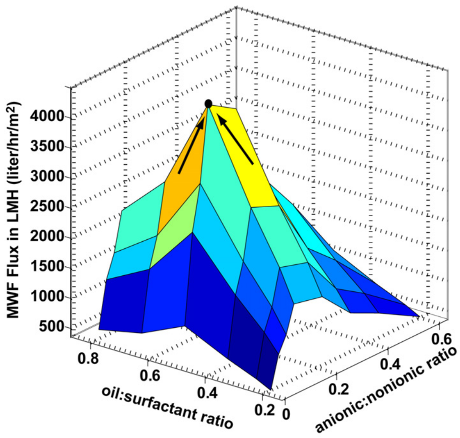

Figure 1. Design microfiltration compatible MWFs by varying oil:surfactant ratio and anionic:nonionic ratio.

Towards Action-Oriented Ecology. Linking Material Ecology, Sustainable Design and System Evolution

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A timely, dramatic transition is required of the structure and content of our industrial systems for metals, chemicals, fuels and recycling. Change is needed because the dilution of metals associated with use and recovery steadily decreases suitable metal stocks, the threat of climate change is imminent and in the foreseeable future the world will run out of cheap oil and gas. Systemic change is needed of our production- and recycling networks.
The optimisation of the recycling of modern consumer products, buildings and other complex manufactured goods is only possible with a detailed understanding of the total production-recycling system as a dynamic feedback system (Van Schaik and Reuter 2004a&b). This feedback system is embedded in and linked to an economic, legislative, natural, and knowledge environment. It spans the product/building design, the physics and chemistry of the separation equipment and its liberation during shredding, statistics of mass flow and element data; and detailed reconciled mass balances, all as a function of time and at a variety of scales – from product components or process unit operation to complex product, industrial complex, society and global cycles.
These aspects can be summarised into three interconnected cycles depicted by Figure 1: the life cycle of the production-recycling/industry-infrastructure network, the design cycle of systems, technology and products and the resource cycle. This figure succinctly summarises the golden thread of our recent research that contributes or shapes an action-oriented ecology.

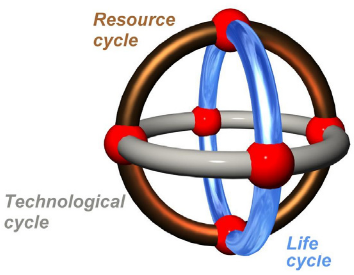

Figure 1 - Achieving Sustainability by linking the three cycles – illustrated by the DutchEVO project – a research project at TU Delft to achieve an environmentally friendly and sustainable car design (Reuter et al. 2004)

The intersections (red balls) between the different cycles in Figure 1 are the exciting areas for future research, which have to be investigated using systems thinking and wherein an action-oriented industrial ecology emerges. This would combine intricate knowledge and understanding of mechanical recycling and metallurgical processes, chemical production and recycling and design of production systems and products. It would require an understanding of the evolution of industry-infrastructure in interaction with economics, ecology and societal preference or acceptability of adverse environmental impacts as condensed in regulation and legislation.

Example 1 – Material Ecology and Complex industrial system engineering

A key principle in industrial ecology is the cyclic use of materials - a characteristic of natural ecosystems, a challenge in socio-technical systems. A key characteristic of present industrial systems is a linear throughput and conversion of resources. As a result, in society material quality retention - the ongoing use or ready availability of suitable metal and hydrocarbon materials in the economy-, between the life cycle stages of resource extraction and final disposal back into the lithosphere, is finite because of the limited grade of secondary (recycled) materials. Currently, <u>metals</u> are maintained in their utility through the addition of high- primary (virgin) metals. The mixing with high-grade primary metals keeps the recycled metals in the cycle. In the long run, the practice of dilution and creation of mixtures alien to nature prevents a closure of the material cycles. <u>Hydrocarbons</u> are predominantly derived from fossil resources; recycling of polymers is largely limited to energy-recovery. In the metal ecology, a dynamic mass-flow model has been developed for the global metal cycles and production network (Verhoef et al. 2004). In the carbon ecology, methods and tools are being developed for multi-scale systemic innovation and sustainable industrial network design (Dijkema et al.2003).

Example 2 - Cars

Some of the authors have been extensively involved in linking design and the recycling of cars. To this end first principle new theory was developed and these models were calibrated from industrial experiments. The models are based on a population balance approach including time, size, element, joint, liberation, material classes etc. in order to capture all properties required to correctly formulate "Design for Recycling" CAD models. This has all been placed in a dynamic framework. Some authors have been involved in the largest car recycling experiment to date for the European car industry in which a statistical sound recycling rate was determined for 1153 cars that were recycled. This will be discussed in the presentation to show how modelling can link product design to recycling rate calculations as required by European law. (Van Schaik and Reuter 2004a &b)

Example 3 - Industrial Network Evolution

Traditionally individual companies only address viz. control part of the value-chain or production network, with the exception of some vertically integrated oil majors. In the past decade, however, with the emergence of 'Systems Thinking', Industrial Ecology, the Cluster concept and Sustainability, industrial regions, companies and governments have realigned their strategies and set out to somehow influence or control the interconnected material networks. We are developing a framework for the analysis, design and management of the co-evolution of industry and infrastructures in industrial regions. This framework will consist of theories, models and tools that (1) offer an insight in the social, economic and technological aspects of the co-evolution (2) helps elucidate the dynamics of interconnected industrial systems (3) support critical actors in decision-making on infrastructure and industry investments and (4) will help policy makes steer the region towards sustainability by suitable systems development (Nikolic et al. 2004).

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Carbon Ecology and Process Systems Engineering
Fostering sustainability by multi-scale systemic innovation

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Sustainable development requires innovation at all system levels, from reaction path to process system, from chemical plant to chemical complex or industry. In short, sustainability requires a systems approach that addresses multiple system aggregate levels in concert, thereby addressing the network character of industry and infrastructure sector. This is the ambition of the emerging discipline of industrial ecology (IE)', which provides an umbrella for numerous and sophisticated analysis methods, such as LCA, MFA and SFA. To date, however, IE struggles with creation, design and realisation of new systems and technology content'.

In what one may call 'the carbon ecology' oil refining and the petrochemical industry play a pivotal role today. These convert fossilized organic matter to suitable feedstock, mainly for automotive fuels and the polymer industry. A myriad of polymers is delivered to businesses and consumers. The combustion of fuel immediately results in CO_2 emission. Waste polymeric material or products are recycled, landfilled or incinerated. In all three cases, sooner or later the material degrades to CO_2 and water.
In this carbon ecology, notably the petrochemical industry is a mature industry that produces commodities - products of standard specification, produced in large volumes. The erection of any new processing plant in this industry represents a huge capital project because of the scale of operations. These plant economics and the associated risk result in resistance to change, which is augmented by entrenchment in existing science-based technology and network structure. As a result, this industry is conservative in the adoption of novel technology or systems and often prefers 'proven designs'. To be accepted, any innovation suggested therefore must have sound technological and system content.
Competitive pressure in this industry often is limited, because of the oligopolistic market structure of many a petrochemical market and the domination of business-to-bussiness sale - no consumers buys petrochemicals and technology-pull from consumers is non-existent.

In the carbon ecology, the problem of unwanted, emitted toxic hydrocarbons largely has become a managed problem. However, the industry's must face the threat of climate-change and meet the associated demand for CO_2 emission-reduction. In the EU it will become subject to CO_2 emission-trading. In addition, the world may run out of cheap oil and gas in the near future. As a result, entire supply-chains in the carbon ecology may be captured by competing industries that use alternate bio-feedstock and biotechnology. Such a change and the related demand for biomass from cultivated crops would severly impact biodiversity. Many industries face similar challenges, society must find a way to deal with the wicked problems of our time (Wetenschappelijke Raad voor het Regeringsbeleid 2003).

We developed a methodology, therefore, to help translate the need for sustainable networked industrial systems into primitive problem formulations suitable for exploration and detailing under the General Design Paradigm (Siirola 1996) (French 1999). Starting from mathematical system theory using the input-output paradigm, a coherent system representation was formulated that links system function, behaviour and transformation to system performance characterisation and valuation. This representation is the foundation of a practical approach for system assessment by the combination of stream-valuation and material/energy balancing. The combination provides a mapping that underpins performance analysis in the carbon ecology, and leads to a proxy to the more complicated approach of Second Law based analysis or exergy analysis (Dijkema 2004).
The system representation through functional modelling allows abstraction of the current method of 'fulfilment' or realisation of the functions of industry or parts thereof (Dijkema et al. 2003). It also allows the specification of novel functions, such as recycling.
These methods were used in a case study on innovations in and around industrial olefins production. In a second case study, the availability of fuel cell technology, an innovative energy transformation, was translated into coherent system innovations spanning the transport sector, petrochemicals, hydrogen and metals production. In short, a modelling-decomposition-synthesis strategy was developed for primitive problem formulation, specification and exploration of the multi-level design-space available to solve wicked environmental problems by synthesis of sustainable systems (Dijkema 2004).

The methodology for “process system innovation by design” is firmly embedded in chemical process systems engineering. As such, it may provide a system engineering foundation for industrial ecology.

Presently, the methodology is being elaborated and coupled with the emerging body-of-knowledge on ‘Transition management’. In the presentation/paper the method will be summarised, the case studies mentioned will be elaborated, and new work on developing systemic innovations for and with the Dutch paper and Board Industry in the context of Transition management will be addressed.

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Going to Pot?
Technology, Sustainability and the Future of the Yoghurt Consumption and Production System

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Dairying accounts for almost one fifth of total agricultural output in the UK and is the largest single farming sector in terms of employment. In the UK, yoghurt uses 2% of total milk production but accounts for around 10% of total milk and milk product sales. The overall UK market for yoghurts has been growing since the 1950s and recent trends have seen an emphasis on healthy (e.g. pro-biotic) yoghurts, yoghurt drinks and organic yoghurts. Many of these trends, facilitated by large advertising budgets of the branded firms, are only possible because of considerable product innovation over the last 10 years: new ingredients such as stabilisers and texture enhancers, sweeteners, flavours and bacterial cultures. Process innovation has been geared toward making the new yoghurt products more efficiently, and, in response to environmental regulation from the UK and EU, with lower water and energy consumption and effluent discharge.

This paper examines the food consumption and production system (FCPS) of yoghurt in the UK, focusing on the sustainability of the yoghurt system from a technological perspective. The current sustainability of the yoghurt FCPS– in economic, societal and environmental terms – is quantified using key indicators and particular unsustainable elements of the system are highlighted. Current technological trends in the yoghurt FCPS are assessed. Drawing on insights from industrial ecology and innovation studies, we examine technologically different futures for the yoghurt FCPS and identify the likely effects on the sustainability of the system. Factors inhibiting or facilitating the transition to more sustainable possible futures are explored and implications for firm strategy and government policy are addressed.

Hazardous Substances – Substitution as an Innovation Process

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Hazardous substances cause some major problems of Industrial Ecology in the fields of health, safety and environment. Substitution of hazardous substances is a relevant option within risk management. But experiences show that it is a difficult task and a very slow process. Often the solution is not just the replacement of one substance by another, but the redesign of an integrated 'application system' affecting the whole supply chain. Thus substitution is a quite complex type of innovation. Besides the questions of the ability to innovate there are difficulties in the innovation direction. In some famous cases the result of substitution was only a shift of risks or even greater risks (asbestos, CFCs, PCBs). Thus extensive uncertainties regarding innovation direction are an additional barrier.
The research project 'Options for Viable Innovation systems for Successful Substitution of Hazardous substances' (SubChem) was funded by the German Ministry of Education and Research within its 'Research initiative on Sustainability and Innovation'. Based on the concept of 'innovation systems' (framework conditions, supply chain, actors, relations, instruments and capability to influence) 13 case studies were analysed with the focus on incentives and impediments for substitution (see table1).

Process auxiliary agents in industrial equipment	Water-based cleaning of metal surfaces
	Biocide-free cooling lubricants and minimum quantity cooling lubrication
	Bio-degradable concrete separating agents from natural primary materials
Chemical products/ components: industrial usage	Biosoluble, artificial mineral fibres in automotive silencers
	Artificial mineral fibres in automotive catalytic converters
	Alternatives to reproduction-toxic softeners in plastics
	Low-solvent automotive coatings
	More environmentally compatible textile auxiliary agents
	UV-drying inks in packaging printing
Chemical products: uses by craftspeople and DIY users	Low-chromate cement
	Biosoluble, artificial mineral fibres for insulation in structures
	Methylene chloride-free stripping agents
	Solvent-free decorative paints made from natural primary materials

Table 1: SubChem case studies

The research questions were as follows: a) What are the conditions, so that actors from economy, state and the civil society are able to cooperate successfully in ‚innovation systems‘ (capability to innovate)? b) How can economic actors in the supply chain improve their orientation, when they try to reduce and avoid risks (innovation direction)? c) What are the means to integrate the task of substitution into management systems along the supply chain based on networks of enterprises (risk management)? The results of the project are 1) a simplified model of the 'innovation system', 2) a set of hypotheses about conditions and factors that promote or impede substitution, 3) recommendations for three different groups of actors.

Some specific results

In the beginning the analysis was focused on actors because it is them who change processes and products. We followed a more or less polarized view of promoters and antagonists but ended up with a more systemic view. In many of the cases there was no real powerful counterpart but there was no progress either. The most important impediment against substitution we found was the ‚inertia of the system‘. Some of the main issues in innovation research like path dependencies, technological lock in and investment cycles are just different aspects of this. Not only substitution but innovation in general is rather unlikely, but nevertheless it happens. So there must be a strong driver to overcome inertia. It is market competition. But alike to 'system inertia' it is worthwhile to have a closer look at specific market conditions. In the first approach focussing on costs, we found out, that 'cost per unit' arguments are frequently overestimated. Transformation costs of training and instruction and 'sunk costs' are more important. But in a lot of markets the quest for increasing revenues, for new markets (e. g. premium segment) is the decisive point. Highly competitive, differentiated, dynamic, demand-dominated markets, quality competition and the proximity to the end consumer in most cases had the effect of encouraging substitution. Also the vulnerability of brands, stock markets and liability aspects play an important role. The most important single driver we found was 'public scandalization' of certain substances. Public scandalization of, for instance, certain chlorinated hydrocarbons had the power to induce the most rapid changes along the whole supply chain and even in the regulatory framework (chemicals and risk regulation, environmental, workers and consumer protection).

Regarding the direction of substitution it is time to accept that risk management cannot be based on complete or even sufficient toxicological knowledge. Sufficient (eco)toxicological knowledge about the potential effects of a hazardous substance and of different potential substitutes in order to make a rational choice seems to be a rare exception. Thus risk management has to find ways of rationally dealing with uncertainties and lack of knowledge.

Based on these findings some recommendations of an 'extended risk management' can be made as an attempt of operationalising the 'precautionary principle':

a) Facing the lack of knowledge (incomplete or insufficient risk analysis) risk management can be based on 'hazard characterization' of the substance (e. g. high persistency, high mobility and bioaccumulation lead to an expectable high exposure and thus request precautionary measures).

b) A more 'targeted' development and design of substances, technologies and application systems oriented on guiding principles (Leitbilder) like 'intrinsic safety', 'chemistry of the short range', 'green or sustainable chemistry' should lead to better results than just the assessment of 'ready made solutions'.

c) Aspects of sustainability like health, safety and environment (HSE) should be recognised as quality aspects of technologies, processes and products. The integration of these aspects into internal and inter-company decision-making procedures and management systems, especially in quality management along the supply chain, is a challenge for 'excellence' of enterprises and individual actors.

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Session E:
Agriculture in IE

Chairmen: C. Binder

Location: Lindstedtsvägen 2
Room: E2

Sustainable bioenergy productlon and trade - a case study on the impact of sustainability criteria on biotrade in Ukraine and Brazil

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1. Introduction

Biomass is receiving more and more attention as a renewable (green or CO_2 neutral) energy source. A perquisite for the large-scale production and trade of biomass (biotrade) is it is sustainable, i.e. beneficial with respect to the social well being of the people (people), the ecosystem (planet) and the economy (profit). **The goal of this study is to analyse the possibilities and limitations resulting from the various sustainability criteria relevant for biotrade.**

2. Methodology

A list of social, economical and ecological criteria and indicators relevant for biotrade is derived from a recent study on sustainable biotrade certification systems [1]. Since there is no definition on what is sustainable or not, a strict and loose set of sustainability criteria is included that vary in scope and depth. The impact of various sustainability criteria is included by estimating the impact on the costs of bioenergy production. The costs of bioenergy production are estimated based on a detailed cost breakdown of bioenergy crop production. Ukraine and Brazil are selected as case studies, because previous research showed that both regions have a relative high abundance of land for bioenergy production [2]. Considering the moderate to sub-tropical climate in the Ukraine and the tropical climate in Brazil, poplar is included as a suitable woody bioenergy crop for the Ukraine and eucalyptus as a suitable bioenergy crop for Brazil.

2.1 Land use patterns

In our opinion, the production of bioenergy production is not allowed to result in deforestation or competition with food production, i.e. bioenergy crop production is restricted to surplus agricultural land. Present and future land use patterns are analysed using an Excel spreadsheet tool as described in Smeets [3]. Data and scenarios are included for e.g. population growth, food consumption and the efficiency of food production (crop yields and the production efficiency of animal products). Results indicate that the present productivity in both Ukraine and Brazil is very low compared to the agro-climatological potential for crop production and maximum efficiency of the animal production system. The costs related to increasing the efficiency of food production are included in the costs of bioenergy by means of a general cost item 'expenses on consultancy and training'.

2.2 Child labour

Labour by children under 15 years old is considered unsustainable. Child labour is avoided in two ways in this study. First, wages of the parents must be sufficiently high to avoid the need of income from child labour (see below). Second, we assume that a lack of day care facilities and/or education for children is another driver for child labour. Costs for schooling or day care facilities are added up to the wage of the parents.

2.3 Wages

The social acceptance of bioenergy production depends on the wages of the workers on the bioenergy plantations. The wages included in this study are based on 'fair wages' that are at least the minimum wage. In case wages are presently higher than the minimum wage, the present wages are used. In case regional circumstances require higher wages than the minimum and/or present wages to allow a minimum level of basic needs (housing, food and clothing) or avoid child labour, wages are increased for basic needs.

2.4 Employment

A key issue for the social acceptance of bioenergy production is the impact on employment. The direct employment at the farm level can be calculated based on the labour demand which is dependant on the silvicultural management system. Direct and indirect employment effects at a macro-economic level are estimated using input output analysis. A standard input-output transaction table includes data on deliveries (both intermediate (inter-sectoral) deliveries and final deliveries (to consumers, government and for export) and data on inputs (both from wages, capital costs, taxes, and profits). In addition, data on employment per sector are required to estimate sectoral specific employment rates. The economic correlations depicted by the input-output table can be used to calculate the direct and indirect macro-economic effects of the production of bioenergy, both in terms of economics as in terms of direct and indirect employment.

2.5 Soil erosion

The present extend and severity of soil degradation is analysed using the Global Assessment of Human Induced Soil Degradation (GLASOD) database [4] supplemented by various national data derived from literature. The GLASOD database shows that soil erosion through water is the most important type of erosion in both Brazil and Ukraine, which is further analysed using the Universal Soil Loss Equation (USLE) [5, 6]. The USLE is an empirically derived method to estimate soil erosion due to water erosion (which is the most important form of soil erosion) expressed in ton topsoil lost per hectare per year. Preliminary results indicate that severe soil erosion is Ukraine is limited to areas with high slope gradients and medium coarse textured soils. In Brazil severe soil erosion is a more severe risk. The costs for appropriate erosion control practices are included in the costs of bioenergy production.

2.6 Water use

The water use of bioenergy crops is analysed using a simple water balance based on a comparison of the annual rainfall and the (crop specific) evapotranspiration using the CROPWAT software tool from the Food Agricultural Organisation [7]. Preliminary results indicate that rainfall in (southern) Brazil is plentiful, but that rainfall in (central) Ukraine is a limiting factor for crop growth. The costs of irrigation on costs and the impact of water shortages on yields are included in the costs of bioenergy production.

4. Discussion and conclusion

In this study a initial assessment is carried out of the impact that various sustainability criteria may have on the costs of the production of dedicated bioenergy crops. The results also show the various trade-offs that are possible between the ecological, economical and social dimension of sustainability. These results can be used as scientific input in discussions on the sustainability of bioenergy crop production.

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Comparison of the Environmental Impacts of Bio-based Products

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Products based on renewable raw materials are generally regarded as environmentally friendly. However, does this mean they have no environmental impacts? And does one really know if this is justifiable for the whole range of bio-based products? In order to go beyond preconceived ideas one needs quantified analytical tools such as life cycle assessment (LCA).

This article is mainly based on a study that reviewed the state of art in life cycle assessments of bio-based products [1]. Several issues need to be addressed:

- How can we characterize the environmental impact of the whole range of bio-based products?
- How and on what basis can we compare the efficiency of different biomass uses? (i.e. determine whether it is more beneficial to produce bio-product X vs. bio-product Y).

The study carried out for the National French Agency for Environmental and Energy Management [1] addressed these issues by:

a) reviewing the state of the art of life cycle assessment (LCA) on biofuels, bioenergy, biopolymers, natural fibers, timber, lubricants and hydraulic fluids, surfactants, solvents and intermediate products,

b) investigating and identifying the main features of each field of application, and

c) comparing the overall performance and environmental efficiency of different bio-based products on a per area basis, as agricultural area is often a limiting factor.

Method

The method applied was a review of available LCA studies on bio-based products, and the development of a method for comparing the LCA results. The basis of the analyses is a collection of more than 800 references of available LCA studies on biofuels (414 references), forest and agricultural biomass for energy production (199), biopolymers (40), natural fibers (36), timber (132), lubricants and hydraulic fluids (27), surfactants (26), solvents (9) and intermediate chemical products (11).

The non-renewable primary energy consumption and environmental impacts of bio-based products were compared on three levels: (I) per kilogram of product, (II) per functional unit and, (III) per functional unit and per hectare of cultivated

land. The third comparison pertains to the use of biomass in terms of agricultural production, addressing the question: what kind of biomass and which products make best use of the limited area available for agriculture and lead to the highest environmental benefits when compared to conventional products?
Two complementary metrics have been developed to evaluate the environmental efficiency of bio-based products in comparison to conventional products:

A) Environmental efficiency per functional unit and per hectare of cultivated area:
(Impacts conventional product – Impacts biobased product) / Area [physical units/hectare-yr]

B) Relative environmental efficiency per functional unit:
(Impacts conventional product – Impacts biobased product) / Impacts substituted parts of conventional product [%]

(Example: the relative environmental efficiency of agricultural and forest biomass is very high as they require little processing when used for energy).

Results and comparisons

One of the outcomes of this research was a characterization of key factors that contributed the environmental benefits of different bio-based applications. The parameter most directly associated with bio-based products is biodegradability. However biodegradability is only an advantage when there is a need and opportunity for it. For instance, chainsaw lubricants are completely lost during use and directly emitted into nature, so biodegradability is an important benefit. In most of the studies the selected end of life options are crucial to the outcomes. Other key factors to consider when evaluating and comparing environmental impacts of bio-based products are the type and yield of the biomass, the allocation of environmental impacts to co-products such as straw, the definition of the functional unit, the amount of product necessary to fulfil the functional unit, the technology for the production, and the life time.
For energy consumption and greenhouse gas (GHG) emissions, almost all of the bioproduct LCAs show significant positive benefits over conventional products. However, eutrophication impacts show in most cases opposite results, negative impacts, due to emissions during the agricultural production (mainly phosphates). As far as acidification impacts are concerned, biomaterials, lubricants, and surfactants show environmental benefits while biofuel and energy crops present a higher acidification potential than petrochemical products. For correct interpretation, it is important to note that the availability and reliability of data on energy consumption and GHG emissions is significantly greater than other impact category data.

It can be stated that the use of biomass for bio-based materials (products containing natural fibers, certain biopolymers) and as energy crops (and energy production from agricultural and forest biomass) offer a higher potential for energy savings and greenhouse gas reduction than biofuels and products based on vegetable oils (e.g. lubricants and surfactants).

Discussion and conclusion

One can conclude that "bio-based" does not automatically mean "environmentally friendly", nor does it mean "without any environmental impact". The conclusions that can be drawn will depend on the weighting of the different impact categories within a sustainability framework.

The presented results are valid for most of the comparisons done with the assessed studies. However, they might not hold when non-bio-based materials are lighter or have better characteristics (e.g. for transport applications and loose-fills).

Therefore, one should not draw a conclusion on the environmental superiority of a material on the material alone, but always on a material in a specific application and in comparison to its alternatives. This leads to one of the main conclusions: One has to assess new promising applications of biomass continuously with a life cycle or total system approach.

Finally, when comparing the overall performance of conventional to bio-based products, one must take into account that most bio-based products are still in their infancy while petrochemical products have been optimised over decades.

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Biobased Economy, the high-tech version of Back-to-Nature

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In the sustainability debate, one of the options frequently named is a transition towards a biobased economy. Not only food, but also energy and materials could be based on biomass. This would imply a shift away from fossil fuels and therefore might be important for a solution of the global warming problem. In addition, it has economic and political advantages related to self-sufficiency and supply security. While this is no doubt true, such a transition also has some severe drawbacks which are not often highlighted. Before the industrial revolution humanity had a biobased economy. This led to a severe pressure on land and biological resources. The industrial revolution has shifted the economic base from biomass to fossil fuels, thereby solving the main sustainability problems of the time. A transition towards a biobased economy is in such a view not a step forward, but a step back, and unfortunately with a much larger world population. It would mean that we have to rely on agriculture far more than we already do. Basically, agricultural production would have to increase 2.5 times even with a moderate assumption for the contribution of biofuels. The major sustainability problems that we face already with agriculture would increase accordingly. Land and water will become scarce resources. Technological improvements and genetic engineering will increase efficiency and in addition may enable us to use biomass formerly regarded as waste. The question is to what extent such a high-tech version of back-to-nature will allow a sufficient production increase. The other question is whether there are alternatives with less doubtful aspects. All basic functions will have to be included in an assessment of alternative resource bases, because of the competition between them if they are based on the same resources. Moreover, the narrow focus on CO2 and global warming will have to be broadened to obtain a complete picture of advantages and drawbacks of such transitions. A first impression of new scarcities based on such a broader view will be presented.

Coffee Cultivation in Tropical Region: A Life Cycle Approach

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Introduction

The world coffee bean market is characterized by the presence of sixty coffee producing countries. Brazil and Colombia together command approximately half of the world market while the remaining countries have small market shares. Brazil is the world's biggest producer of coffee beans with approx. 30% market share. Depending on weather conditions, approx. 30 million bags of coffee beans are exported annually from Brazil while domestic consumption is around 10 million bags, which makes Brazil the world's third largest coffee-consuming country. Coffee exports are the third largest Brazilian exporting product, which generated about US$ 2 billion in the last years.

Approximately 80% of Brazilian coffee exports are Arabica coffee, which is considered higher quality drink than Robusta coffee besides its higher prices. Germany and USA are the biggest buyers of Brazilian green coffee, that is why the main roaster companies of the world are located in these countries (MAPA, 2003).

In Brazil, it is estimated that 2.5 million hectares distributed among 320,000 coffee farms are used for the cultivation of coffee, being 75% of these farms less than 10 hectares in size. In Minas Gerais and São Paulo States are located the biggest plantations of *Arabica* coffee, corresponding to approx. 1,300,000 hectares of cultivated area.

Goal and Scope

For LCA study it is necessary quantify inputs of production systems such as energy, water, nutrients and chemicals; and outputs such as grains, stubble, wastes, etc., in order to assess the environmental performance during the whole life cycle of the product.

The goal of this study was to present the main inputs and outputs related to the cultivation stage of coffee beans for exportation in order to generate data for the development of LCA case studies of green coffee in Brazil.

Functional Unit

The functional unit is the cultivation of 1,000 green coffee bags (i.e. 60,000 Kg of green coffee destined for exportation).

Data collection

All information considered in this study (use of water, fossil based energy, fertilizers and chemicals) were taken up in-depth data collection and evaluation by questionnaires applied on farm level and/or received by mail.

Time-related coverage *- Data refer to the 2001/2002 crop.*

Geographical coverage

Four Brazilian coffee producer regions were evaluated: Cerrado Mineiro, South of Minas Gerais State, Marília and Alta Mogiana regions in São Paulo State. These regions have the following geographic coordinates: 44 to 50° W longitude and 18 to 24° S latitude (TOLEDO FILHO et al., 2002).

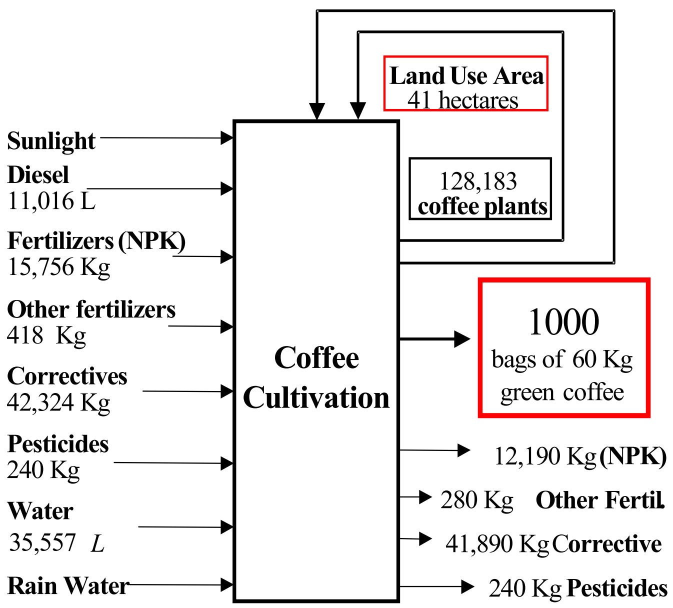
According to United States Department of Agriculture - USDA, the evaluated regions are classified as "tropical wet and dry". The annual average precipitation ranged over 1,136 - 1,575 mm per year. Annual average temperatures were approx. 22°C, in 2002 / 2003.

Representativeness

The data refer to a production of 172,300 coffee beans bags. The varieties of coffee beans considered in this study were Mundo Novo, Catuaí (yellow and red), Icatu (yellow and red), Catucaí (yellow and red) and Obatã, with an average plants density of 3,143 pl/ha.

Results

The results presented in Figure 1 represents the average inputs and outputs for 1,000 green coffee bags production. The fertilizers were expressed as the total sum of nitrogen, phosphorus and potassium added by functional unit. The load of inert was not considered. The correctives refer to the salts added for correction of the soil acidity. Pesticides include the active ingredients acting as fungicides, herbicides and insecticides. Micronutrients were included in the mass of other fertilizers. The water used



for fertilizers and pesticides application and for equipment washing was considered. Diesel is the fuel used by the agricultural vehicles. The outputs represent the excess mass of inputs that are not absorbed by the coffee grains. Until the moment, any assumption about the environmental impact of them was made.

Conclusion

The publication of inventories of agricultural products is a fundamental step for understanding the potential environmental impacts of each tillage. In this way, this work is the first Brazilian initiative for the elaboration of the coffee cultivation inventory. Detailed evaluation of LCI associated to the climatic data will allow a sustainable management of the natural resources. Different agricultural practices produce different environmental performances. The amount of agricultural defensive is directly related to agricultural practices as tillage rotation, density of plants, etc. This study will supply important results for better correlation of the agricultural practices and potential environmental impacts of this product.

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Acknowledgments

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Economic and Environmental Consequences of Food Production and Consumption:

MFA approach

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Agri-food sector is a crucially important part of the society, because it is a major factor affecting public health and welfare and it also contributes - directly and indirectly – both to the environment and to the national gross product and employment. Improving sustainability of the agri-food sector implies production of nutritionally better food by using fewer inputs and by reducing environmental burden. A comprehensive view of the whole system is necessary. The holistic MFA approach may be a practical tool, as it provides means to evaluate environmental and economic consequences of production and consumption.

In reducing environmental burden, it is essential to restrict the material throughput, to identify the most voluminous material flows and direct the measures to them. Improving performance of the food sector requires, that the benefits and inputs be quantified in an unambiguous way and that the inputs are estimated for the whole production chain.

Here, the materials flow approach (MFA) has been used to describe the Finnish food system. The quantitative numerical data have been derived from the farm models data basis, and the data have been adjusted to comply with the production and consumption statistics of Finland in 1995.

Using the compiled data an extended input-output model has been constructed. The model allows evaluate some of the economic and environmental consequences, when the structure of food production and the patterns of food consumption are changed. The consequences can be traced within agriculture, within the food sector as a whole or at the level of nation-wide economy. In combination with other information the model, thus, serves as a practical tool for planning.

The paper at hand gives an overview of the data basis and the basic principles of the model. The usability of the model is demonstrated with results from examples, in which the share of organic production or the share of vegetarian food in the average Finnish diet has been increased. The possibilities and restrictions of the approach as well as some of the needs for further development are discussed.

The study is the first step in developing MFA methods to analyse and to monitor the materials flow of the Finnish food flux. It is a part of the project "Materials

Flow and Ecoefficiency of Agriculture and Sustainable Compatibility of Food Production" carried out in collaboration between the MTT - Agrifood Research Finland and the Thule Institute at the University of Oulu. The results are used also in compiling the Finnish physical input-output tables. The study, thus, contributes to the overall development of the materials flow accounting statistics.

Key words: agriculture, economics, environment, input-output model, material flow accounting (MFA).

June 14.
Technical session T3

T3 AM

Session A: **Modelling Theory**

Chairmen: A. Horvath

Location: Lindstedtsvägen 3
Room: E2.

Adding Entropy Generation as a Measure for Resource Consumption to LCA – Thermodynamic Background and Software Implementation

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Abstract: Here, an implementation of entropy generation as a measure for resource consumption within the framework of LCA is proposed. Entropy generation is chosen over other measures (such as exergy) mainly for conceptual reasons, and for reasons of scientific stringency and conciseness (see below). The implementation is facilitated via one of the widely used software tools (Umberto), which can be extended to accommodate thermodynamic data for the material and energy flows. Thus the same computer model that is used for the LCA can be used for entropy analysis, significantly saving time and effort. At the example of copper production, it will be shown that the use of entropy analysis is straightforward and relies only on commonly available thermodynamic data (in addition to the detailed life cycle inventory). Implementation into a standard LCA tool opens the way for further applications of this method, even for LCA practitioners with little expertise in thermodynamic analysis.

Background: Life Cycle Assessment (LCA) is a tool for environmental decision support with a strong accentuation of material and energy flows. The emphasis lies on analysing flows at the interface between the analysed system and its environment, while the actual transformations within the system are not taken account of. LCA thus delivers valuable insights into the problems generated by industrial processes, which usually appear at the interface between the technosphere and the environment, but it is only of little help in finding viable solutions to these problems, which must be sought within the technosphere. One of the shortcomings of LCA in this respect is the lack of a common measure for assessing the consumption of resources. Resource consumption happens within the technosphere and its analysis along the life cycle of products can help considerably in finding alternatives with a lesser environmental impact.

Consumption is usually the result of physical and chemical transformations and the accompanying degradation. It is thus straightforward to search for a common measure of consumption in the realm of thermodynamics. The two most promising candidates thus far are exergy loss [1, 2, 3] and entropy production [4]. While they are closely related thermodynamically, they still differ considerably in their fundamental definition. The exergy concept draws much of its appeal from the notion of “useful energy”, which, in theory, can be extracted from the system under consideration when it is brought into equilibrium with its surroundings by reversible processes. The "useful energy" of fossil fuels or steam is a good example for the practical relevance of this notion. In general, however, especially for materials which are not used as energy carriers, the notion of "useful energy" bears little significance. In addition, its definition is based on a fictive reference environment (as for example laid out in [5]) and thus its absolute value can only be a more or less accurate estimate, depending on the similarity of the system's actual environment and the fictive reference environment. On the other hand, the absolute values of exergy are rarely used for argumentation; it is rather the loss or destruction of exergy which is of interest. Since this loss is independent of the specific reference environment, its values can be used to approximate resource consumption regardless of the system's actual environment. The reference environment is still needed for the calculation of the exergy of the system's constituents, but its value drops from the calculation once only differences are considered. An alternative to this procedure would be to use entropy production as a measure for resource consumption instead. The definition of entropy does not require a special reference environment and its values are readily available from thermodynamic tables and interpolation functions. The result of an entropy analysis, i.e. the entropy generated within the system under consideration, is then the sought after measure of resource consumption, and it is equivalent to the exergy loss from an exergy analysis. In terms of scientific stringency and conciseness entropy generation seems to be the appropriate choice for a measure for resource consumption in LCA.

So far there is no known LCA tool that can also carry out an exergy or entropy analysis. These analyses are usually carried out with the help of additional software, which virtually doubles the necessary modelling efforts. By fitting a standard LCA tool (Umberto [6]) with thermodynamic capabilities, some of these efforts can be saved. In addition, changes to the model, scenario calculations, and parameter variations are implemented much more easily.

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Dynamic Industrial Systems Modeling: Issues in Integrating Economic and Physical Modeling

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The analysis of physical material and energy flows conventionally is performed using energy/material flow analysis (MFA) using physical/engineering parameters combined with mass balance equations. However conventional MFA tends to be static or comparative static and it does not ask/answer questions regarding the forces that influence physical flows such as capital inertia, path dependency or learning – and thus does not link physical analysis to the economic drivers of change. Yet, physical flows do not exist in isolation from economic variables. Any change in physical flows, be it to improve energy or material efficiency, or to change the material or energy mix used in a production process, is influenced by economic decision-making and the economic and physical realities of the already installed capital stock. Industrial ecology has accumulated a wealth of information on the character of material and energy flows in almost all industrial systems. If we can link this wealth of information to descriptions of industrial behavior we as industrial ecologists can provide powerful descriptions of how to change energy and material flows and thus become more relevant in policy making and economic management of industrial systems. This paper discusses the main issues that need to be addressed when linking physical flow analysis and economic drivers, in the context of dynamic industrial systems analysis, and provides examples from various case studies.

When linking physical flow analysis with the economics of change, we face conceptual and empirical issues surrounding for example, the definition of system boundaries, representation of industry dynamics, the level of temporal, regional and technological aggregation, to name a few. Our choices in each case influence the outcome and descriptive powers of our models. For example a description of industry dynamics and industry evolution include several components. An industrial system is built of different age classes of capital, called capital vintage. New capital is added to the preexisting capital stock via capital investment, whereas older capital slowly depreciates and is gradually retired. Each vintage is characterized by specific features such as input efficiency and rates of depreciation, but the input efficiency, and the output structure of the system is shaped by capital vintage as well. An industrial system evolves as new capital is added to the stock that has different features than pre-existing vintages. Such evolution is neither spontaneous nor random, but is driven by goal specific and path dependent investment behavior, where the pre-existing capital stock shapes the nature of the new capital being installed. Consequently, the evolution of any industrial system is closely linked to the character of capital vintage, and without explicit descriptions of its structure, models are likely to overstate the potential for change.

Technological change, changes the input efficiency of a capital stock, and can either be embodied or disembodied. Embodied technological change captures the three Schumpeterian steps, invention, innovation and diffusion, and it is via diffusion that the innovated invention becomes embodied into the productive capital stock. Diffusion is driven by investment behavior, and the rate is influenced by experience (learning). Experience (or learning) curves influence diffusion, because as experience is gained, both the risk and the cost of the new capital equipment decline. This indicates a positive feedback relationship between learning and diffusion. Thus systems that are growing or are going through retrofits, experience faster learning and thus enhance the input efficiency of the capital stock faster than other firms. Yet, embodied changes are often irreversible, and occur at lumpy intervals. The input efficiency and output structure of the diffusion is restricted by path dependency, which occurs as mature firms tend to invest in similar technology as before, and thereby locking-into a specific technology trajectory. In essence, the structure and size of a preexisting capital stock, greatly limits the evolution of industrial systems. This feature is called capital inertia. Disembodied technological change is in many cases reversible as it does not change the core elements of the capital stock, but occurs via low cost changes in input efficiency or due to learning. Substitution and structural change also are essential components of industrial dynamics. Both are closely linked to the character of the capital stock, and do not easily occur without adjustments via investment.

Including each of those factors enables us to describe the physical and economic realities industrial systems face, and thus anticipate the response (adaptation) to changes in the economic or policy environment. Contemporary economic models that are used to describe industrial behavior do not possess this realism, as they in most cases focus on a single input to the production process, ignore the importance of the capital stock, ignore learning and assume that technological change simply occurs (called autonomous technological change). Consequently, models derived from industrial ecology have much to offer where increased realism can help anticipate responses, for example, to surprise events and thereby not only be relevant in policy discussion but also be relevant for managers pursuing anticipatory management.

Cluster Analysis Technique for Regional Materials Flows and Urban Sustainability

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Cluster analysis techniques are in common use in regional economics to discover and contribute to increased understanding of regional agglomerations of industries. Questions about why particular types of industries locate in a region and employment trends in those industries have important implications from an economic development perspective. Regional agglomerations are equally important to the impacts that industries have on their environment locally, regionally and perhaps globally. This study tests the utility of extending cluster analysis technique for understanding materials flows and contributing to urban sustainability. In particular, this study develops a materials flows network and life-cycle inventory of pollution. The paper presents results from pilot projects in Los Angeles County.

In terms of urban sustainability, cluster analysis may be helpful for identifying agglomerations of industries that share a common profile of upstream pollution within an urban region. These data can be combined with employment data to help planners better understand the balance between employment and regional pollution for a given regional agglomeration. The technique also holds promise for projecting the effects on pollution from growth or declines of particular industrial clusters.

In terms of regional materials flows, cluster analysis may be helpful for optimizing existing reverse logistics “loops” or creating new network links for by-product recycling. Industries that are already tightly networked in a conventional supply chain may be well positioned for reverse logistics that optimize or increase exchanges of wastes and by-products.

To begin the pilot studies, a principal components analysis (PCA) is performed on the purchasing coefficients for a matrix of 237 industrial sectors. The PCA uses regional economic data provided by the IMPLAN model for 1998 for Los Angeles County (IMPLAN Pro, 2000). Clusters are identified using standard techniques and selected for further analysis. In this technique, comparisons of the purchase patterns are constructed using correlation coefficients. Correlation analysis permits the assessment of linkages between pairs of industries based on their total patterns of purchases across multiple industries in the region. PCA is then performed to discover shared sets of purchase patterns. The PCA ranks all possible combinations on a scale of +1 to –1 for the strength of the shared pattern. A cut-off value is established, and clusters are identified from the remaining data and chosen for further analysis.

To show the usefulness of this approach, an economic input-output/life-cycle assessment (EIO-LCA) is used on a cluster of textile industries. The EIO-LCA is combined with regional economic data to better understand sources of air pollution in the Los Angeles region. For the regional materials flows pilot study, a cluster of "electronic and electrical" industries was selected. Although the study finds promise for applying cluster analysis techniques to aid in understanding regional materials flows, a number of obstacles are encountered and identified.

Session B: **Tools in IE**

Chairmen: B. Davidsdottir

Location: Lindstedtsvägen 3
Room: E1.

The Added Value of Mathematical-Statistical Tools to Material Flow Analysis

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Material flow analysis (MFA) has become a reliable instrument to describe material flows and stocks within a system. It is not only applied to classical questions of waste management, but also to analyse, evaluate and design the anthropogenic material household in general. The standardization of terms and procedures of MFA makes rapid progress. For instance, in Austria a Standard for the Application of MFA (OENORM S 2096) will soon be issued. MFA has become an integral part of many environmental impact statements/assessments and it has to be assumed that an increasing number of MFA-studies will be performed in the future.
A major problem of many MFA-studies is how to handle uncertain or fuzzy data. Often only mean values are employed. So far it is not state-of-the-art to consider uncertainties and their consequences on the results. In this way valuable information for decision making gets lost.
The paper presents selected mathematical-statistical tools appropriate for MFA. It will be shown how to apply these tools to specific problems and what the added value is. The main goal is to show how the available database is best used to get the most reliable information for decision makers. The following topics will be described:

(a) Data reconciliation: Measurements are subject to random errors. Hence, it cannot be expected that they obey the model equations (laws of mass conservation and other constraints). Therefore the values have to be optimally adjusted. This procedure is known as data reconciliation. It can only be performed if there is redundancy in the system, i.e., there exist more constraints or model equations than unknown variables. A side effect of data reconciliation is that the uncertainty ranges of the adjusted measurements get smaller and thus the result more reliable.

(b) Gross error detection: If the measurements contain gross errors, serious corruption of the results will be observed. Thus biases, or gross errors, should be identified by statistical tests and either be corrected or the measurements discarded. Otherwise the results would be distorted.

(c) Propagation of errors: If enough information is given the unknown quantities can be computed. Using Gauss´s law of error propagation it is also possible to quantify their uncertainties. This additional information is mandatory for sound decision making.

(d) Monte Carlo Simulation: If the measured data are not normally distributed Gauss´s law can not be applied. In these cases a different approach is useful - the Monte Carlo simulation. This method assumes that the probability distributions of the parameters are known. For each parameter, a computer algorithm creates a random value according to its distribution. These values are used to calculate the unknown quantities. If this procedure is repeated, e.g., a 1000 times, then 1000 possible results will be obtained. These results are then analyzed to get information about the probability distribution (e.g., mean, standard deviation) of the unknown quantities.

(e) Sensitivity analysis: It could be of interest to find out what happens to a variable when one of the parameters is changed. If a small change in the parameter results in a relatively large change in the outcome, the outcome is said to be sensitive to that parameter. This means that the parameter has to be determined very accurately to get reasonable results. To get this information it is necessary to perform a sensitivity analysis.

Dynamic Modeling of Cement In-use Stocks in United States

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The key attributes of sustainable infrastructure systems are – extended service life, enhanced performance, optimal life cycle costs, and minimal environmental life cycle impacts including the use of virgin raw materials. The rate of addition of new stock and the repair of existing stock are key determinants of infrastructure sustainability. The condition and performance of, especially, concrete infrastructure, in the United States has shown an alarming decline and it is anticipated that billions of dollars of investment will be required over the next decade to replace and/or rehabilitate existing structures. Globally, contemporary concrete production is approximately 12 –15 billion metric tons [1]. Cement is an essential component of concrete, usually in the range of 10-15% by volume. The production and use of cement are both energy- and material- resource intensive. The objective of this study is to characterize the stocks and flows of cement mobilized and utilized during the twentieth century in United States using the generic cement life cycle (Figure 1). The motivation for estimating historical inventories of cement stocks and flows is to provide accurate informed estimates of contemporary cement in-use stocks in U.S.

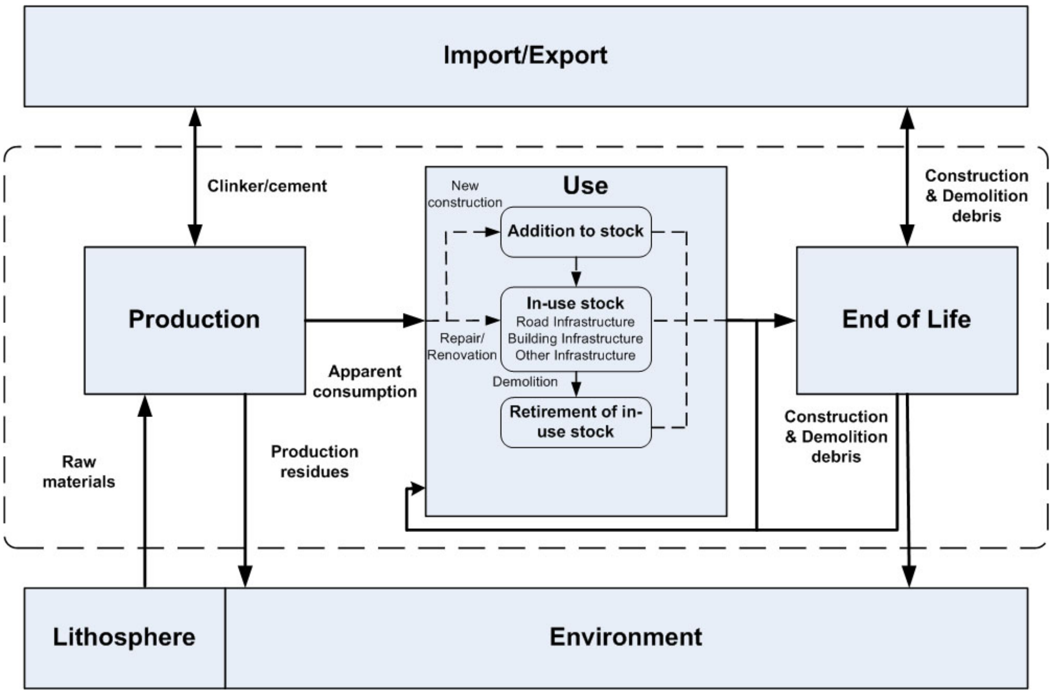

Figure 1. Generic life cycle of cement

infrastructure and future discards to relevant stakeholders such as federal highway administration, department of transportation, public/private utilities, and the construction and cement industries.

A dynamic substance flow model was developed using time-series data on apparent cement consumption and lifetime distributions for each cement end-use infrastructure application. There is buildup of stock when the inflows exceed the outflows of the use reservoir. The lifetime distribution determines the residence time of the in-use stock in the use reservoir. The consumption of cement has increased six-fold over the last fifty years (Figure 2). During the last century, the consumption of cement in the United States was approximately 4.5 billion metric tons. Apparent cement consumption was partitioned into various end-use markets such as roads, bridges, highways, buildings (residential, commercial), water and wastewater utilities, based on historical and contemporary data available from the Portland Cement Association and United States Geological Survey. For the time periods where cement end-use market share data were not available, missing values were interpolated based on existing trends. The contemporary cement end-use market in United States for the year 2000 is shown in Figure 3. The use of cement for road infrastructure accounts for about one-third of this market.

Dynamic lifetime models based on statistical Weibull distribution were constructed for each of the end-uses. The Weibull distribution is the most commonly used and preferred distribution in lifetime modeling of products [4]. The model-derived estimate of the in-use cement stocks in United States is in the range of 2.5-3 billion metric tons. This indicates that 55-70% of cement utilized during the last century is still in use. A sensitivity analysis of the results shows that uncertainties in choosing the appropriate Weibull lifetime distribution exert a stronger influence on the results than do variations in cement end-use market values.

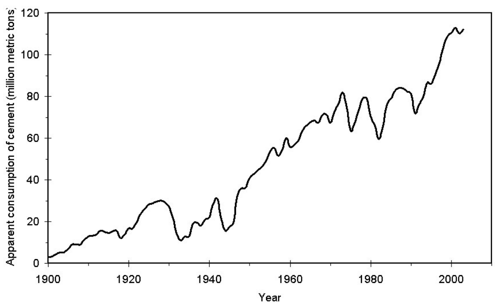

Figure 2. Apparent consumption of cement in U.S. [2].

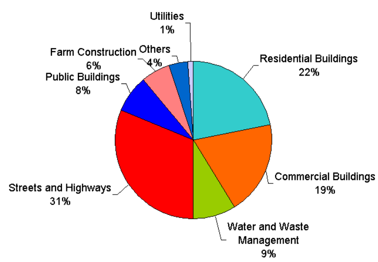

Figure 3. Cement end-use market in U.S. in the year 2000 [3].

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Dynamic Route Planning in Truck Fleet Management: Economic and Ecological Advantages from Using Optimization Strategies

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The rapid convergence of the areas of telecommunication and computer science is confronting those using conventional techniques to plan and optimize truck routes with new challenges. This paper documents simulation algorithms in the field of truck fleet management. It tests the effect of including short-notice orders that come in after trucks have left the loading area. Various algorithms used for static dispatching were expanded for dynamic dispatching as a simulation. Dynamic orders are understood to be short-notice jobs that have to be integrated into existing routes after a truck route has been begun. A simulation model to do the simulation experiments was designed and implemented in Java, which simulates the order-input process, the rough planning process and the successive execution of the routes. This model even includes parameters to cover all limitations relevant in reality, for example, the different capacity limits of vehicles, the number of vehicles available, driver work hours, etc. Another parameter makes it possible to vary (0-100%), as desired, the percentage of orders that come in on short notice to be integrated into existing truck routes. In this way the quality of various strategies to solve one variation of the Dynamic Vehicle Routing Problem (DVRP) with various percentages comprised by dynamic orders and under other boundary conditions set by parameters can be tested in a simulation. Important output variables are the sum of distances driven, the costs for the company incurred by them and the emissions into the atmosphere, which can be reduced noticeably by this technique of route optimization. In general, an increase in the percentage of routes that are dynamic causes a linear increase in the distances to be driven, costs and environmental impact. When various optimization strategies are used, it becomes apparent that the distribution of the dynamic orders influences the magnitude of the distances in completely different ways depending on which strategy is used. If a company knows approximately when short-notice orders are likely to arrive, that makes it possible for the company to decide on short notice which planning strategy to use. Depending on the size of the company, several thousand Swiss francs can be saved each day. At the same time enormous reductions in environmental impact can be realized, as the length of distances driven can be reduced by as much as 15% per day.

Regional Input-Output Analysis: A New Basis for Life-cycle Assessment

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Key words: life-cycle assessment, regional analysis

Economic input-output analysis-based life-cycle assessment (e.g., the EIO-LCA model by Carnegie Mellon University) has been used by academia, industry and government since the mid-1990s. It has been developed into a comprehensive and widely accessible, web-based tool (www.eiolca.net) in order to estimate the energy and other resource use, and the hazardous and non-hazardous emissions and wastes associated with the manufacturing of products and generation of services in the United States. Since its introduction, I-O based LCA has been adopted by other countries as well, and the development of national, monetary as well as physical I-O tables-based models is under way.

However, many decisions would be wise to take into account local or regional characteristics (e.g., availability of natural resources and labor). Thus disaggregated models would be useful for decision-making on regional and local levels. This paper describes a regional economic input-output analysis-based LCA (REIO-LCA) model. The basis for the model is the Gross State Product, which is a different approach than the ones used by regional economists in the U.S., but most appropriate for environmental decision-making. These regional economic multipliers are linked to energy (electricity and fuels), criteria air and toxic emission factors, and hazardous waste generation intensity factors, which are also available on a U.S. state level. REIO-LCA is currently being integrated with EIO-LCA at www.eiolca.net.

The advantages of the regional I-O-based LCA model include the opportunity to assess the resource use and pollution intensities of products and services on a regional or local level, to help the regional industry benchmark environmental performance against the national practices, to show the spatial distribution of supply chain environmental impacts of different economic activities on local, regional, state, and multi-state level, and to aid strategic, governmental planning for a locally sustainable economy that is cognizant of the cross-regional commercial links (imports and exports). Typical analyses include location of a new manufacturing plant, shifts from manufacturing to service sectors, interregional commerce, etc. The use of the model is demonstrated through a rank-order sectoral effects comparison associated with proposed changes in economic activity levels and sectoral mixes.

Participatory Material Flow Analysis for Production Chains.

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To optimize production chains it is not sufficient to analyze material flows only. Even the integration of flow costs accounting, analyzing the optimization potential and an approved communication of these results to the enterprises seems not enough to change the production chain significantly. Rather it is appropriate to create a learning process within the cooperation of the enterprises to motivate and guide them through the process of production chain optimization. There is no golden rule to do so. Nevertheless this paper will present a reasonable proceeding to create such a learning process based on some experience within metal industry and automobile recycling.
First of all it should be pointed out that cooperations are a rare form of coordination of enterprises. This form of coordination stays between market and hierarchy. (It is not a focus of this paper how to establish a cooperation. For short: there are several aspects to consider i.e. personal confidence, low transaction costs, self-interest of the enterprises.). At least three kinds of cooperation may be distinguished: market based, strategic and partnership. For optimizing the production chain the partnership-cooperation is worth striving for. Furthermore, partnership-cooperations are able to make a contribution to the social dimension of a more sustainable economics.
The objective of this paper is (1) how Material Flow Analysis (MFA) can be coupled with participatory elements (PE) and (2) how the Material Flow Modeling (MFM) as part of the MFA can be carried out in an evolutionary manner.
(1) To develop an approach to couple MFA with PE experiences of several case studies have been analyzed: Integrated Assessment, System Dynamics (i.e. group modeling) and Technology Assessment. One finding was the importance of the point in time of participation within the modeling process. Three different points are distinguished, ex ante, ex post and in continuum.

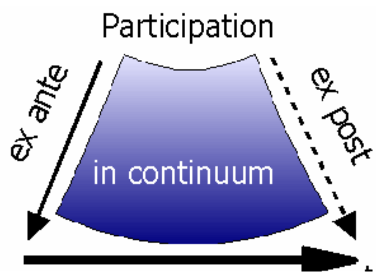

Fig 1: points in time of participation

Ex ante participation is basically used at the beginning of the modeling to get knowledge and information from the participants (i.e. interview, brainstorming, hexagon diagrams). Ex post participation is basically used at the end of a project to provide information (i.e. simulation, scenarios, diagrams). An extreme way of participation is in continuum participation. At this all participants are involved over the hole time span of the modeling procedure. All steps of the modeling as problem definition, scope, valuation and interpretation are carried out in intensive dialogs. This means all relevant assumptions are made with the legitimation of the participants involved. As it is seen in Fig. 2 these participation times may be (ISO 14040).

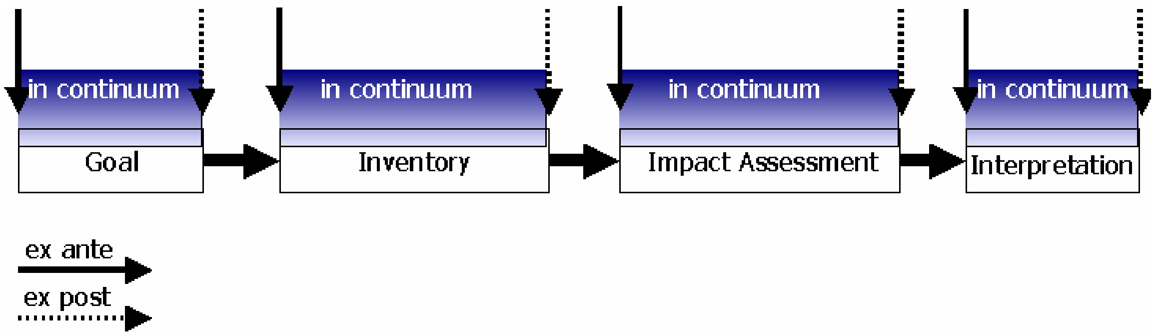

Fig. 2: point in time of possible participation for each stage of LCAallocated to all steps of analyzis

In continuum
participation is a promising way to initiate and to establish a mutual learning process within the participants (including the modeler). To reach this objective it is necessary to minimize the time needed for this kind of participation, since the shortage of time is one of the most pressuring restrictions someone is facing in cooperation with enterprises. But what kind of participation should be used at which specific part of modeling? There is no general answer to this question. To many aspects (framing, sector of industry, goal, point in time, ...) do influence the best way of participation. As an example an approach usable for few enterprises in a production chain has been developed (automobile recycling). The scenario is based on one workshop, one-to-one interviews and literature. The background of this approach comes from consulting (energy and environmental managing) and from the project "Sustainable Metal Economy in Hamburg" (Gleich et al. 2000; 2001; 2004) where several short case studies have been applied. For example we showed that the used metal beads from surface blasting are not waste but constitute a valuable resource for producing metal foams. Another focus was the reduction of cooling lubricants in metal processing with several partners. A further case study was to analyze Life Cycle Impacts and optimization strategies for the product design and product use of forklifters (Gottschick 2000).
(2) 'In continuum participation' means that the modeling has to be carried out in a evolutionary and flexible manner. Beginning with a very simple model each step of participation should provide information for model improvement and each step of the improved model should provide new and helpful information for the participants. For this task the software UMBERTO has been used. With UMBERTO Material Flow Networks can be created including Material Flow Cost Accounting. For presenting the results visualization tools (i.e. sankey-diagramms) are available.

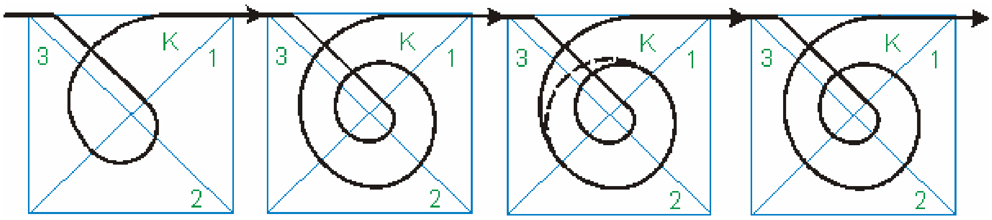

Fig. 3: proceeding to couple MFA and participation within the phases of cooperation

Finally the approach of this paper comes to an proceeding shown in Fig. 3. Each spiral symbols one phase of the developing process of the cooperation (initiating, establishing, achievement of objectives, chance of broader scope). The sectors of the squares stands for: (1) goal of the model, (2) inventory analyzing, (3) presentation and (K) aspects of cooperation. The line indicates how often the sectors should be run through (iteration loops). For each phase and each sector specific kinds of participation are provided.

Northern Limits. A Resource Flow Analysis and Ecological Eootprint of Northern Ireland. A Case Study from the UK Sustainable Resource Use Programme.

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Key words: Resources, Mass Balance, Resource Flow Analysis, Industrial Metabolism, Ecological Footprint, Systems, Sustainability.

Aims

The paper will report on the outputs of the Northern Ireland Resource Flow Analysis and Ecological Footprint project, Northern Limits. The project carried out a resource flow analysis of Northern Ireland and calculated the Resource Efficiency, Direct Material Input and Ecological Footprint. The footprint methodology was also used to model a range of scenarios in waste management, food consumption and energy.

Objectives

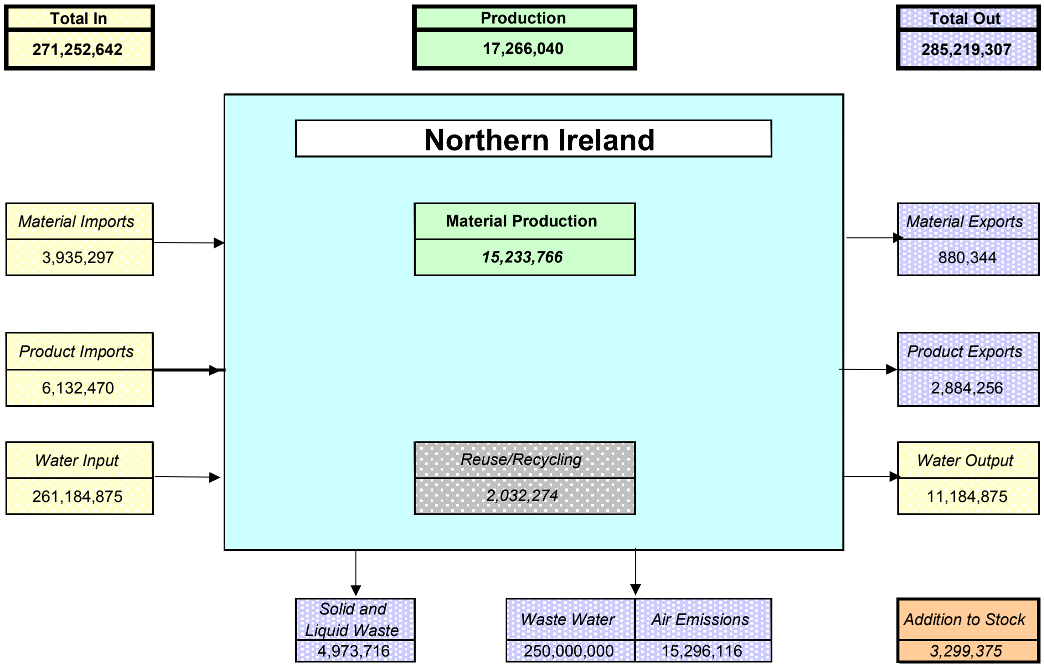
The objectives of the project were as follows:-

- To quantify the flows of energy and materials into, out of and within the Northern Ireland economy;
- To calculate the Resource Efficiency of the Northern Ireland economy;
- To calculate the Ecological Footprint of Northern Ireland;
- To compare the Resource Efficiency and Ecological Footprint of Northern Ireland with other regions;
- To measure the Ecological Sustainability of Northern Ireland;
- To model a number of Improvement Scenarios in terms of Ecological Sustainability;
- To assess data gaps and needs and make recommendations for improvements and further research and capacity building..

Results

The Northern Limits project was completed in March 2004, the results of the RFA are presented in Figure 1.

Figure 1. Resource Flow Analysis for Northern Ireland 2001



The Northern Limits report is available on the project web site at www.northern-limits.com

Conclusions.

The Completion of Northern Limits represents the first application of industrial ecology principles such as resource flow analysis to the development of sustainable development policy in Northern Ireland. A follow-up programme of education, training and capacity building is currently being developed. The paper will present on both the outputs of Northern Limits and the follow-up work

Dr Robin Curry
November 200

Indirect and Direct Carbon Emissions in the Swedish Building Sector

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The building sector accounts for more than one third of the global carbon emissions. The bulk of these emissions derive from the operation phase (here referred to as direct emissions). The production of buildings itself is also a very important sector with significant materials use and carbon emissions (here referred to as indirect emissions). For example, the production of cement alone accounts for as much as 6 percent of the global carbon emissions.
Previous bottom-up studies using process-LCA methodology typically arrive at an indirect energy use of 3-4 GJ per square meter floor area in residential buildings. About 90 percent of this is attributed to materials, 5 percent to transports and 5 percent to the erection of buildings.

In this study we use a top-down input-output methodology to assess indirect energy use and carbon emissions in the Swedish building sector. The findings differ significantly from previous bottom-up studies. The indirect energy use per square meter is about 50 percent higher for multi-family houses (5.3 GJ/m^2) and 100 percent higher for detached houses (7.6 GJ/m^2). Contrary to the bottom-up results a significant portion of the indirect energy use is linked to transports and construction site activities. The inputs of diesel, petrol and jet fuels constitute about 35 percent of the total energy inputs. For detached houses 44 percent of the indirect carbon emissions come from transports and mobile machines, 40 percent from stationary energy use and 16 percent from chemical processes (e.g. calcination in cement production). The corresponding figures for multi-family buildings are 31 percent from transports and mobile machines, 43 percent from stationary energy use and 26 percent from chemical processes.

We analyze differences in methodology and data causing the differing results between the top-down and the bottom-up approaches. Potential weaknesses in the process-LCA approach may be systematic truncation of upstream energy use, exclusion of certain sectors as well as very crude estimates of transports. Other problems arise in the input-output analysis with its coarse aggregation of production in assumed homogeneous sectors and handling of imports as domestic production. Moreover, the currently low rate of new-construction in Sweden may result in high energy intensities if the energy use is not proportional to the economic activity.

Finally, we discuss the potential for carbon mitigation in the production of buildings by means of materials substitution (e.g. wood frames for steel frames), resource substitution (e.g. change cement or filler in concrete), energy efficient materials production, improved materials quality (e.g. high strength concrete/steel), improved end-of-life management and logistics of transports.

Session C:
Environmental Management

Chairmen: J. Korhonen

Location: Lindstedtsvägen 17
Room: D1.

EMAS Registration of a Local Authority and the Urban Water Cycle: Cervia Case Study.

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The EU voluntary Eco-Management and Audit Scheme (EMAS) is a management tool, which includes ISO 14001 Environmental Management System, for the organisations willing to evaluate, report and improve their environmental performance. The scheme has been extended in 2001 to all sectors of economic activity including Local Authorities. Local Authorities have in fact an important influence on the environmental behavior of the citizens and can make a major contribution to the implementation of the principles of sustainable development. In this paper the main steps of the process of applying the EMAS procedure to the municipality of Cervia, a well known tourist destination located on the Adriatic coast of the Emilia Romagna region, are described. In the studied area, heavy tourists flows during the summer season, which multiply by ten the residential population, coexist with important protected natural areas. The Environmental Review, recently concluded, showed that the main environmental pressures in the summer season, described according to the PSR (Pressure, State, Response) model, are related to water consumption, to the emissions of the treated wastewater in the coastal waters and to production of wastes. The paper focuses in particular on the Cervia urban water cycle, quantifies the water flows used for urban and agricultural purposes in the entire municipal territory, presents the adopted indicators, outlines the possible responses for a better water resource management by Cervia Municipality. Important water savings can be achieved by improving the leakage rate of the drinking water nets and by a more efficient use of water by end users. Moreover, the analysis of water regulations showed that the City Council is in a key position in the life cycle of the water resource for exerting a positive influence both on the drinking water provider and on the water end-users.

Life Cycle Methodology in the Acquisition Process of Defence Materiel

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A suggestion for how to integrate Life Cycle methodology into the procurement process, in order to take environmental consideration with a life cycle perspective will be presented. The focus of the study was on public procurement, with procurement in Swedish Defence as a special case. Since the description of the Swedish procurement process is rather general, it is probably comparable to that of other countries. Environmental aspects are considered today in Swedish Defence, but without a life cycle perspective. The suggestions involve taking current consideration a step further.

The method involved a study of current literature and interviews with different actors in the acquisition process. The life cycle methods considered were quantitative Life Cycle Assessments (LCAs), a simplified LCA-method called the MECO-method and Life Cycle Costing (LCC).

We identified four areas for use for LCA in the acquisition process: To learn about environmental aspects of the product; to fulfil requirements from customers; to set environmental requirements and to choose between alternatives. Therefore tools such as LCAs are useful in several steps in the acquisition process.

It is an advantage to use internationally accepted methods, such as LCA, in order to communicate results with organisations from other countries. From the interviews it became clear that the actors in the acquisition process think that environmental aspects should be included early in the process. The actors are interested in using LCA methods, but there is a need for an initiative from one or several of them if the method is to be used regularly in the process. Environmental and acquisition issues are handled with very little interaction in the controlling and ordering organisation. An integration of environmental and acquisition parts in these organisations is probably needed in order to integrate environmental aspects in general and life cycle thinking in particular.

In order to include the most significant aspects when procuring materiel, it is important to consider the whole life cycle of the products. Our major suggestion is that the defence sector should work systematically through different product groups. For each product group quantitative, traditional LCAs or simplified LCAs (in this case modified MECOs) should be performed for reference products within each product group. The results should be an identification of critical aspects in the life cycles of the products. This knowledge should then be used when writing specifications of what to procure and setting criteria for procurement. The reports should be publicly available to allow reviews and discussions of results. To make the work cost-effective, international co-operation should be sought. In addition LCAs can also be performed as an integrated part of the acquisition process in specific cases.

Toward a Managerial Approach of Industrial Ecology: A Case Study in the Canadian Industry

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The emerging field of Industrial Ecology is built upon the research and practical field of sustainable development. More than ever, businesses are called to play an essential role to ensure the rehabilitation and transformation of residuals in their industrial processes, and to move from a linear or quasi cyclic mode of production to a complete cyclic one, which tends to maximize the use of resources at different levels of the production process. The involvement of more and more enterprises in experiencing Industrial Ecology practices shows the need to understand and analyze these practices as part of the enterprises' business strategies. Since the 1990's, some scholars have claimed that the outstanding of different approaches of Industrial Ecology might represent a key element for its development as a scientific discipline of research and study. However, Industrial Ecology still remains especially focused on natural science, engineering, and technical approaches and scientific models that tend to be unaware of the concrete implications of Industrial Ecology practices on business management. Few empirical studies making it possible to understand the strategic and organizational aspects related to the process of experiencing the practices of Industrial Ecology were carried out. For a better understanding and development of a conceptual framework of a managerial approach of Industrial Ecology, a case study (based on semi-directed interviews with top managers) in twelve Canadian companies involved in the valorization of the residuals was carried out. The results of this study show that the use of the residuals as inputs in processes is primarily motivated by the search by the managers of more productivity. Secondly, the success of these practices depends, mainly, on the development and control of knowledge and know-how, which fall under a step of organizational training irreducible to the only technological aspects of Industrial Ecology. Third, upon the above, four elements seem to be relevant for a managerial approach of Industrial Ecology strategic management of the firm, learning process and core competencies development, pragmatic rationale, and progressive modernization. The managerial approach of Industrial Ecology thus lies within the scope of the comprehension and of the analysis of the operations which surround the design for environment, the use and the transformation of the by-products, the prevention of pollution, eco-efficiency, green accounting, and the exchange of by-products between the companies. The investigation carried out contributes to foster the conceptual links between organizations and the field of Industrial Ecology. It also contributes to present a framework of a managerial approach of the discipline, from the perceptions of the managers who had

designed and are implementing practices of Industrial Ecology at a multi-functional level within the corporation. And finally, the investigation carried out contributes to the development of Industrial Ecology at the level of the firm.

Key words: industrial ecology, managerial approach, residual, strategy, learning process, pragmatic, progressive modernization.

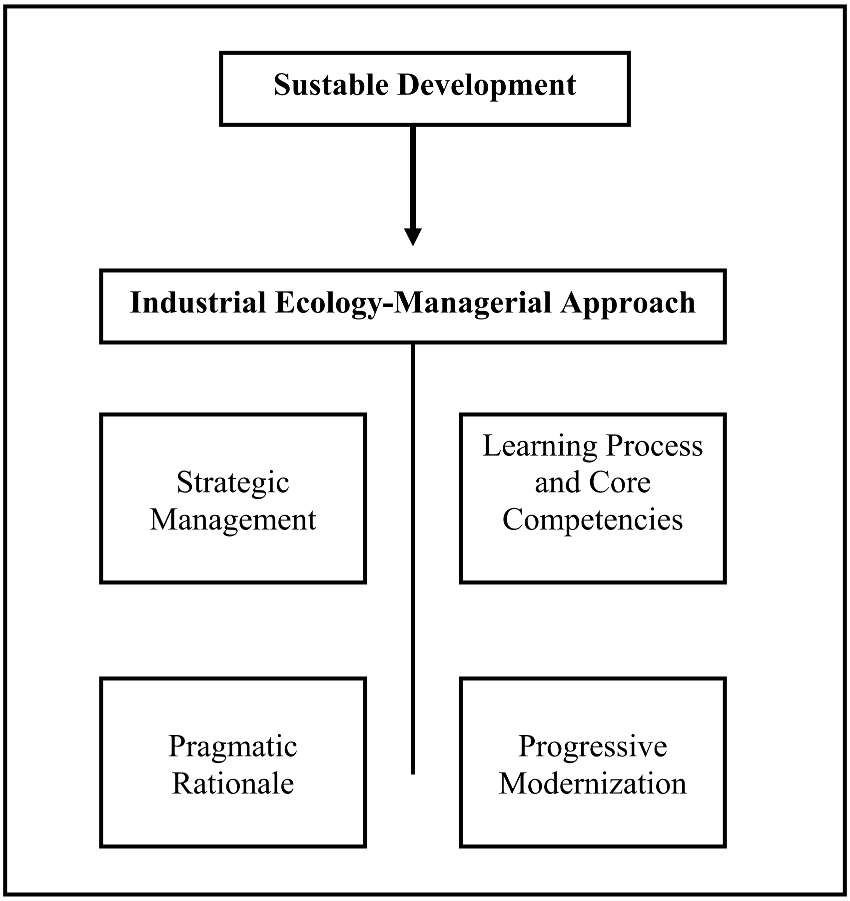

Figure 1. Conceptual framework of a managerial approach of Industrial Ecology

Can the Green Beast Be Tackled?
Methodological Challenges in the ‘Pays To Be Green’ Research

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By the dawn of the 21st century, a greater number of *Industrial Ecologists* start accepting that the profitability of environmental investments is conditioned to contextual circumstances. Research slowly moved away from the grand topic of ‘*whether or not*’ corporations can offset the costs of environmental investments to one questioning ‘*when*’ it is possible to do so. According to this renewed research agenda, the profitability of environmental investments do not follow universal principles but are contingent to both organizational capabilities and the industrial context in which firms are embedded. But if the new research focus represents a step forward in the ‘*pays to be green*’ debate (as it has been popularized in the *Journal of Industrial Ecology*), it poses renewed methodological challenges for researchers. By addressing the circumstances favoring green investments, the renewed debate necessarily incorporates the disputes about the origins of competitive advantage of firms – in particular, between the *resource-based view of the firm* (RBV) and Michael Porter’s *positioning school*. In this sense, the identification of ‘*when*’ depends, primarily, on how competitive advantage is defined. Additionally, the profitability of environmental investments, such as eco-brands, can also be diluted in time and any short-term analysis would fail to recognise the value of the investment. This paper not only addresses these issues from both methodological and ontological perspectives but also provides the reader with a general framework to develop research in the ‘*pays to be green’* area. The paper draws from the design phase of a broad research project sponsored by the *Marie Curie Program* involving European and Australian industries.

The Global Textile Chain – Opportunities and Challenges for the Sustainability Management of Small and Large Businesses

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Production processes that extend across several continents are widespread in the age of globalisation. The majority of businesses that operate transnationally depend on raw materials, intermediate or finished products from every continent. Their products are marketed and consumed world-wide. As a response to businesses' growing political and economic influence in the course of the globalisation, expectations to improve the sustainability performance are being voiced by governments and other stakeholders. This development is particularly pronounced in the textile industry, given that the production of the clothing worn in Western countries has largely been moved to other parts of the world. Lead by the Wuppertal Institute, an international project consortium has recently developed a toolbox promoting sustainability improvements along the textile chain[3].

Analysing the situation of large European textile retailers as well as their Indian and Vietnamese suppliers, the challenges faced by "both sides of the chain" to improve the sustainability performance become evident.

On the one hand, textile retailers try to respond to the increasing expectations like assuring basic labour standards in their supply chain or reducing chemical residuals in textiles by applying instruments such as environmental or sustainability management systems, codes of conduct or labels. An obstacle to successfully reach out to the supply chain with these instruments lies in the nature of the business relationships in the sector. Textiles are commonly procured on a job-order basis, hindering the establishment of long-term business relations. Fast changing fashion leads to "on-demand" production, making long term planning difficult. Yet, long-term relationships would help to alleviate barriers for implementing formalised management systems and compliance with codes-of conducts.

On the other hand, textile suppliers in Asia, many of them small and medium sized enterprises, struggle to life-up to the increasing expectations voiced by their

[3] The e-textile toolbox is available at www.e-textile.org and features amongst others background information, an easy to use performance measurement and management system and a database with eco-efficiency measures.

customers. They face differing codes of conducts from the various retailers, high administrative burdens to implement formal management systems and a general lack of financial and human resources to implement these systems. In addition, they commonly lack the necessary background knowledge about the political and society expectations of their export markets.

Examples from India and Viet Nam show that eco-efficiency measures are a good starting point to overcome some of these obstacles. Eco-efficiency improvements often result in win-win solutions both for the bottom line and the environment. Unlike measures in the social domain, results from eco-efficiency measures are easier to communicate and can be measured with existing business indicators. But they are also of benefit for the retailer, who benefits from an improved ecological performance both of the product as well as the production process. At least as important is the fact that the improved performance is likely the result of a systematic approach to measure the performance and to manage improvements. In a sense, the basis for an environmental management system is being laid. Yet, key for a broad take-up of these strategies is to raise awareness for the importance and benefit of these strategies as well as the availability of easy to use instruments and tools.

Consumer Willingness to Recycle Electronic Waste in California

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The growing stockpile of used and obsolete consumer electronic devices (CEDs) has been called the "largest toxic waste problem of the 21st century". With technological advances, the average life span of the typical CED has dropped significantly in the past several years. In addition, more and more consumers around the globe are using an increasing number of CEDs. From public health and environmental perspectives, many of the components in electronic products are extremely toxic. Some of these hazardous materials include lead, cadmium, mercury, barium, beryllium, hexavalent chromium, plastics, polyvinylchloride, and brominated flame retardants. Electronic waste or "e-waste" management is a major concern and the issue is currently being debated at various levels of government and in the media.

E-waste is one of the fastest growing components of the municipal waste stream in California and across the U.S. Unfortunately, reliable data on the amount of e-waste generated, recycled, exported, and discarded in the U.S. is currently unavailable. A recent study of e-waste diversion in California also indicates that the current recycling infrastructure is inadequate to handle the projected increase in the volume of e-waste between now and 2006.

The successful implementation of effective e-waste recycling policies requires two critical pieces of information that are currently missing. First, there are no reliable estimates of the volume of e-waste stored by households. Second, there are no explicit studies on e-waste recycling. The goal of this paper is to start addressing these two questions.

We first present results from a cross-sectional mail survey of consumer recycling behavior using a random sample of California residents. We randomly selected 6 California counties and in each county we randomly selected 500 households for a total sample size of 3000. The survey was administered during the spring of 2004; we obtained a response rate of 12%, which is appropriate for this type of study and comparable to similar mail surveys.

Survey responses indicate that Californian households are currently stockpiling approximately 7.7 million obsolete TVs (small and large), 7.0 million computers (desktop and laptops), 5.4 million monitors, and 33 millions of other large and small consumer electronic devices. These findings provide a more reliable estimate of the current volume of household e-waste and it confirms the inadequacy of the current recycling infrastructure in California.

Using contingency table analysis, we then analyze relationships between key demographic/socioeconomic characteristics and environmental behavior/attitudes. Survey results also indicate that 54% and 36% of the respondents are respectively very likely and likely to recycle e-waste, whereas 7% are not very likely and only 2% are not prepared at all to recycle e-waste.

Overall environmental performances of a telecommunication provider

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Introduction: Firms often employ in-house methods based on qualitative criteria without looking at life cycle burdens of their products and services. This can cause errors in the identification of environmental priorities, inducing an inefficient use of economic resources. This paper describes an innovative LCA based analytical tool purposely developed to quantify the environmental impacts of company activities, products and services through the entire life cycle to be used in the frame of procedural tools such as Environmental Management Systems (EMS) and Environmental Performance Evaluations (EPE). It combines life cycle oriented environmental and cost assessments enabling transparent decision on development and investments.

Method: Four types of information are used to assess the overall activity of a company: (1) purchased goods to characterize the supply chain, (2) on-site direct emissions (if any) to define the in-house company performances, (3) the sales to link the overall company activities with the use phase and (4) the product requirements, to characterize the impacts related to the use phase. Combining these information with existing LCI databases and related monetary costs, a matrix approach has been developed to assess in a consistent way overall company impacts and related costs. This tool has been tested on several private and public companies using a first prototype of program and demonstrating its effectiveness. It is here applied in the service sector to the overall assessment of Swisscom, the main telecommunication provider in Switzerland.

Results: Annual flows of material and energy are analysed based on a primary energy and CO2 balance and expanded to include activities usually not considered in the annual report, like commuting travels, advertising, infrastructure, etc. Figure 1 compares the different contributions to the primary energy consumption over the company life cycle. 56% of the overall impacts are directly related to the company activities and 44% linked to the use of the service they provide. For the Company subsystem, electricity generates the most important non renewable primary energy (25%) consumed in this subsystem. On the other hand CO2 emissions due to electricity are restricted to 2% because the electricity source is the Swiss electricity mix, i.e. mainly hydropower and nuclear electricity. The other important contributions in the company consumption are the production of the network infrastructure (23%) as well as advertisement (14%). The use of services by customers also causes significant impacts. It is equivalent to 44% of primary energy consumption and 39% of CO2 emissions of the system. In the latter aspect, the main contribution comes from the Internet (manufacturing and use of computer allocated to internet use), followed by the production and use of mobile phones and finally the use of fixed phones.

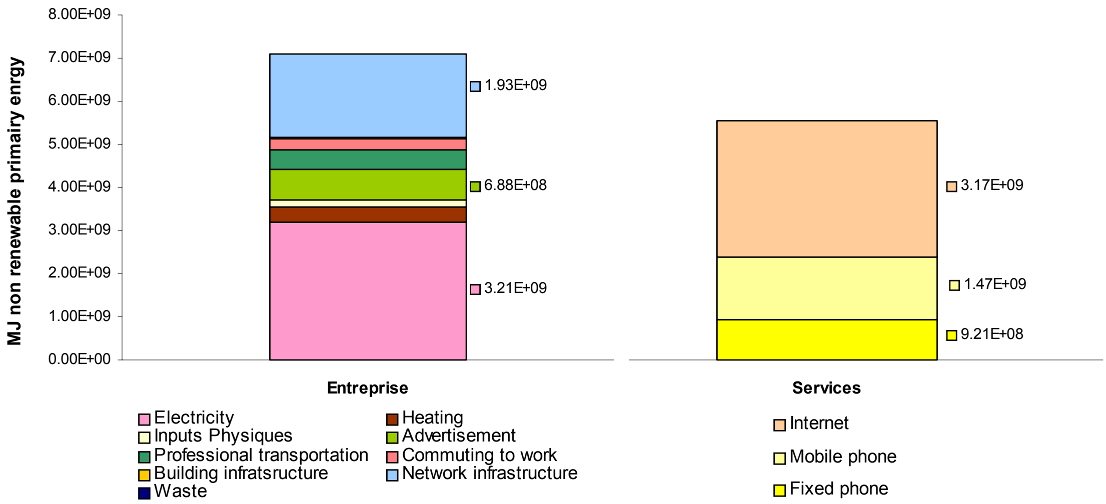

Figure 1: Primary energy consumption over the company life cycle directly related to the company activities and linked to the use of the service by customers.

Conclusions and recommendations: The environmental assessment that has been conducted using the Green-e approach enabled to identify the significant environmental aspects of Swisscom as well as their associated impacts. Moreover, specific recommendations could be made related to all aspects of the considered system. This includes:
- to introduce purchase criteria that give priority to low consumption devices and environmental friendly compositions,
- to analyze the commuting behaviour of employees,
- to offer a range of attractive low consumption telephones (fixed and mobile) and to sensitize the customers to the impacts that the use of the services involves.

It is now essential to integrate the suggested recommendations and actions in the environmental management system when updating it.

Session D:
Comlex Systems Theory

Chairmen: R. Isenmann

Location: Lindstedtsvägen 5
Room: D3.

Natural Economics – The Quest for an Economics of Sustainability and the Sustainability of Economics

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This presentation first briefly reviews the contributions that concepts from neoclassical economics have made and can make to model and better understand human impacts on the environment as well as environmental repercussions for economic activity. In the second part, I focus on physical and biological constraints on economic processes, and how these constraints may be incorporated into models of industrial ecosystems. Specifically, I will discuss how laws from thermodynamics and principles from ecology may be used conceptually and empirically to inform analysis, guide adaptation to new conditions, and help anticipate future constraints and opportunities for system change. The discussion and examples will center on production and consumption processes at the firm and household level but I will also address implications at higher levels of system organization, such as regional and national as well as global economy-environment issues. The presentation will conclude with insights from dynamic systems analysis, adaptive and anticipatory management, and present suggestions for investment and policy decision making to promote sustainability.

A Multi-Agent Simulation of Green Niche Market Development under Uncertainty

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This paper introduces a multi-agent simulation framework for investigating the emergence of niche markets for environmentally innovative products. We present our motivation in developing this system, describe the detailed model we adopt for our simulations, and analyze the results of simulations that span a range of market scenarios.

Regulatory agencies have a keen interest in fostering the emergence of niche markets for products that have a smaller environmental impact than existing market alternatives. Yet the individual decisions that govern the emergence of markets for these "green" products are often fraught with imperfect information: agencies must formulate regulations despite having imperfect environmental knowledge; firms must sell products in an evolving and uncertain regulatory environment; and busy consumers must make choices without all the relevant environmental facts at hand. Additionally, viable markets for green products often depend on the early support of "green" consumers, who constitute an enthusiastic minority among a broader, heterogeneous class of consumers.

The framework we present here employs formal models of these important factors to enable the simulation and analysis of niche markets under alternative regulatory strategies. To model the environmental impact of market evolution, we associate the production and consumption of products with environmental consequences or footprints. To model the role of imperfect information in decision-making, we adopt a multi-agent approach in which consumers, firms, and a governmental regulatory agency all make their individual decisions at each step. These decisions are characterized by various forms of uncertainty: consumers, firms, and the regulatory agency all lack certainty about product footprints; firms lack certainty about current and future demand for potential products and about the regulatory environment they may face in the future; consumers lack certainty about which products are available and what the environmental consequences of their purchases are. We provide a mechanism by which the government and individual firms can carry out research on particular products to reduce their environmental uncertainty. Finally, to model heterogeneity among consumers, we distinguish several types of consumer according to how environmental factors enter into their preferences and how much work they are willing to do to find the best product.

We use illustrative simulations to demonstrate how our implemented framework supports the emergence of niche markets for green products. We show how successful niche market creation is affected by heterogeneity in the class of consumers and the diffusion of improved information about alternative products. (See Figures 1 and 2.) We then present results from a set of simulations of a range of market scenarios and regulatory strategies. We analyze and explore how various parameters interact with regulatory strategy to determine the simultaneous evolution of the market and the environmental state. We conclude with a discussion of the implications of these results for regulatory policy.

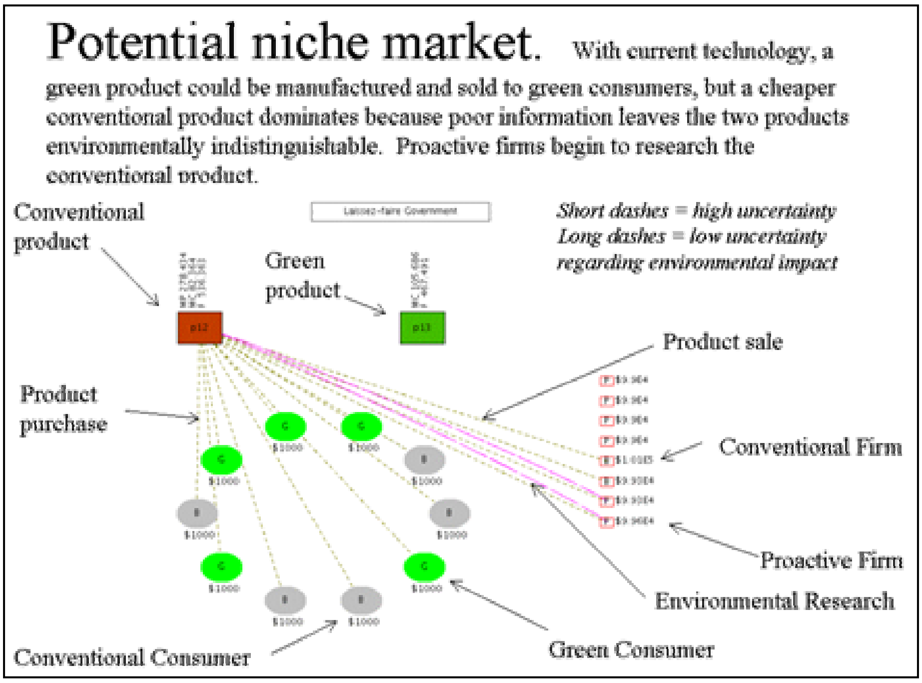

Figure 1. A potential niche market.

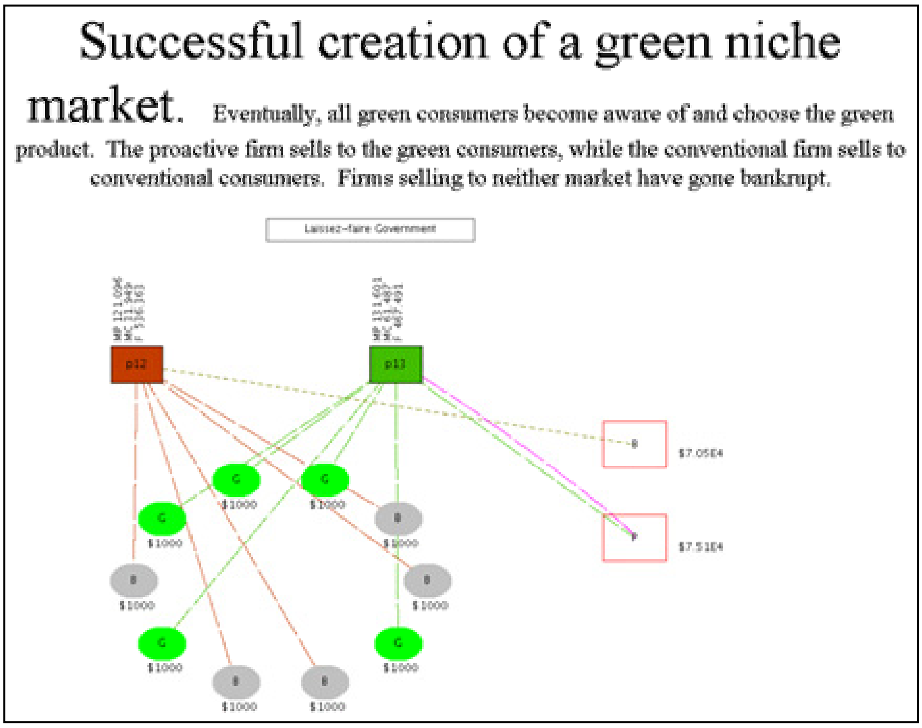

Figure 2. The successful creation of a niche market.

A Multi-Agent Model of the Environmental Polymer Processing Firm

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We investigate behavioral and organizational questions associated with the environmental performance of firms, using a multi-agent simulation modeling approach, based on case studies of plastics processing firms in New Jersey. Results show that a more realistic account of corporate environmental behavior depends on representing employees not as *homo economicus* but as agents having bounded rationality and subject to social influences.

This paper presents a bottom-up view of industrial ecosystems by examining the interpersonal dynamics that influence corporate environmental behavior. Employees of profit-making firms don't always behave in the shareholders' best interests due to misaligned incentives, impaired information flows, and bounded rationality. Even worse, there are sometimes conflicts between shareholder interests and the broader public interest, evident in the moral struggles of people over their dual roles as employees and as citizens. Employees operate within the formal, regulative structures of the firm and government, as well as the informal, normative or cultural structures of social networks.

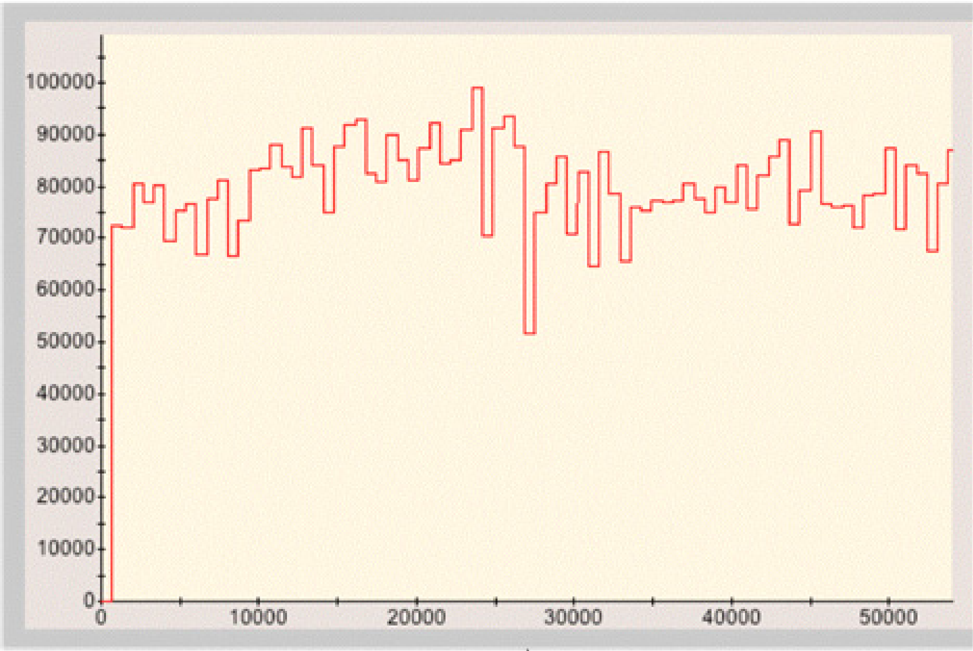
The paper triangulates to identify useful insights about personal networks and corporate environmental behavior, using interviews at firms, review of archival data, and a computer simulation model. Interviews and archival data provide empirical grounding, while an innovative multi-agent simulation modeling exercise supports formal theorizing. The empirical work is based on case studies of plastics processing firms in New Jersey. The simulation model characterizes production technologies, social and economic structures, and interpersonal interactions under a variety of conditions.
Illustrative results, shown below, demonstrate how closely environmental performance depends on worker error, which confirms previous linkages to the Quality movement. Surprising results on the role of ideology suggest that employee environmental bias is a less powerful predictor of emergent corporate environmental performance.
The model may eventually prove helpful to managers interested in improving on existing organizational practices and procedures. The model could also help regulators understand corporate environmental behavior more fully.

This work is funded by a U.S. Environmental Protection Agency STAR grant.

Realistic Worker Error Raises Modeled Air Pollution 120%

Homo Economicus assumed for hours 0 to 27,000 | Realistic Employees assumed for hours 27,001 to 54,000

Hiring Environmentalists Drops Modeled Air Pollution <5%



A minority of employees are environmentalists on average | Plant manager starts preferentially hiring environmentalists

Promoting Industrial Symbiosis through Game Theory

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Industrial ecology has progressed in recent years and has become a hot issue of growing importance both in academia and industrial circles, since the concepts, methods and tools of industrial ecology industrial will improve the planning and performance of business operations.

Industrial symbiosis (IS) is an important concept and practical application in the field of industrial ecology. IS aims to improve efficiency and effectiveness resources and capacities via collaborative interactions between different business entities.

In industrial symbiosis network, industrial entities are interconnected through various mass and energy chains. The increasing complexity and uncertainty of industrial system demands new approaches. Operations research provides approaches to solve such real problems on the design, operation and management of industrial symbiosis. This paper will propose game theory in order to obtain potentials for environmental, economic, and social benefits at a system level.

After material flow accounting and analysis of material processing sector, ecosystem indices are introduced to describe the economic and environmental sustainability based on resource productivity. This sector includes the material exchange between the independent plants (entities). Because of market economics, the interest and production strategy of an individual entity may change dynamically. A two-person game theory is proposed to solve the operation problem of this sector. The detailed procedure for strategy game is presented at different operating strategy in the market environment. To find the value and optimal strategies, linear programming formulation is proposed.

Afterwards, we apply this approach to the integration of two plants system in Quzhou Eco-industrial Park, zhejiang. The benefits of the proposed approach are illustrated.

Keywords: Industrial Symbiosis, Operations Research, Game Theory, Resource Productivity

Development of Modelling Tools for Optimisation of Complex Networks

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Globalisation, the opening of markets and radical technology innovations are all contributing to an increase in complexity of industrial, business and organisational networks. Whereas once networks were characterised by operation at a local or regional level, with a small number of actors and consistent and long-lasting relationships, current networks display a rapid turnover of actors, and actors being involved in many different types of relationships with multiple global players. This dynamic behaviour is not only due to ongoing changes in relationships governing material transformation and exchanges, but is further influenced by a number of 'implicit' relationship characteristics, including those norms, values, joint intentions, conflicts and cultural rules of the interacting organizations which influence their decision making processes, and to multiple uncertainties which relate to the reliability, honesty, level of trust and even power relationships between organizations.

Planning and optimisation in such complex dynamic, evolving and uncertain environments provides a significant challenge. To compound the challenges, organisations are under increased societal and governmental pressure to improve performance in line with the considerations of sustainability – to give due regard to their societal and social impacts in addition to their economic performance.

Many existing business strategy models and tools fall short in their ability to incorporate such complex considerations into planning and decision making. Those models and tools which do exist take the perspective of a single decision maker, and are potentially limiting in two ways. Firstly, such models generally assume overall control and complete knowledge of the decision maker on the system as a whole, an assumption which is generally not reflected in reality. Secondly, from a sustainability perspective, what is an apparently optimal scenario for a single decision maker is not necessarily an optimal position for the network as a whole.

The research work presented in this paper explores considerations in the development of a set of modelling and optimisation tools to address these limitations. A discussion is presented of the existing models from a range of disciplines which may be drawn upon to support our work, including those of static models, dynamic models, self organisational models and evolutionary models. A description of the types of tools which are available to implement such models, such as Multi-Agent Systems and neural networks, is presented.

Finally, the practical challenges associated with using both the models and the tools is presented.

Based on this understanding, an approach to the modelling and optimisation of complex networks is proposed. This approach includes a vertically and a horizontally coupled set of models and tools. The vertically integrated system explores the interrelationship between the functionality or resource exchange aspects, the ‘implicit’ aspects of individual relationships and the implicit characteristics of the network as a whole. The horizontally coupled system draws on system dynamics modelling and Multi Agent Systems to allow for incorporation of evolution and ‘self learning’ of agents into the analysis.

Application of Business Innovation Concepts to the Design of Industrial Networks

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Traditionally, industrial networks have been perceived as a collection of actors, with relationships between the actors in the networks being formed as a result of transformation or transaction of resources. Traditional modeling and optimization tools draw on insights from network theory and the rather constraining view of linear and static relationships between actors to analyse networks in terms of (semi-) quantitative objectives, generally relating to economic performance. Furthermore, such models and tools typically assume that all actors behave according to full rationally.

Where such network analyses have been extended beyond those which purely relate to economic and efficiency arguments, objectives which have been addressed include environmental and social issues, such as energy use, greenhouse gas emissions and/or health effects. With the increased pressure on businesses to become more sustainable, considering not only the economic implications of their actions, but their environmental and social impacts, the application of multi-objective optimisation tools are being explored for their ability to optimise performance of the networks to include such considerations.

In addition to considering an expanded set of objectives and impacts during optimisation, there is a growing awareness arising out of the socio-economic and organizational sciences that the organizations in a network cannot be modeled as rationally behaving actors, who can choose between specific sets of alternatives to transform or transact their resources throughout the network. These sciences suggest that the interactions between organizations in a network are not only functional in the sense that they involve resource transformation or exchange, but that the interactions also incorporate various implicit or relational characteristics which affect the functionality of the network and the potential for the network to achieve certain objectives. These implicit characteristics can either relate to certain cognitive or normative values of the interacting organizations, such as norms, values, joint intentions, conflicts and cultural rules, or they can related to uncertainties which relate to the reliability, honesty, levels of trust and even power relationships between organizations. Furthermore, positive and negative feedback loops exist between the functional characteristics, between the implicit characteristic and between the functional and implicit characteristics, a scenario which results in an ever changing and reshaping environment.

An added dimension to the impact of implicit characteristics on the functionality of networks is that modern networks are continually becoming more interconnected, more complex and more widespread. This has resulted in increasing levels of uncertainty within and between organizations, and an increase in diversity between the normative and cognitive values of the different organizations in a network. For the individual organization or policy maker aiming at designing industrial networks with a more sustainable outcome, new instruments must be developed that can take into account the modern network characteristics and that allow for the increasing impact of implicit characteristics on the functionality of networks.

This paper presents a framework for exploring how functional and implicit characteristics of organizational relationships interact in a complex and dynamic industrial network and how they impact upon the functionality of that network. It applies business innovation concepts, such as the systemic and complex innovation approaches, to aid in understanding how to improve the functionality of industrial networks in the context of sustainability. The systemic innovation approach does not see innovations, technological or methodological, as the outcome of a linear process between a certain chain of rational behaving actors, but rather as the product of the interaction of a complete system supporting or constraining these innovations by different on-going social, economic, juridical, infrastructural, cultural and political factors on the level of individual organizations, organizational relationships and networks of organizations.

The proposed framework includes the considerations that:

- the transformation and transaction decisions in a certain organization are determined by functional characteristics of that organization, by its norms and values which result in bounded self-interest and its level of uncertainty and routines resulting in bounded rationality and bounded willpower;
- the transaction of tangible and intangible resources between different organizations is affected by conflicting or corresponding norms and values between organizations and perceived levels of reliability, honesty, trust and risk between organizations;
- the ability to transact certain tangible and intangible resources between organizations is determined by the regulative, normative and cognitive norms of conduct in the entire network in which the organizations are operating, and the power relationships in that network;
- functional and implicit characteristics on the different levels have positive and negative feedback loops emphasizing the dynamic features of the network;
- the network is always evolving and organizations are constantly learning and so changing their modes of operation.

Use of this framework to design a modeling tool for networks will provide greater insights into the magnitude and direction of the dynamic interactions between functional and implicit characteristics on the functionality of networks. These insights can be used to develop new business strategies or policy instruments, which are more successful in handling and dealing with the features of dynamic and complex networks in the context of sustainability.

Understanding and Shaping the Sustainable Co-Evolution of Industry and Infrastructures

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The development of industrial regions, for example those dominated by chemical and metallurgical complexes is an evolutionary process. Past investments in facilities represent huge sunk costs, their lifespan is multiple decades and many of their markets exhibit low growth. Furthermore, there is a high degree of interconnectedness and interdependencies between the regions components [1][2]. As a consequence, industrial regions must be characterized as complex networked systems that are resistant to change.

A successful transformation of these networked industrial systems in a more sustainable direction is a prerequisite for sustainable development. This implies a need for facilitating the evolution of truly successful eco-industrial networks, and putting Industrial Ecology concepts into practice. To that end we must first understand the nature of this evolution and understand the internal properties of actors involved in shaping the complex networks that form our socio-technical systems.

Design implies a conscious choice in the direction of development. Industrial Ecology has so far mainly focused on objective, value free <u>analysis</u> of the socio-technical systems. In order to <u>design</u> socio-technical systems, an explicit, transparent, coherent and value based framework is necessary [3].

We are developing such a framework with at its core a Genetic Algorithm, with business and technical "DNA" that allows the evolution, adaptation or optimization of business strategy and technical systems deployed. This "DNA" is contained in Agents, which definition and DNA is sufficiently “rich” to allow representation of industry or infrastructure systems and related system elements. These Agents are connected through a multidimensional network of monetary, mass, energy and information flows.
This networked system is placed in a World in which economic, legal and policy conditions determine the fitness landscape for the actors that shape the content and the structure of the network. Their business strategy, local feedstock availability, market development and availability of infrastructures determine the direction of the co-evolution.

The structure of the framework [4] is presented in figure 1. Starting from an observation of a real-world complex industry – infrastructure network, a decomposition is performed into a Agent based, Genetic Algorithm driven evolutionary network model. The states of the model are analyzed and fed back to the user, such as a regional development manager, business developer of government. The new understanding of the co-evolution of industry and infrastructure is then fed back to the design, and operation of the industrial and infrastructural systems.

This approach allows analysis of the industry-infrastructure response to a changing environment or the design of the optimal economic policy and business strategy to foster a sustainable industrial network. The framework developed will be presented together with first case study, involving the co-evolution of innovative combinations of infrastructures in the Rotteram Europoort region. Preliminary data on the co-evolution of the metal processing and automotive industry will also be presented.

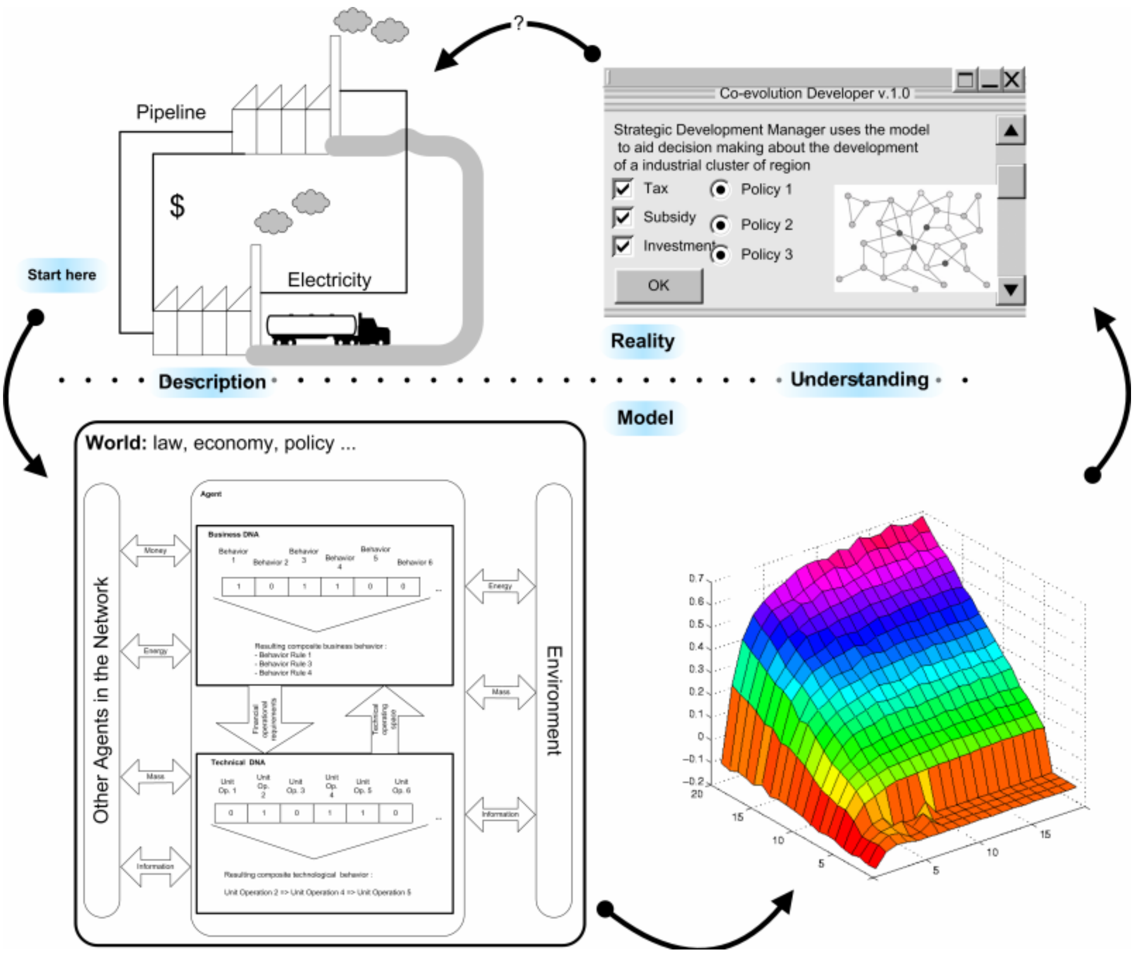

Figure 1 Structure of Action Oriented Industrial Ecology framework

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Session F: **Eco-efficency**

Chairmen: M. Ruth

Location: Lindstedtsvägen 3
Room: E2.

Product Quality-Based Eco-Efficiency Applied to Digital Cameras

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INTRODUCTION: Eco-efficiency is an effective method for measuring the sustainability of a product, and is expressed as the ratio of the product value of a system to its environmental influence. When calculating eco-efficiency, it is generally accepted that the environmental influence of the whole life cycle is measured by using Life Cycle Assessment (LCA). But, there still remains considerable confusion and controversy about what product value is and how it should be quantified. We proposed here a quantification method for eco-efficiency derives the ratio of product quality to whole environmental impact, which is in line with the conventional eco-efficiency. The applicability of the proposed method to an actual product was also evaluated using a case study on digital cameras.

METHOD: Three steps are applied to quantify the product quality as one value. These are: normalization based on a value function, determination of subjective weighting factors of attributes, and summation of the quality of the chosen products. The ranges and units of attributes are different, and these differences are resolved by normalization based on a non-linear value function, which reflects the market situation. To calculate the value functions of each attribute, one should investigate the attributes' values for all products that have been sold in the market and calculate the minimum, average, and maximum values for each attribute. Minimum, average, and maximum value means minimum acceptable value, middle value point, and maximum desirable value, and corresponds to the normalized scores 0, 0.5, 1, respectively. A value function can be drawn by using these three coordinates. Finally, actual values for each attribute are normalized by applying the calculated value functions of each attribute. The second step is to determine the weighting factors of the attributes. The preferences for each of the selected attributes are different and these differences are considered by weighting factors. Here, the weighting factors of attributes are determined by the consumer's questionnaire because consumers are the main actors in purchasing, using, and evaluating products. It is possible to sum the quality of chosen products using normalized values and subjective weighting factors of the attributes. The final outputs are the relative quality values of chosen products. On the other hand, environmental impacts are calculated by following both Life Cycle Inventory (LCI) analysis based on ISO 14041 and 14049 documents and the Life-cycle Impact assessment Method based on Endpoint (LIME) modeling, which was developed by RCLCA, AIST in Japan.

CASE STUDY: The applicability of the proposed method was evaluated using digital cameras. Among 15 digital cameras that got the Type III label (Eco-leaf) in Japan, we chose seven products that were first sold in 2003. To quantify the product quality, a total of eight attributes were selected as major attributes of digital cameras. These are: effective pixel number, optical zoom, product weight, product volume, maximum recordable pieces, screen size of liquid crystal display (LCD), pixel number of LCD, and maximum recorded pixel number. Based on these eight attributes, the qualities of selected products were calculated by applying the proposed three quantification steps. We also calculated the LIME results by using LCI results, which are included in Eco-leaf. Finally, the eco-efficiency of seven products was calculated by using the formula as the ratio of quality values of products divided by their LIME results. As shown in Figure 1, product 7 has highest eco-efficiency value, 0.605, followed by product 2, product 6, product 5, and so on. Although the chosen products have got Eco-leaf, eco-efficiency values were quite different. For example, eco-efficiency value of product 7 is 2.65 times higher than that of product 1. The results also show that the eco-efficiency values of products using rechargeable batteries (2, 6, and 7) were higher than those of products using alkaline batteries (1,3, and 4). It is because the product values of products using rechargeable batteries were higher than those of products using alkaline batteries, but the environmental impacts were lower.

Product	Product quality (no unit)	Environmental impact (Yen)	Eco-Efficiency (1/Yen)
Product 1	43.85	192.51	0.228
Product 2	63.98	111.23	0.575
Product 3	38.47	155.49	0.247
Product 4	39.17	171.00	0.229
Product 5	47.68	127.51	0.374
Product 6	51.16	92.45	0.553
Product 7	63.51	104.97	0.605

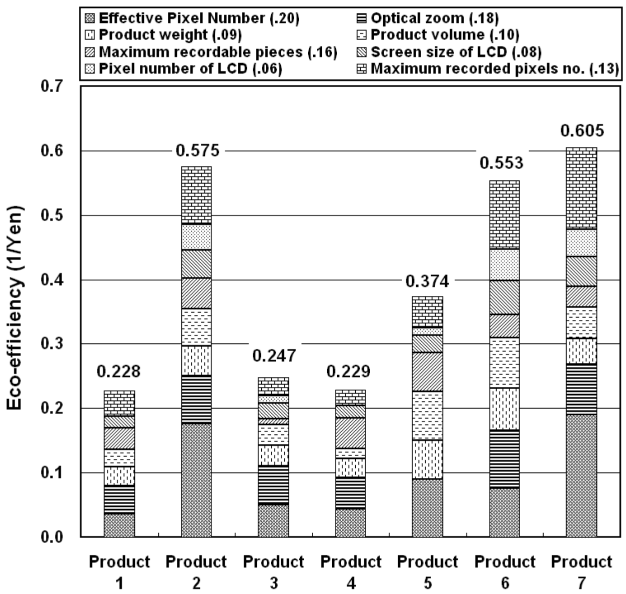

Figure 1. Quality values, environmental impacts, and eco-efficiencies of digital cameras

CONCLUSION: The quantification method for eco-efficiency derives the ratio of product quality to whole environmental impact based on LIME was proposed, and applicability to digital camera was evaluated. The major advantages of the proposed method are that it applies a non-linear value function that reflects the market situation, and that it is possible to identify the quality level of chosen products by considering all products that have same functions in the market.

The Structure and Hierarchy of methods for Eco-Efficiency Improvement

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Technical University of Denmark

An architecture of methods for Eco-Efficiency improvement has been developed comprising the various disciplines and tools involved. It identifies industry as the major actor and target group. To improve Eco-efficiency, there is a limited number of intervention points: the emission, the individual process/unit operation, the production system, the product/product system, and to some extent the whole societal system. At each level, environmental performance measured as Eco-efficiency can be addressed and changed by choice of solution. Because improvement is the aim of Eco-Efficiency measures, the discipline of synthesis – design and creation of solutions – will form a core pillar of the architecture. Other disciplines exist forming the necessary background and frame for the synthesis. The framework of methods and tools underlying measures for Eco-Efficiency improvement, thus, in essence comprise the disciplines of: management, system description & inventory, analysis & assessment, prioritisation, synthesis, and communication, each existing at all levels of intervention. The developed architecture of methods for Eco-Efficiency improvement, thus, consists of thirty individual disciplines, within each of which one or more methods and tools can be identified.

The architecture involves a hierarchy. In the creation of Eco-efficient solutions, fulfilling human demands is a common denominator and base of comparing alternatives. The very concept of Eco-efficiency involves a quantity, or unit, of demand fulfilled. Therefore, any environmental improvements made on any intervention level shall be measured per unit of demand fulfilled. For this reason, the final human, or customer, demand and the final product to meet this demand is the highest level in the intervention hierarchy. A measure on emission level (a treatment plant) or process level (e.g. a process intensification) may lead to changes at higher levels e.g. in the product chain, thereby loosing any benefits gained at the lower level. In principle, therefore, any measure at lower levels shall be subject to an assessment of Eco-efficiency at the highest level.

Experience of Eco-Efficiency improvement at the various levels of intervention will be presented demonstrating the various disciplines and tools and results achieved in industry. There are no overlaps between interventions at the various levels, and improvements at different levels are, thus, additive. Our experience with Eco-Efficiency improvement in industry shows that significant improvements can be found at all levels. Eco-efficiency improvements of a factor of 5 or 10 have been mentioned as longer term targets for a sustainable development to be achieved in a period of 30 – 50 years. It is our judgement that

such improvements are technically achievable. But importantly, they do not arise from economic optimisation driven by conventional market forces alone, a conscious and targeted effort is needed.

Key words
Environmental Engineering, Eco-efficiency, Sustainable development, industry, disciplines, tools, hierarchy, structure, architecture, drivers

The Role of Eco-Efficiency in Industrial Ecology

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Industrial Ecology is both ‘industrial’ and ‘ecological’ (Lifset et all, 2002). It is ‘industrial’ in that it focuses on product design and manufacturing processes, and thereby views upon firms as the primary agents for environmental improvement, as they possess the technological expertise, management capability and financial and other resources necessary for successful execution of environmentally informed design of products and processes. Industrial Ecology is ‘ecological’ in at least two senses. Firstly, it looks to non-human ‘natural’ systems as exemplary models for effective recycling in industry and society. Secondly, it places industry in the context of the larger ecosystems that support it by providing sources for the resources used in industrial and human activity and sinks that absorb and detoxify the wastes discharged by society and industry.

Over the past decade Industrial Ecology researchers and academics have primarily developed the ecological ‘leg’ of Industrial Ecology. This has provided the discipline with a distinctive set of tools for and datasets of material, substance and resource flow analysis, and with a distinctive set of exemplary models of industrial symbiosis and eco-industrial estates. The translation of new analytical insights into new product, service, process and/or technology concepts for the industrial practice appears so far to have received far less attention. In other words, the development of the industrial ‘leg’ has not kept up with the development of the ecological ‘leg’ of Industrial Ecology.

The industrial ‘leg’ of Industrial Ecology deals with the development and evaluation of decision support frameworks and metrics, of strategies and organisational arrangements, and of product and process design criteria and tools that enable firms and other industry stakeholders to improve their ‘industrial ecology’. It has been argued before (e.g. van Berkel et all, 1997) that such efforts could build upon the diagnostic tools and methodologies developed through Cleaner Production and alike preventive environmental management practices. While valuable progress has been made in the industrial practice, now most commonly under the banner of Eco-Efficiency, it appears that such is not yet captured nor critically reviewed within the context of Industrial Ecology, thereby preventing Industrial Ecology from making breakthroughs on the basis of integration of its two constituent ‘legs’.

Eco-Efficiency is by origin a business efficiency strategy, which capitalises on the deeply entrenched business imperative to continuously improve the efficiency of use of all business resources (finance, human capital, technology, etc.). The underlying imperative in Eco-Efficiency is '*to do more with less*', i.e. to produce more value with lower ecological impact through the development and delivery of better products and services which are competitive and better meet customer needs. Firms become Eco-Efficient by developing and implementing measures that reduce the consumption of resources, reduce the impact on nature and/or increase the product or service value (WBCSD, 2000). Eco-Efficiency outcomes can be measured in terms of '*resource intensity*' of products, processes, services or societies at large, a metric, which complements '*resource flow*' analysis customary to Industrial Ecology.

A range of Australian examples will be presented in an effort to clarify the linkages between Industrial Ecology and Eco-Efficiency. In eco-industrial parks individual firms practice for example Eco-Efficiency to reduce their waste streams and improve the quality thereof, so that these wastes can become valuable resources for another company, thereby realising industrial symbiosis. Materials flow analysis can for example pinpoint to sources of materials inefficiency, which can then be addressed using Eco-Efficiency principles and tools.

The examples illustrate that Eco-Efficiency and Industrial Ecology are both aimed at achieving and/or restoring a balance between industrial activity and sustainable use of natural resources, including energy, materials, water and the capacity of the environment to assimilate waste and render valuable services. Industrial Ecology does so by providing for objective assessment of resource flows, while Eco-Efficiency does so by developing innovative products and services. As Industrial Ecology becomes the science of resource efficiency, Eco-Efficiency is the business practice of being resource efficient. Both Industrial Ecology and Eco-Efficiency can enrich one another. Industrial Ecology can inspire and boost Eco-Efficiency in regards to the conceptualisation of innovative products and processes, through the more vigorous application of the ecosystem metaphor and natural analogy. Vice versa, Eco-Efficiency provides a starting point for developing the industrial 'leg' of an Industrial Ecology science.

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Is it possible to fulfill the End of Life Vehicles directive 2000/53/EC?

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According the EU-directive 2000/537EC End of Life Vehicles (ELV) shall member states take the necessary measures to ensure the following targets:

- No later than 1january 2006, for all ELV´s the reuse and recovery shall be increased to a minimum of 85% by an average weight per vehicle and year.
- No later than 1 January 2015, for all the End of Life Vehicles the reuse and recovery shall be increased to a minimum of 95% by an average weight and year.

The tendency is that the plastics and composites used in cars are increasing stable to a cost of the metals used in cars, which are easy to reuse. There are no dependable methods or outlets for the recycled plastics as for metals. Therefore it is very important to continuously have the competence of the materials used in cars. So is it possible to fulfill the ELV directive?
First of all the car industry is affected by a hard competition and cost strain, which leads to that they by themselves, can not manage the ELV targets. Secondly the European community has not solved the problem of the target calculations.
Another problem regarding the ELV directive is that the directive is not harmonized in the EU, which leads to distorted competition between the member states. The national interpretations leads to, that in one member state the incineration counts as material recovery and in another member state as energy recovery.

And finally the tax system in the member countries differs, which leads to that in some member states it is “cheaper” to recycle compare to another one.

The paper will thoroughly discuss these problems and possible solutions from the basis of resource effectiveness.

T3 PM

Session A: **Product/Service System**

Chairmen: A. Tukker

Location: Lindstedtsvägen 3
Room: E1.

Integrating Corporate Responsibility Awareness along the Electronics Supply Chain

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Like many companies, not only in the electronics sector, Panasonic are working to ensure that their corporate social responsibility (CSR) is not compromised by their suppliers: environmental and social impacts must be managed along the complete supply chain through to the end of life of the product. In the particular case of mobile phones, the design cycle is rapid so that systems and tools for managing the supply chain must be simple, practical and rapid. The number of companies in the supply chain is typically very large: a design site can typically have 100 first tier suppliers, each with many companies in its supply chain. The work to be described in this paper is directed at developing a system to enable collection, collation and management of chemical substance data for all components used in a mobile phone handset, to ensure that all future products comply with environmental requirements – both legislative compliance and company-imposed – from "gate to grave". The system will also manage information on CSR performance along the supply chain, as a guide to spreading understanding of Panasonic's objectives and concerns to other organisations in the supply chain. The system will enable Panasonic to manage the various risks associated with future developments and product designs, including potential damage to reputation, the environment or society in addition to conventional financial risk.

Product Service Systems for Industrial Water Management as a new business strategy for companies

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Keywords: sustainable water management, product service systems (PSS), cost reduction

The situation for companies concerning their (waste) water costs is getting worse in the next years.
The high developed countries in the world use 59% of their water consumption for the industry. Water withdrawal for industrial use will increase by 50% till 2025. More demand means higher costs, especially in regions with a lack of availability.
The companies in the EU will also have to deal with the EU Water Framework Directive that came into effect in 2000. There have to be national action plans in every country in the EU till 2009. Three years later the actions have to be implemented in practise.
The two main principles of the EU Water Framework Directive concerning companies will be

- the cost covering principle for water supply and waste water treatment
- and the Cost-by-cause principle (incl. quantity and quality)

If you take a look at the structure of the companies in the EU you will see, that there exist more than 20 Mio. private companies with about 122 Mio. employess in the EU. More than 99% of these companies are SME´s (Small and Medium Enterprises) and they call their main problem a missing in-house competence and no chance to get highly qualified workers.
These companies will have to deal with higher prices for water supply and waste water treatment and will not be able to provide adequate hardware to reduce the quality and/or quantity of their waste water.

Product Service Systems can be a possible solution for companies dealing with these future problems or with already existing high costs in their water management.
Reduced to its basic meaning Product Service Systems mean substitution of a product with a service aiming at a Win-Win situation for all parties. An example for this is car-sharing. A service company provides the service movement instead of selling a vehicle.

Benefits for the costumer are besides a concentration on its core-business (water treatment is not the core business of most companies at all, its just an annoying duty), operation costs instead of investment costs, the offering of an optimized solution for each client and comfortable “one-stop-shopping” with a single partner. Benefits for the service providing company are a long-term costumer loyalty beyond the “point-of-sale”, the development of new markets and the added value of non-saleable in-house know-how.

In the case of Product Service Systems for water in the industry this means that possible services can be the water supply, cooling, process water treatment or waste water treatment with all kind of combinations.
There can be a single service-provider or a group, starting with a water supply company, a technology manufacturer (i.e. a membrane production company), consulting enterprises and process/waste water treatment firm.

The more companies combined in a service providing unit the harder the negotiations will be because each company wants to maximise its profit and sees its field of interest in different areas, i.e. cooling and waste water treatment.
The solution is that each part of the unit has to have his own field of activity with clearly cut interfaces, where it has the leadership and possesses its major knowledge.
The definition of possible interfaces will be presented in the contribution. It will cover experiences during the project “Product Service Systems for water” in Austria and will reveal possible inner-unit problems of the different companies and its solutions. Further more, it will deal will questions of the service-provider and the client (producing enterprise).
You will see, that the two major problems concerning producing enterprises are a lack of knowledge combined with an overestimation of their own know-how and a lack of information.

The information presented is based on a questionnaire in 358 Austrian companies and 91 communal decision makers. Further interviews with companies and communal decision makers were carried out and a series of 4 work-shops with participants from

- water supply companies
- waste water treatment companies
- technology providers
- consultants
- financing organisations
- juridical support and
- producing enterprises

was organized, with the two goals:

1. identifying a possible way of organizing such a service-providing-unit and
2. how to implement a product service system for water in a producing company

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From Fossil Resources to Renewable Resources as Raw Materials for Chemical Products: Impact Analysis in the Supply Chain

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Sustainable development becomes a key issue for organisations as they should progressively include this dimension in their future evolution. This is typically a problem where a systemic approach has to be considered. The organisation is not an island and its efforts to develop environment-friendly products and processes must take into account the complex network in which it is embedded. Especially relationships with suppliers and customers will have a deep impact on the organisation's environmental strategy. All actors in the supply chain provide the organisation with pressures and incentives that will help or block its environmental gait [2]. Adopting a systemic view where power relationships and potential synergies are understood is the only way to build a coherent sustainable supply chain demonstrating responsiveness towards an increasing environmental awareness of the consumer and, sooner or later, new environmental regulations.

Such a systemic approach was already chosen for the building of "industrial ecosystems" or "industrial symbiosis" in Scandinavian countries [1]. These networks where regional firms collaborate in order to optimise resource management are built following a global analysis of material and energetic inputs and outputs. This analysis will allow to discover and implement possible co-production, cascade use of by-products, energy sharing, etc. This approach can be linked to the "Life Cycle Assessment" methodology used to ensure the sustainability of products and processes all along the supply chain.

For our research work, we are interested at a particular problem: the replacement of fossil resources by renewable resources as raw materials for the chemical industry. Here also, the objective is to optimise the use of resources, considering the increasing scarcity of fossil resources. For our empirical analysis, we have focused our study on the production of two materials: surfactants, which are the main component of shampoos and detergents, and polymers, which give, for instance, packing plastic films. Considering these materials, we have analysed all actors intervening in the supply chain: farmers, transformers, producers, distributors and consumers. In order to propose some tracks for new environmental policies in this particular case of renewable materials, we have tried to understand the inputs and outputs at each stage of the supply chain, the obstacles and incentives to such a change for each actor, the location of decision power to catalyse the change and the fitness of the "industrial ecosystem" and "Life Cycle Assessment" framework.

This paper gives some of the results that we have obtained through our empirical study and makes preliminary proposals for the implementation of supply chains integrating the environmental dimension from the raw material producer up to the consumer.

This research work is part of a project realised under the auspices of the Belgian Federal Scientific Policy Services (PADD II programme).

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Product Service Systems-Selling Functions or Desires

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Product Service Systems (PSS) is a new concept for sustainability. By selling the function and not the product sustainability gains can be made. The assumption is that the environmental impact will be reduced with PSS such as:

- Product life extension services
- Product use services
- Result services

Another assumption is that companies will design more robust and long living products if they sell just the function that the product provides but keep the ownership. Electrolux has made tests with selling not washing machines but washes. The user paid a sum for each washing cycle and the washing machine was owned by the company. Rank Xerox is a well known example where the user just pay per copy. Another successful example is ITT Flygt selling m3/sec from their pumps.

However one can doubt if consumers really buy functions. The role of the designer has changed from fulfilling need to stimulate desires. The basic function is more of a constraint that must be there to legalise the product but secondary properties defining HOW the function is "delivered", are the important factors for purchase. The product carries the function but today very often the actual carrier is more interesting than the carried function.

Selling functions B2B is quite another story. In this case the functional sale offers a possibility to calculate on costs and usability but in this case the defining of the function is essential. The Functional Unit (FU) as defined in Life Cycle Assessment (LCA) is very strategic. If we can define the FU such as copies/s or m3/sec it works but when the quality of delivery is at stake it is different. Something that is experienced when public service transportation or medical care is outsourced. The quality of the delivery is then what is perceived not the strict main function.

This paper will try to define the relation between the function and the carrier as well as our willingness to share products/functions and put light on the basic fundament of functional sales.

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Session B:
Scenario methods in IE

Chairmen: A. Horvath

Location: Lindstedtsvägen 5
Room: D3.

Modelling Industrial Ecology Futures Scenarios: The Nature of the Design Approach

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The definition and role of industrial ecology is becoming increasingly sophisticated. Articulating analogies to and interactions with ecological systems demands modelling frameworks that yield powerful insights. Scenario development methods are seen to be central to improving the human-machine interaction to provide deep interpretation of the abstracted reality and the evaluation of futures that have a basis in physical accounting. Methods to consider futures scenarios within Industrial Ecology have not been explicitly developed. Defining different scenario-modelling frameworks allows us to compare the extent to which these approaches address sustainability outcomes. This paper specifies requirements in assessing scenario- macro modelling frameworks in Industrial Ecology futures studies.

The Design Approach has the potential to address a number of concerns on the appropriateness of modelling and scenario development methods in futures studies (Hoejer and Mattson, 2000; Aligica, 2003). The Design Approach method is contrasted with approaches of optimisation and closed-loop simulation. In addition to using design information to construct models for simulation, alternative futures are designed through repeated simulation. Key tenets of the Design Approach are: the formation of futures based on physically feasible relations, according to known constraints of existing stock-flow relationships and levels; the separation of decisions from actions and thus separate the human- machine space so that behavioural assumptions are made transparent; an open loop system without behavioural feedbacks, where disequilibria are exposed; and the consideration of a scenario management system so that the user can be actively engaged in system learning (Gault, Hamilton et al., 1987). This last aspect facilitates complex scenario narrative development. By articulating the significance of these characteristics, it is our intention to demonstrate the potential contributions of the Design Approach in assessing meso/macro Industrial Ecology futures.

Industrial Ecology paradigms can be distinguished by sustainability concepts of economic-ecological interaction, space and time causation, and approaches to addressing the uncertain nature of the future. Models can consider nature as a stock to exploit, nature with a limited carrying capacity, or nature as a model with which the anthroposphere is intertwined (Isenmann, 2003). There are levels of system causal identification, the most complex being morphogenic (Maruyama, 1991). Uncertainty of physical and socio-economic relations requires a cautious approach to empiricism. From this discussion certain modelling requirements and pitfalls can be recognized in current Industrial Ecology practice at the meso/macro scale. Methods in formulating Industrial Ecology futures must consider approaches to model parameterization, the linking of spatial and dynamic scales, and the interaction of the user.

Scenarios represent the use of models. We investigate the nature of four broad scenario purposes: Normative, Explanatory, Exploratory and Comparative (van Notten, Rotmans et al. 2003). There are various approaches in scenario narrative development applied to modelling. How a model is employed to generate scenarios may be defined as either optimization, simulation or envelope analysis. Optimisation determines the trajectory direction to a desired end point. Simulation considers conditional predictions of possible trajectories. Envelope analysis considers a window of feasible pathways. We illustrate model- scenario interaction with reference to a range of meso/macro industrial ecology studies.

A number of investigations using the Design Approach are presented. The CSIRO owned Australian Stocks and Flows Framework (ASFF), based on the *What If* platform by Robbert Associates has been applied to several issues. These include: resource dilemmas associated with population growth (Poldy and Foran, 2002); assessment of land and water futures (Dunlop, Turner, et al., 2002); and freshwater and marine fish stocks (Kearney, Foran et al., 2003). Another use of the *What If* platform was by the Waterloo Municipality in Canada to assess land use implications of growth in the built environment. We compare a case study of transportation systems using ASFF with other simulation approaches in transport planning scenarios. These studies describe practice in futures studies and can act as a guide for defining requirements in developing Industrial Ecology Futures for simulation frameworks.

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A Classification of Scenario Methods - Useful for the Expansion of Tools of Industrial Ecology

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A sustainable future is the overall aim for the field of Industrial Ecology (IE). One part of the field consists of analytical and procedural tools for the assessment of environmental and economic aspects within corporate and public work at all levels. Examples of these tools are Life Cycle Assessment (LCA), Strategic Environmental Assessment (SEA), Environmental Management Systems (EMS) and Cost-Benefit Analysis (CBA).

One major application of the tools is to support decision-making. Since all decisions affect the future, assumptions about the future are, if not explicitly expressed, an implicit component in the analyses. Particularly in studies supporting long-term decisions there is a need for explicitly stated information about the future, which is the case for studies supporting decisions with implications on the long-term target sustainability. To reach a sustainable future, conscious decision-making enlightening the implications for sustainability will be required. Incorporation of scenario methods in IE tools might enhance the capability of the tools to support this kind of forward looking decision making, providing information originating in another field of research. In the discussion surrounding development of the tools a need of incorporating some kind of study of the future has already been recognised, see e.g. Finnveden et. al. [1] for the case of SEA.

In a paper we have elaborated a typology of scenarios and a typology of scenario techniques, which is the term used for designating practical methods and procedures for scenario development, from the point of view of a user of scenario studies. The aim is to give some guidelines on which scenario type is appropriate for what purpose and also which scenario techniques are appropriate for the development of the scenario types. One application is when the user of the scenario study wants to develop other fields of research, as is the case when combining scenario methods with tools used in IE. A user could be someone with the intention to carry out or order a scenario study, or someone just interested in utilising an existing scenario study.

The scenario types are classified according to questions that would be relevant for a user to pose about the future. The scenario techniques are classified according to how they contribute to scenario generation.

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Backcasting and Indicators for a Sustainable Society

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There are two different approaches for the environmental work at companies. The traditional approach is still that the environmental work is driven mainly by authority requirements, which limit the core activities of the company. The second approach is based on the insight that sustainable development in a substantial way will change the conditions of the market and that an early insight of this can imply market advantages and business possibilities.

A *backcasting model* can be used at a company that follows the second approach to succeed in their strategic planning towards a sustainable society. A suggested backcasting model includes four steps [1], see Figure 1, which at a company level can be described as:
1) a broad and well structured picture of the future demands on a business in a sustainable society,
2) an analysis of the present business based on such future demands,
3) an analysis, and creative exercise, of future business possibilities based on the prerequisites of the present business and future demands,
4) a strategic planning for the fulfilment of these possibilities.

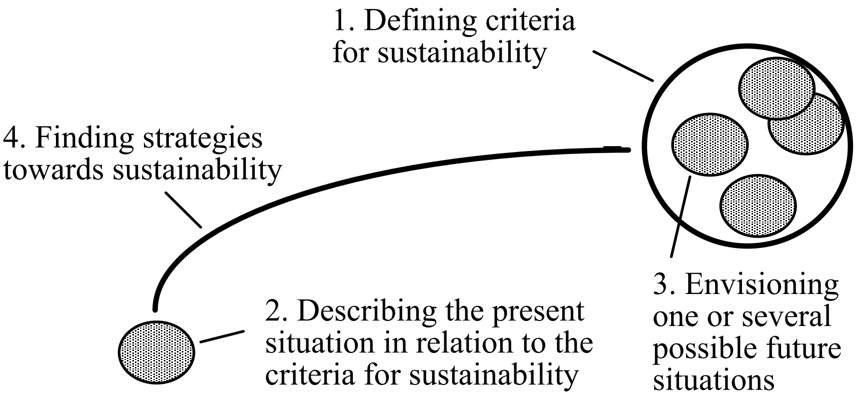

Figure 1 The steps in a backcasting model for a strategic planning towards sustainability [1].

Principles for sustainability that describe the demands of a sustainable use of resources can be used in the first step [2,3,4]. Indicators for sustainability can be used in the second step to analyse the present state and the development of a company [5,6]. Strategies for dematerialisation and transmaterialisation can be used in step four [7].

The large difference between backcasting and traditional *forecasting* is that forecasting is based on the present situation and trends while backcasting is based on future demands and possibilities. The application of backcasting in the strategic planning at a company can facilitate to see new possibilities at an early stage and to avoid lock-in effects [8]. There are also other scenario models somewhere between forecasting and backcasting, for example, the scenario model that has been used by Shell [9].

Backcasting has been applied at companies in some case studies. The next step is to implement backcasting at companies and to integrate backcasting in the processes for strategic planning and product development already at use within companies.

The objective of this project is to further develop the backcasting model in the context of sustainable development and to present recommendations for the process of implementation of the model at companies. The objective is also to present a structure for the development of sustainability indicators at a company level.

The project is performed in close collaboration between researchers at Chalmers University of Technology and some larger companies: ABB, IKEA, and SCA, connected to the Centre for Environmental Assessment of Product and Material Systems (CPM) at Chalmers. The researchers knowledge on sustainability and model methodology is combined with the companies' practical experience and creativity. The backcasting model is applied in different case studies at the companies. General characteristics are identified in the different cases, and it is identified how the backcasting model affect the innovation process and strategy processes. The case studies are supervised by the researchers, there are regular meetings with the researchers and companies, and the researchers also perform interviews at the companies. This type of research can be classified as *action research* when researchers both follow and to some extent affect strategy processes under development, but also contribute with evaluation and reflection processes to collect knowledge that otherwise risk to get lost in the daily work within companies.

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Scenario analysis of the UK clothing and textiles sector

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Despite many years of discussion of sustainable production systems, most work on the measurement of incremental changes in existing systems, or in the design of policies to make 'external' costs internal. There is a significant shortage of work on practical implementation of changes which would lead to greatly improved environmental performance of production systems and on the requirements of the production technology that would allow them to be commercially feasible.

In order to examine the effects of changes in supply chain structure on the sustainability of an industrial sector, a major study of the UK clothing and textiles sector is being undertaken. This paper will give an interim report on the project, describe the methodology being developed and give preliminary results.

A materials flow analysis of the Clothing and Textiles sector in the UK is being completed to give a primary data set. However, 80% of the clothing bought in the UK is produced in other countries, and the clothing and textile sector has global environmental consequences. So, the UK data set is augmented by estimates of global impact derived from published sources. In addition to the collection and analysis of data on material flows, further data on costs, energy consumption and other environmental burdens will be gathered in detail for the UK, and estimated for components of the supply chain outside the UK. This comprehensive data set is used to form a simple model for the prediction of cost and environmental impact of the entire supply chain.

The existing supply chain for clothing and textiles is largely global, with obvious concentration in Asia. However, numerous other supply chain structures exist to serve niche or local markets, including local supply of clothing in India, and the development of fast response structures in Spain by Zara. Similarly, while cotton is the dominant material for UK clothing, other fibres could be used, and less intensive sources of material could be considered. While recycling of clothing is currently limited, future technologies may facilitate material re-use, and this also suggests different supply chain structuring. A range of alternative structures for the sector are therefore determined, by analogy with existing systems, by examination of other sectors and by fundamental analysis of the sources of major impacts.

The model based on the data set is used to predict the environmental and economic consequences of these alternative scenarios. Some scenarios with improved environmental performance prove to be more costly. The evaluation of the different scenarios is therefore performed in parallel with examination of the technologies of clothing and textiles production and re-processing. This will allows identification of feasible short term changes, and allows specifications of technologies and materials required in future to allow significant reduction in the environmental burden of the sector while retaining competitive profitability.

Session C:
Environmental Management

Chairmen: B. Frostell

Location: Lindstedtsvägen 17
Room: D1

From Cleaner Production to Advanced Product Development Strategies– a Business Success Story

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Industrial Ecology is still an unknown concept in most of industry. Only the most advanced companies know the term and can give an explanation about what it means to them. However, most companies have an understanding about what environmental consciousness mean, and when you start talking about environmental management and how to benefit from environmental strategies most companies looks at this as very important in a global market. In Norway we see that many small and medium sized enterprises have problems with taking theses challenges into account, especially since they have limited personal resources to deal with these aspects. For them it is important to have support from experts who can guide them through the jungle of different environmental management standards and help them to implement the right ting at the right time.

This paper will present how a group of small companies have been taught about the different aspects of industrial ecology and how they gradually have implemented environmental management systems from simple “Cleaner production” projects, to environmental management and internal accounting systems, reporting practice, environmental conscious product development, LCA, environmental product declarations and finally is the leading company in the development an advanced modulus product development tool where also economic and quality aspects are included. The presentation will finally sum up with the lessons learnt and the benefit for the company and its influence on the triple bottom line.

Dioxins Flows in the NY/NJ Harbor Watershed: Challenges and Opportunities

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The New York Academy of Sciences has undertaken a study to identify pollution prevention (P2) strategies for five contaminants (mercury, cadmium, PCBs, dioxins, and PAHs) entering the NY/NJ Harbor. This study uses the tools of industrial ecology, mass balance, and economic analyses to identify P2 strategies that will have the greatest environmental impact and that are economically feasible. P2 strategies for the first two contaminants are completed and the final reports are available on the New York Academy of Sciences website at: http://www.nyas.org/programs/harbor.asp. The overall scientific and policy implications of the Harbor Project will be described in a separate talk ("Policy Cases: developing pollution prevention (P2) strategies for the New York - New Jersey Harbor"). This presentation will focus on the strategies and process we have undertaken to address ongoing dioxin inputs into the New York/ New Jersey Harbor from ongoing and historic sources.

As this study has moved forward to study the last three toxicants (PCBs, dioxins and PAHs), data availability has become a much greater obstacle to quantifying flows of these contaminants through the watershed. Dioxins and most PAHs were never produced intentionally and therefore have no economic value. These pollutants are expensive and difficult to measure, are long lived, bind to particles, and are ubiquitous in the environment. Although the track down of these compounds shares some similarities, each of them presents unique challenges.

Dioxins are unintended by-products mainly from processes involving combustion. As measures to reduce or eliminate industrial dioxin emissions are being taken, other sources become more relevant. For instance, open burning and accidental fires, which are far more difficult to control than industrial sources, not only may become the largest dioxin sources to air, but also its impact may be magnified if emissions occur in the vicinity of agricultural areas. Dioxins are commonly cited in fish and shellfish consumption advisories in the region and can be the cause for dredged materials to fail clean-sediment tests. Although most dioxin compounds have relatively low volatilities at ambient temperatures, volatilization also plays a larger role in the redistribution of these contaminants than originally considered and makes modeling the system much more difficult.

Dioxins provide an interesting case study because the major source of the current dioxin levels in the Harbor is a Superfund site on the shores of the Harbor. The redistribution of the dioxin compounds from a chemical manufacturing facility has shed some light on the sediment hydrology of the Harbor system and drawn attention to the need to understand the physical characteristics of the Harbor in order to respond in a timely fashion to contamination before it spreads. Furthermore, remobilization of dioxins from reservoir sources, and recycling through the food supply (e.g. via animal feed) may have direct implications for human exposure.

These challenges will be described, as well as the recommendations to stem the ongoing flow of these contaminants to the New York/New Jersey Harbor. The impacts on the communities around the superfund site and their relationship to the Harbor will also be discussed. We will also put our findings in the larger context of national and international efforts to address these contaminants.

The environment as an opportunity to stimulate regional development – the case of Nakskov

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A positive image of a city and a region may attract people, tourists and investors. Many cities are today struggling with "image problems". These may be connected with an industrial past, poor housing, social problems, crime, or a poor environment. Several cities try to make use a green profiling for increasing their attraction. In a study on small and medium-sized cities in the Baltic Sea region (MECIBS) different examples of how cities are trying to use the environment to improve their image and stimulate economic and social development have been focussed. The most interesting case in this study is Nakskov in Southern Denmark. It is an old industrial harbour city, formerly dominated by a large shipyard, which closed in the 1980s. Nakskov is one of the poorest cities in Denmark with a chronically high unemployment. Since the late 1990s, the city has put increasing emphasis on a sustainable business strategy for attracting industrial investments. Through the opening Vesta's windmill plant in 1999, Nakskov became a centre for environmental industry and this is further emphasized in the development of "the industry and environment park", Stensö, where new estates are offered for industry. The waste dump has been reshaped to a combined modern recycling station and concert arena, and there are several projects under way, e.g. biomass heating plant and an industrial symbiosis built around the water wastes and heat from a sugar plant. Besides enhancing the green profile of Nakskov, these projects have a potential to become strategic examples showing that environmental concern and flow management can be profitable and have several positive effects in relation to regional development. The municipal business development department plays a central role as creator of ideas, initiator, and negotiator with different partners. This example shows interesting experiences concerning commitment, creative thinking, flexible organisation and opportunism necessary for success of such strategies. It is still too early to evaluate the results of these efforts. The success of these initiatives is to a large extent dependent on broader development trends. During the 1990's, it seemed inevitable that environmental concern and ambitions would pay off, but in the last few years, it has seemed more risky to be an environmental forerunner. For Nakskov, the most evident success is perhaps that the activities have contributed to a new regional self-confidence and action capacity in sharp contrast to the passive pessimistic attitudes, which has dominated the region. However, it seems very important with concrete success to keep the ambitions, commitment and enthusiasm.

Session E:
Sustainable Transportation

Chairmen: E. Hertwich

Location: Lindstedtsvägen 5
Room: D2

Energy use and CO2- emissions from building, maintaining and using rail and road transport systems

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The transport sector generates a substantial share of society's environmental pressures caused by our society. Consequently, a lot of studies have been made regarding the contribution from different transport sectors. However, the bulk of these studies concerns only the transports and thus omits the environmental pressures from the material use needed to support these sectors, i.e. building and maintaining the infrastructure. Most of the studies regarding the transports come to the same conclusion that due to the reliance on fossil fuels in the road transport sector, railways are environmentally preferable. However, the few studies where the contribution from infrastructure is included suggest that the railway infrastructure is more material intensive and consequently also has a higher material related energy use than the road infrastructure.

This study uses a life cycle approach to investigate the energy use and CO_2-emissions from the long distance road- and railway transport systems in Sweden. Data were collected from literature sources and the results were aggregated to energy use per transport equivalent, i.e. passenger kilometer or tonne kilometer, to make a comparison between the two systems possible. To be able to perform the study several assumptions had to be made. These regards load factors for the vehicles, estimated life time for the infrastructure, choice of roads and railways to study, allocation of the share of infrastructure to passenger and freight traffic. Furthermore, certain system boundaries have been chose to limit the scope of the study. For instance, we have limited us to study the energy use for the pre-building and use phase and do not include after-use measures.

The relative importance of the infrastructure is larger for the railway since it uses more energy intensive materials. In Sweden the trains are mostly run by electricity from renewable energy sources while the cars and trucks use fossil fuels. Consequently, the CO_2- emissions from the railway system is still lower than for the road system if the trains are operated by electricity.

The results have strategic implications since the railway is assumed to have an environmental advantage against the road transports. However, if or when, the road transports starts its transition towards renewable fuels, the railway may very well loose this advantage if not similar improvements are made. The latter could include setting demands for the use of renewable energy in the production of infrastructure products. Furthermore, the diesel passenger trains that are quite common in the countryside of Sweden seem to be an unfavorable option compared to long distance buses.

Sustainability Developments of Transport over the Last Two Centuries

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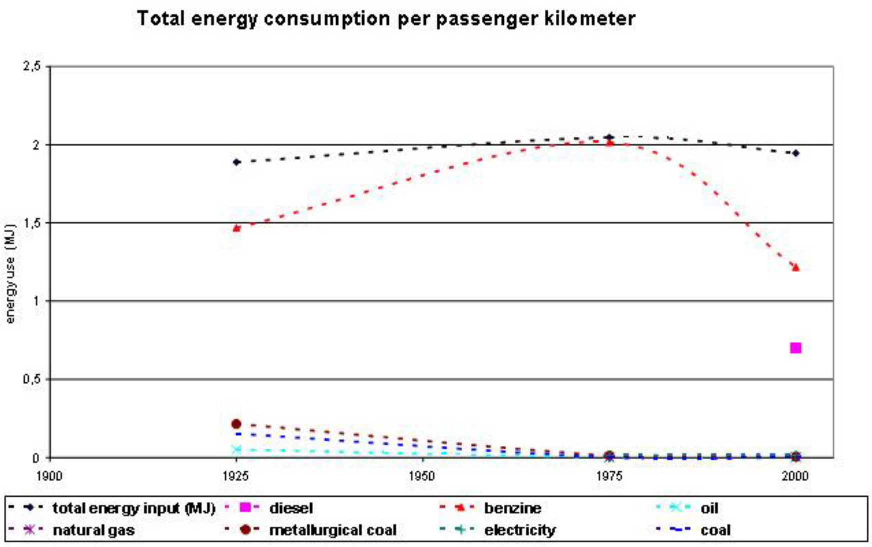
The interdisciplinary research project "(Un)sustainability developments of product systems, 1800-2000" is carried out by the History Department of the Free University of Brussels (VUB) and the Flemish Institute for Technological Research (Vito) and instructed and financed by the Belgian Federal Public Planning Service – Science Policy . For this project we do not want to start from today's situation to think of scenarios for future sustainable development, but we wish to gain insight into the process of (un)sustainable development during the past two centuries. The central point in the project is the research of the process of (un)sustainability development on a micro-level, and this for four products which can be considered as basic needs, being: bread, potable water, heated living space and transportation of people over land. We examine the environmental, social and economic aspects of these four products in the 'key-years' 1800-1850-1900-1950-1975 and 2000, using quantitative and qualitative analysis, in order to be able to interpret and steer recent and future developments. Both the production and consumption phases will be studied and related with one another. That way we will research the 'lifecycle' of a product, taking into account all the factors that can be of influence.

To quantify the environmental developments a LifeCycleAnalysis (LCA) is performed. LCA is a global analysis of the environmental cost, directly or indirectly produced by a product, a material, a process or by a system, during its whole lifecycle. LCA examines the integral environmental load from 'cradle to grave', taking into account every input (materials, energy use) and output (emissions, waste). The environmental data will be combined with several socio-economic factors. By combining environmental aspects and socio-economic indicators the 'total cost ' of these four product systems will be defined, now and during the past two centuries, in Belgium.

This abstract focuses on the sustainability developments of the transport case. In this case vehicles used for people transportation over land are considered, being on foot, by bicycle, by train, by car and by bus or tramway. The functional unit for the LCA is defined as "a human movement by land over 1 km". A mode of transportation is taken into account when it is actually used by a large part of the population. An exception is made for the car where the T-Ford is considered from 1925 onward, although, at that time, this was not a transportation system used by a large part of the population. We take it into account, because of its popularity and because it meant a real breakthrough in car production, and therefore in the production system of transportation modes. The following table gives an overview of the transportation modes that are relevant.

The life cycle assessment studies the following life cycle stages: the production (extraction, processing) of materials needed for making the vehicle, production of the vehicle in the factory, driving the vehicle, disposal of the vehicle (dumping, incineration, recycling).

At this moment, the environmental profile of a car over the reference years is calculated and will be discussed in this abstract. By the end of this year, the data inventory will be finalized and environmental profiles of all relevant transport modes are calculated. Based on these figures, the environmental profile of the combination of all relevant modes of transport can be drawn. The following figure shows the evolution of the energy requirements for the life cycle of a car.



In 1975 en 2000 more than 95% of the energy input is attributed to the fuel consumption of the car. In 1925 only 80% comes from fuel consumption, the remaining part is caused by the energy consumption for steel production which was significantly higher in 1925 than in the other years (and the share of steel in a car is also higher in 1925). It is remarkable that despite the decrease of the total energy input per vehicle kilometer, the total energy consumption per passenger kilometer (functional unit) is increasing over the years. This is due to the fact that the average seat occupancy is assumed to be higher in 1925 than in 2000 (3 versus 1.42). The fuel consumption per vehicle kilometer is, as expected, lower in 2000 compared to 1925.

The environmental aspects related to transportation over the last 2 centuries will be combined with socio-economical aspects over these years, like extent of the road network, accidents, real prices, share of transport in total expenditures. This allows us to draw general as well as more specific conclusions regarding the sustainability developments of transport by land between 1800 and 2000.

Reducing Freight Throughput in Cities: Potential Synergies Between Logistics and Network Infrastructure

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Freight transportation systems should be seen as driven by an integrated demand rather than simply a derived demand for goods (Hesse and Rodrigue, 2004; Nielsen, Jespersen et al., 2003). Integrated demand recognises that there are two flows in the freight task: the underlying material flow and the load unit (vehicle fleet) flow (Priemus and Konings, 2001). Load unit volumes are mediated by spatial relations, transport infrastructure and the traffic system. Consequently, the flow structure of freight is more difficult to forecast than passenger traffic. In Europe, supply chain and distribution logistics drivers have been mapped to operational freight indicators (SULOGTRA, 2002). Through our research review on freight modelling methods (Beavis, Black et al, 2005), there appears however to be no model that combines logistics drivers and network infrastructure to assess freight task outcomes, and our aim is to fill this gap.

This paper develops an analytical simulation technique to assess sustainability indicators of urban freight transportation. We consider both demand and supply aspects. The demand drivers in logistics trends lead to a unique flow structure within an urban area. Existing distribution and other transportation infrastructures engender mobility characteristics. Our sustainability objective is to assess the extent the dematerialisation of the freight task is feasible. This investigation focuses on network retrofit opportunities from logistics initiatives. An integrated analysis of logistics and infrastructure supply may lead to opportunities for transformation to an infrastructure system that considerably reduces throughput whilst maintaining function (AUSCID, 2003).

Analytical techniques to assess indicators of transport sustainability for practical planning and assessment remain poorly developed (Black, Paez, et al., 2002). The paucity of analysis is particularly evident in the field of freight transportation. Sustainable freight –network indicator interaction through hierarchy analysis remains unexplored. Given the complex nature of transportation services, particularly in an evolving, built-up system, an integrated framework of indicators is necessary (Federici, Ulgiati et al., 2003). Fischer-Kowalski (2001) has observed that in order to track dematerialization trends, a procedure of intra-system and inter-system dynamical analysis is required.

We assess the combined effect of logistics trends and network supply provision through the system dynamics software, Powersim™. Given the operational complexity of logistics and supply, linear causal modelling is not appropriate (Zografos and Giannouli, 2001). We present a number of hypothetical examples that explore the integration of logistics trends with nodes and links in a transportation network.

Finally, the results of the intra-systems simulation allow a set of technical narratives to be built for scenario generation in a macro setting. An inter-systems dynamical analysis allows us to assess more systemic vicious cycles, scrutinise nominal efficiency gains, and investigate system disequilibria. The Australian Stocks and Flows Framework of CSIRO utilises a Design Approach methodology based on bio-physical relations which engages the user in knowledge building through the accrual of scenarios (Turner, 2002). Longer-term sustainability concepts of redundancy and adaptivity of freight infrastructure as a system can be investigated through this macro- scenario approach. We explore possible coupling with this model.

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June 15.
Technical session T4

T4 AM

Session A: **Tools in IE**

Chairmen: A. Tukker

Location: Lindstedtsvägen 3
Room: E1.

Using the System of Environmental and Economic Accounts (SEEA) in Industrial Ecology

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In 1993, Statistics Sweden (SCB), the National Institute of Economic Research (NIER) and the Swedish Environmental Protection Agency (SEPA) were instructed by the Government to prepare a study covering the physical links between the economy, the environment and natural resources, the monetary reflection of these relations, and the state of the environment.

The environmental accounts at SCB are a system of physical accounts that are linked to the economic activities described in the national accounts. This system of environmental and natural resource statistics is linked to the industry, product and sector categories used in the national accounts, thus forming a satellite system of accounts.

The Swedish Government has called for a number of studies based on the accounting data. They have created national commissions on climate change, the Committee on Environmental Objectives, the committee for growth and environment, green taxes and Producer responsibility, all of which have commissioned analytical work relating the economy and the environment. These commissions are central to the Swedish process for identifying key policy issues and analysing strategies to resolve them. Thus the accounting data are feeding into high-visibility public debates about tax policy, climate change, environmental policy and economic growth.

The areas that receive most interest in Sweden at the moment are:

- Economic instruments: taxes and subsidies, green tax reforms
- Indicators: accounting as a basis for sustainability indicators, social issues
- Chemicals policy: chemical product indicators
- IO-analyses: decoupling & decomposition analysis
- Resource policy: water accounts on catchment/ water district basis
- Sectoral policy: households and Integrated product policy measured from the consumption side
- Modeling: trade emissions, long term economic survey, water accounts

Examples on results from studies made will be given. The data have been used by a variety of actors in Swedish society and has made new analyses possible, which could not be performed with earlier statistics. Future work will, together with refining of the methods to produce the data that is now in the system, be concentrated on getting more timely data and on refining the underlying factors behind the changes in environmental performance.

Weighting in LCA Based on Ecotaxes – Development of a Method and Experiences from Case Studies

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The weighting phase in Life Cycle Assessment (LCA) is and has always been a controversial issue, partly because this element requires the incorporation of social, political and ethical values. Values are not only involved when choosing weighting factors, but also in choosing which type of weighting method to use, and in the choice of whether to use a weighting method at all. Despite the controversies, weighting is widely used in practise. It is therefore important to critically review its methods and data. Evaluating weighting methods is difficult because the values involved are difficult to identify and evaluate. However, all weighting methods include some scientific parts, if we use a broad interpretation of the word science to include not only natural sciences but also social and behavioural sciences, economics, etc. These scientific parts can be evaluated and the value choices can be identified and clarified.

A large number of economic methods for valuing environmental impacts have been developed. There are also a number of different types of economic values that relate to the natural environment. For example, distinctions can be made between use and non-use values and these can be further subdivided. Different methods for valuing environmental impacts, capture different economic values. Different monetisation methods should therefore result in different results, and they do. If a monetisation method is used, the same method should therefore ideally be used to derive all economic values within the method.

In this paper we will present an approach for monetisation of environmental impacts which is based on the consistent use of ecotaxes in Sweden as a basis for the economic values. The idea behind this approach is that taxes and fees are expressions of the values society places on resource uses and emissions. An underlying assumption for this is that the decisions taken by policy-makers are reflecting societal values thus reflecting a positive view of representative democracy.

In the method a number of different ecotaxes are used. In many cases they can directly be used as valuation weighting factors, an example is the CO_2-tax that can be used as a valuation of CO_2-emissions. In some cases, a calculation has to be made in order to derive a weighting factor. An example of this is the tax on nitrogen fertilisers which can be recalculated to an emission of nitrogen which can be used as a weighting factor for nitrogen emissions. The valuation weighting factors can be connected to characterisation methods in the normal LCA practise.

Since there are more ecotaxes than impact categories, alternative weighting factors can be derived. These can be used as measures of the uncertainties in the societal valuations. We have therefore developed minimum and maximum sets of weighting factors.

The use of ecotaxes in Sweden as a basis for a weighting method was first developed by Jessica Johansson (1999) and the method was updated by Peter Eldh (2003). The method has been used in a number of case studies by us and others. The case studies include such diverse issues such as waste management systems, energy systems, agricultural systems and ammunition. In this paper we will describe the method and present results from some case studies.

We have often used the Ecotax method in parallel to other weighting methods such as the Ecoindicator and EPS methods and the results have been compared. Often the different methods tend to give similar results, but for different reasons. Compared to the other weighting methods, the Ecotax methods often highlights the toxicological impact categories. A tentative conclusion from the use of the Ecotax method is that they often tend to give results which are reflecting societal concerns.

The use of weighting methods is not only relevant for LCA but also for other tools for Indsutrial Ecology. The Ecotax method has also been used as a valuation method for Strategic Environmental Assessment (SEA), Cost-Benefit Analysis (CBA) and Life Cycle Costing (LCC). The applicability of the Ecotax method for different tools will be discussed.

Future-oriented Industrial Ecology Tools for Small and Medium Size Enterprises

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It is no secret that a high percentage of the costs and environmental burdens of products, processes and services are determined in early stages of design. Decisions made in early stages of process design often determine costs, social and environmental impacts for 20 years and more. During a long period of time very few possibilities for product and process improvements in running production systems exist.

So a wide range of methodologies and computer-based tools have been developed to support enterprises to improve products, services, and processes in a sustainable way. Life Cycle Assessment of products supplemented by life cycle costing aims at achieving a better understanding of all stages of environmental product life cycle and its social, economic and environmental impacts. Design-for-Environment tools have been developed to incorporate sustainability assessment directly in product design. Integrated into frameworks like Product Lifecycle Management, these approaches help to assess the economic, environmental and social impacts of products and services in early stages of product and process design.

Large enterprises in almost all industrial sectors have implemented environmental management systems and appropriate computer-based tools to face the challenges of Integrated Product Policy (IPP) and Corporate Responsibility. These tools allow for instance process engineers to collect the know-how of internal and external sources in models to provide a reliable decision-making support considering costs, social and environmental aspects.

Small and medium Size enterprises rarely make use of these instruments, because of lacking resources of time, money and because of the missing expertise and know-how about all processes influenced by their decisions in the supply-chain. In particular comprehensive life cycle assessments from the scratch overextend SMEs.

The presentation will introduce concepts and a preliminary version of a software tool for sustainability assessment in early stages of product and process design combining the methodologies of reference modeling with wizards that meet the special requirements of SME users: A tool with an easy to understand user-interface, meeting the user exactly in his decision situation. Reference models for a certain industrial sector fill the data gaps that exist in early stages of process design due to incomplete knowledge on the future production system. The first version of the sustainability assessment tool is developed for the sector biotechnology by ifu Hamburg GmbH in cooperation with several German partners like Wuppertal Institute and Dechema e.V. funded by the German Ministry of Research and Education (BMBF).

Symbiosis among Analytical Tools of Industrial Ecology
- The Case of MFA, IOA and LCA -

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There are a number of players (concepts, approaches, methods, and tools) in the field of industrial ecology. Each of them has their own background and has been contributing to the progress in industrial ecology. Considering that the "symbiosis" is one of the key concepts of industrial ecology, we may apply this useful concept to the industrial ecology research itself, by linking different tools so that they get mutual benefits. MFA (Material Flow Analysis/Accounting) and LCA (Life Cycle Assessment) are well known analytical tools for industrial ecology. IOA (Input-Output Analysis), which has its origin in economics and has long history of application to environmental issues, has recently emerged as another key tool for the industrial ecology. The case of these three tools can be a good example of symbiosis.

For example, the author and several other groups in Japan applied economic IOA to life cycle studies from the very beginning. More recently, so-called IO-LCA or hybrid LCA (IOA plus process analysis) became more popular within the mainstream of LCA research community. Economic IO tables are useful source of information to estimate physical material flows among industrial sectors. PIOT (Physical Input Output Tables) can be a common framework to link economic IO studies with MFA studies. Fig.1 shows a variety of MFAs in different scales and their linkages and IOA and LCA.

Theoretical similarities and dissimilarities among these tools have to be further investigated, but it will be more useful to put focus on their empirical aspects. Considering limited human and financial resources for data acquisition, a harmonized strategy for compilation of common database has to be carefully designed. Needless to say, it is even more important to direct these tools towards a common goal of industrial ecology studies.

Uncertainty Bounds for Metal Concentrations in Waste Wood

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It is a well-known fact that the presence of metals in consumer products and construction materials sooner or later causes substantial emissions to the biosphere. However, very little is known about the accuracy and precision of the presented estimates. Examination of already published reports shows that metal flows are normally presented without any measures of uncertainty and, if such measures are given, they are normally based on subjective judgment. Moreover, it can be difficult to analyse existing data sets by employing conventional statistical methods. The number of analysed samples can be very small, and it is not unusual that the underlying probability distributions are so heavy-tailed that the standard deviation is larger than the mean.

Here, we used data regarding heavy metals in waste wood to address the problem of computing uncertainty bounds for the mean concentration of metals in strongly heterogeneous materials. Because the observed concentrations can have a highly skewed distribution we paid special attention to lognormal models and how they performed in comparison to nonparametric approaches. Furthermore, we compared Bayesian statistical methods with conventional frequentistic approaches, and entirely data-driven resampling techniques.

The Bayesian statistical framework provides a general method of thinking about prior knowledge, observed data, and uncertainty. Probability is used as the fundamental measure of uncertainty, and Bayesian methods describe how a given personal belief, or any other prior knowledge, is modified when it is confronted with observed data. We demonstrated how expert knowledge about the median of a lognormal distribution of concentration values can be combined with observed data into a posterior distribution of the theoretical mean of the observed values. Furthermore, we showed how Bayesian hierarchical models can handle the fact that that wastes often exhibit a substantial variation between suppliers as well as deliveries from the same supplier. Several simulations studies were performed to illustrate how sensitive the Bayesian inference is to the choice of priors. As expected, we found that a relatively vague or non-informative prior is quickly overshadowed by observed data, whereas a more definitive prior can long influence essential features of the posterior distribution of the theoretical mean value that shall be estimated. In fact, the uncertainty bounds obtained by performing a Bayesian analysis with a non-informative prior were almost identical to the intervals obtained by computing conventional (frequentistic) confidence intervals for the mean of a lognormal distribution.

Resampling techniques, such as different variants of bootstrap methods, have many supporters because they can be applied without making any assumptions about the distribution of collected data. We showed that the choice of bootstrap technique can be crucial when observed data represent a highly skewed distribution. In particular, we found that so-called BC_a (accelerated bias-corrected) intervals are preferable when observed data contain outliers that represent unusual but correct observations.

Considering that all statistical methods and models we propose have been well published for more than a decade, it is relevant to ask why these tools are not yet used by scientists dealing with flows of metals and other fields in industrial ecology. Technical obstacles may be one explanation. Both the Bayesian inference and the bootstrap methods illustrated in this article require some kind of computer simulation and at least a minimum of programming skills. Furthermore, it is generally recognised that resampling techniques become inadequate when data are sparse, and that the choice of priors in a Bayesian inference can be a matter of discussion. However, none of these circumstances provides any strong arguments against a more systematic assessment of uncertainty. Hence, it is difficult to disregard that the lack of convincing case studies and good illustrative examples have been an important obstacle for widespread use of statistical methods to compute uncertainty bounds. This study aimed to reduce that obstacle.

Key Drivers of the E-waste Recycling System: Assessing and Modelling E-waste Processing in the Informal Sector in Delhi.

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The management and recycling of waste electrical and electronic equipment WEEE was assessed in the city of Delhi, India. In order to do this, the personal computer was defined as the tracer for which a model was designed. The model depicts the entire life cycle of the tracer, from production through sale and consumption - including reuse and refurbishment-, to the material recovery in the mainly informal recycling industry. The field work included interviews with the relevant stakeholders, transect walks and literature, which was followed by a software-supported material flow analysis (MFA) of the whole life cycle chain of the tracer item. In addition to the MFA, several economic aspects of the recycling system were investigated. The study revealed that the life span of a personal computer has considerable influence upon the system, most notably in the following two aspects: *(i)* a prolonged life span creates value by means of refurbishing and upgrading activities and *(ii)* it slows down the flow rate of the whole system. This is one of the simplest ways of preventing an uncontrolled increase in environmentally hazardous emissions by the recalling sector. The material recovery of the system is mainly driven by the precious metal content of personal computers. A first estimate showed that precious metal recovery contributes to over 80% of the personal computer materials' market value, despite the small quantity of them found in computers.

Embodied Energy and CO_2 of Construction Materials in U.S buildings rom Domestic and International Supply

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There are many complex issues about the concept of sustainability of building construction and materials. Immediate actions to address the environmental impacts of buildings and construction focus on the reduction of construction waste and the reduction of energy consumption in buildings. The construction industry is also an intense consumer of global natural resources particularly in the transportation stage as well as the processing stage of construction materials, the majority of which are very resource and energy intensive. These include: Steel, Aluminum, and Cement. These materials embody huge energy resources, which occur during the process of conversion from raw material to manufactured construction products.

The construction of new buildings requires energy, and the building materials themselves embody energy. Embodied energy is the energy consumed by all of the processes associated with the construction of a building, from the acquisition of natural resources to product transportation. This includes the mining and manufacturing of materials and equipment, the transport of the materials and the administrative functions. Embodied energy is a significant component of the lifecycle impact of a building. All these processes use energy. The distance that materials must be transported, and the intensive energy needed to prepare them for use in buildings, should be considered when choosing a material. The initial embodied energy in buildings represents the energy consumed in the acquisition of raw materials, their processing, manufacturing, transportation to the site, and construction. (See Fig. 1) As buildings become more energy efficient in the use phase the ratio of embodied energy to lifetime operating energy consumption becomes more significant.

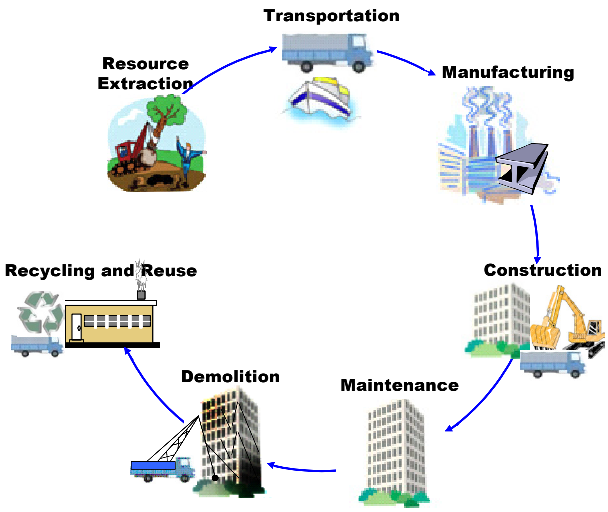

Fig. 1 Life Cycle of Building Materials

Table 1 shows that apparent consumption and imports of construction material commodities has increased steadily between 1995 and 2000 in the United States. Of the major materials, 30% of steel, 52% of aluminum, and 22% of cement were imported from the other countries.

Table 1 Apparent consumption and Imports of materials commodities in the United States (Unit: tons)

	Steel		Aluminum		Cement	
Year	Apparent consumption	Imports	Apparent consumption	Imports	Apparent consumption	Imports
1995	102,000,000	22,100,000	6,300,000	2,980,000	86,003,000	10,969,000
1996	108,000,000	26,500,000	6,610,000	2,810,000	90,355,000	11,565,000
1997	114,000,000	28,300,000	6,720,000	3,080,000	96,018,000	14,523,000
1998	118,000,000	37,700,000	7,090,000	3,550,000	103,457,000	19,878,000
1999	116,000,000	32,400,000	7,770,000	4,000,000	108,862,000	24,578,000
2000	120,000,000	34,400,000	7,530,000	3,910,000	110,470,000	24,561,000

Historical Statistics for Mineral and Material Commodities in the Unite States (2002)

A great deal of research has been done on embodied energy of construction materials. But, this research mostly does not consider the various supply methods such as domestic and international supply. So, the purpose of this research is to evaluate the embodied energy and CO_2 of construction materials in domestic and international supply, and to encourage reductions in embodied energy of construction materials. Also, in this study, we compared embodied energy and CO_2 of construction materials in South Korea with United States. For example, in case of steel, among the world's eight largest steel-producing nations, South Korea's steel industry is the most energy-efficient, using fewer than 20 gigajoules (GJ) per metric ton of steel in 1994 (the higher the energy intensity, the lower the energy efficiency of the industry). The U.S. stands at slightly over 25 GJ/metric ton (1994). In these two countries, many materials are exported and imported. For this reason, comparision of two countries' embodied energy and CO_2 of construction materials has many meanings.

The embodied energy and CO_2 assessment methods used in this research are as follows: Energy Input-Output analysis, which is a technique used in economics for tracing resources and products within an economy; a Statistical analysis method which is using method published statistics to determine energy use by particular industries, and Process analysis method, which involves the systematic examination of the direct and indirect energy inputs to a process. The analysis usually begins with the final production process and works backwards as the energy of each contributing material or energy input needs to be ascertained. Also, this research will perform a structure path analysis as an example to show how the model can be utilized for cleaner production and supply chain management, and a contribution analysis such as important direct input analysis and important direct primary energy analysis in life cycle system of each of the construction materials.

Keywords; Embodied energy, CO_2, Construction materials, Energy Input-Out Analysis, LCA

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Session B:
Waste Management

Chairmen: E. Kituyi

Location: Lindstedtsvägen 5
Room: D2.

About the Role of LCA in the Analytical Phase of SEA

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Strategic policy-level decisions can have considerable environmental impact. But in the nature of strategic decisions lies large uncertainties about how the strategy will be implemented. Probably much because of these uncertainties, potential environmental impacts tend to be assessed first when specific projects are being implemented, as is done in Environmental Impact Assessment (EIA). At this stage, the specific site and type of action (such as choice of technology) is known, making environmental assessments easier, but leaving little room to consider alternative strategies.

As a reaction to this, the concept of Strategic Environmental Assessment (SEA) is gaining in interest. SEA is a process tool, the main purpose of which is to facilitate early and systematic consideration of potential environmental impact in strategic decision-making. The growing significance of SEA as a form of support to decision-making is manifested by the recent EC directive (2001/42/EC) on the assessment of environmental effects of certain plans and programmes. The directive is explicitly based on a view to promoting sustainable development.

The adoption of this directive may be interpreted as an expression of increasing understanding of the principles of Industrial Ecology (IE), and a view that those principles can and should be incorporated in legislative procedures. While this is a promising development, the EC-directive gives little guidance as to how the environmental assessment should be performed. The analytical procedures of SEA need to be developed before it can become a truly powerful instrument.

SEA can and should apply several different types of analytical tools, in different combinations for different applications. Finnveden et al. (2003) have proposed a framework that integrates available tools of varying scope, both quantitative and qualitative. Some can be recognised as typical IE tools (e.g. life cycle assessment, ecological footprints), while others are of different origin (e.g. back casting, future studies, risk assessment). This "cross-breeding" of tools from different disciplines provides a good basis for comprehensive environmental assessments. The framework was tested by application to a specific case, that of introducing a proposed tax on incineration of wastes in Sweden (Björklund et al. 2003). This case has interventions not only on waste management, but also on the energy sector. By following different possible "routes" through the framework, using qualitative and quantitative tools for environmental analysis and evaluation, the strengths and weaknesses of different tools in relation to the type of strategy were evaluated.

One of the tools that were tested in the proposed SEA framework was life cycle assessment (LCA). LCA was originally developed for environmental assessment of products, usually with little site-specificity. In this case it was applied to a strategy concerning a technical system, with an attempt to include some degree of site-specificity in the impact assessment. This paper will present the results of the LCA of the proposed incineration tax and discuss the role of LCA in SEA. How can it contribute to the analytical phase of SEA and what can it not do? How can combination with other tools enhance its capabilities?

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Environmental Implications and Market Analysis of Soft Drink Packaging Systems in Mexico. A Waste Management Approach.

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This paper presents a waste management analysis of the packaging systems for soft drinks in Mexico, with emphasis on Polyethylene Terephtalate (PET) containers. The work presented is part of a project sponsored by a consortium of Mexican industries that participate in the PET market, such as resin producers, bottle manufacturers, soft drinks producers, distributors and plastic recyclers.

The PET bottle's market has increased substantially in the previous years due to its high resistance, light weight and adaptability to many bottle designs which constantly improve. As part of this work, a robust Simulation Model was developed to forecast the demand and collecting rates for PET bottles in the next five years. Results show that PET will continue to increase its market participation in the bottle sector at a significant rate. Due to this increase, there is some concern about the environmental implications of PET use and disposal, therefore a comparison between this and other packaging alternatives was carried out. In order to perform these evaluations, two different LCAs were elaborated with the purpose of providing insight on waste management scenarios and waste products comparisons, respectively.

The first LCA was a description of the actual PET market and PET waste treatment in Mexico. As part of this study a series of sensitivity analyses were conducted in order to understand: (i) the effect of different collecting distances in environmental impacts, (ii) the effect of different recycling rates in environmental impacts, (iii) the effect of different collecting rates in environmental impacts, and (iv) the effect of different collecting rates with it's associated distances in the environmental impacts.

An optimal degree of PET waste collection was identified as a result of considering different collecting rates and distances. At this point minimum environmental impact occurs. This is due to the excessive increase in environmental resources that is needed in order to collect higher amounts of waste by travelling longer distances. These results may pose significant implications on current environmental legislation and waste management policies in Mexico and can well be applied into other Latin-American and developing countries.

On the second LCA a series of results were generated for three systems: PET bottles, Aluminium cans and Glass bottles. Conditions at which one type of waste results more environmentally friendly were identified. Furthermore, the effect of geographical boundaries on the system were also studied and documented. Other results show that production processes represent the highest environmental impacts along the supply chain, which are considerably higher than those impacts related to transport and collecting activities. Because of this, the environmental advantages of waste management in Mexico can be significant as long as the material that is collected is also recycled.

In addition to the results mentioned above, this study also shows the different advantages and disadvantages that each material presents in terms of environmental issues. These advantages depend on the different packaging conditions (refillable or disposable bottles and disposable cans).

Two major barriers were encountered during the project. The first one was the fact that environmental, economic and social conditions in Mexico differ substantially from those in developed countries. This problem was resolved by analysing different scenarios taking into account Mexico's special characteristics. The second and major barrier during the process was the lack of data. There is no database that contains impact information about any industrial activity. In order to tackle this problem, dozens of interviews, plant visits and bibliographic researches were conducted during 14 months. Results to be presented include specific impact data on electricity generation and transport in Mexico.

This work can be used as a basis for decision making in environmental policy. Moreover, it provides technical grounds to demonstrate that under certain conditions traditional waste management systems may cause higher environmental impacts than the environmental benefit/credit that they are supposed to deliver.

The Movement of the World's Paper Industry to Recycled Fibre

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For it's first 100 years, the world's paper industry was primarily based on virgin fibre, primarily timber. While some paperboard grades have always been made of recycled fibre (for example in boxboard packaging), the large majority of pulp and paper products were mostly made harvested wood. For the last 30 years this situation has changed dramatically. The paper industry has gone from significant reliance on production in the northern highly forested regions, such as Canada and Scandinavia, to locating 100% recycled mills closer to major world's cities where both the recovered paper source and product use are.

This paper will cover the growth in the use of recycled fibre in the various paper making regions of the world: Europe, North/South America, Asia, and Africa. We will present the usage of virgin wood-based production versus recycled fibre over a 30-year time span. The fibre base contrast between the printing/writing grades, newsprint and the packaging grades will be analyzed. Asia's strong demand for recycled fibre based on its growth and lack of forest resources will be examined in the context of the demand for recovered paper from Europe and Asia (please see graph at the end of this abstract).

The presentation will then turn to the sources of this recycled fibre: what's been happening to paper recovery rates and recycling programs in the major world regions. Dramatic growth in recycling programs in both the residential and commercial/industrial sectors has been the norm for several decades now. We will project about the continuation of this trend and the future of recycling in the all-important Asia region.

Finally, we will examine a side of paper recycling production that is often overlooked – residuals generation. While the recycled fibre based production of the packaging grades is considered fairly efficient, by other manufacturing industry standards, it has significant yield losses. In the production of white printing/writing papers, yield losses can run an intolerable 35%! This is what hampers the production of high-recycled content copy papers. The close of the presentation will be the status of the management of these residuals: how much are produced and the disposal/recycle options that are being practiced.

An Operational, Logistic and Economic Analysis of Plastics Recyclate Pools.

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A quantitative analysis has been carried out of the performance required of plastics recyclate pools set up to "aggregate" waste polymers into quality-certified materials for secondary applications. The objective is to establish a framework against which the detailed requirements and operation of recyclate pools can be developed, covering both operational and logistical aspects. The operational aspects are described in terms of material inputs, degrees of segregation by polymer type and qualification by grade; qualification of post-use materials is essential to raise value as a secondary material. The logistical aspects are modelled to enable optimal siting of plastics recyclate pools. A specific case study is developed for an inner city area: the London Borough of Wandsworth. The case study leads to estimates of likely gate fees and their relationship to market prices for virgin and recycled materials.

Environmental and economic impact about material and energy recovery from past final disposal waste

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Introduction

Waste disposal with production and consumption activities finally results in an environmental emission while an appropriate treatment is made. In Japan, most of municipal wastes are incinerated after the recovery of some valuable materials from them and the incineration residue is mainly landfilled. Due to the geographical condition of Japan, the available area for the landfill site is very limited, and it is difficult to find new space for final disposal. Figure 1 shows the remained capacity of landfill site in Japan, indicating that it is important for us to reduce quantity of final disposal and to save existing final disposal space.However more conservation of landfill site seems to be difficult only in existing treatment. Under these background, "the Relandfill activity" is being promoted by material industries.(Fig.2) It implies the digging up of the landfilled wastes, the recovery of valuable material and energy resources and, thus, the reuse of the space as a new landfill site. The relandfill activity is actually examined in some prefectures of Japan. The landfilled wastes together with a municipal waste and an incineration ash are treated by the gasification-melting furnace system. This system

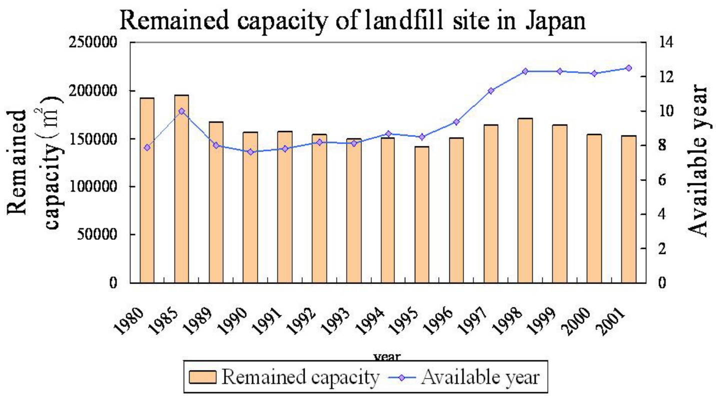

Fig.1: Remained capacity of landfill

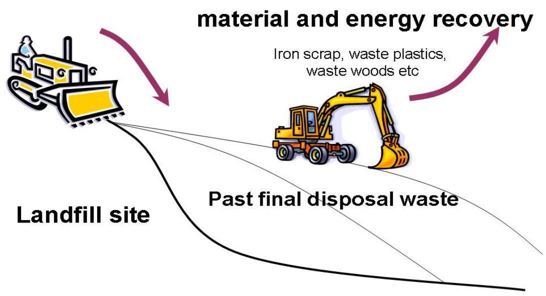

Fig.2: Material and energy recovery

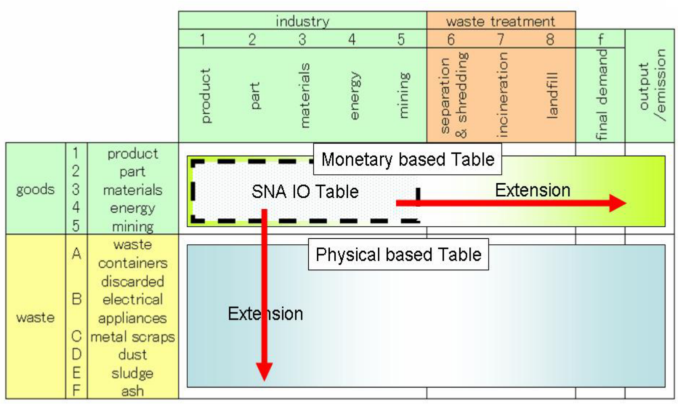

Fig.3: Waste Input-Output Table

enables to recover metals such as aluminium, copper and iron, other inorganic materials as the slag and energy included in the waste. In many method of environmental assessment by using input-output model, final disposal site is not considered to be an object of material recovery. The purpose of the present work is the development of methods to evaluate environmental burden and economic impact on the relandfill activity.

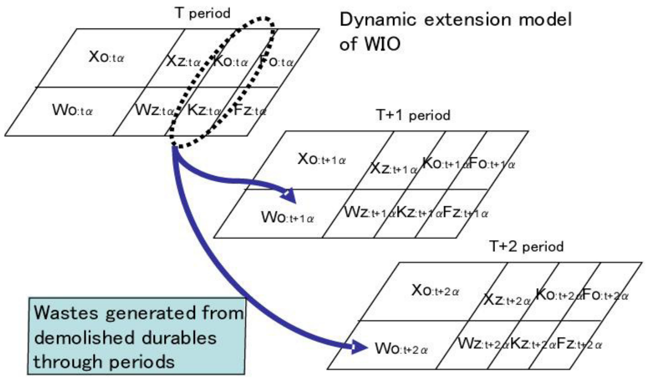

Fig.4: Dynamic extension of Waste Input-Output Table

Model

The model used in the present work mainly follows Waste Input-Output model(WIO). WIO, which has been developed by Nakamura(1999), is based on SNA input-output table and extended from the view point of material recycling, energy recovery and landfill site consumption. WIO table has the information of waste material flow between sectors, and describes mutual relationship between production sectors and waste treatment sectors(Fig.3). WIO is basically a static model but recently Yokoyama(2004) extended it dynamically.(Fig.4)

In order to consider material and energy recovery from landfill site, it is necessary to modify the definition of waste generation W_{ot} in WIO. In the present work, W_{ot} is defined as the sum of wastes with production activity, wastes generated from discarded durables and waste material recovered from landfill site. The landfill site consumption E_{lt} in environmental emission is defined as $E_{lt}=(E_{pt}+E_{rt})-E_{qt}$, where E_{qt} is the quantity of landfill waste dug up, E_{pt} is landfill consumption with production activity, and E_{rt} is landfill site consumption with material and energy recovery activity.

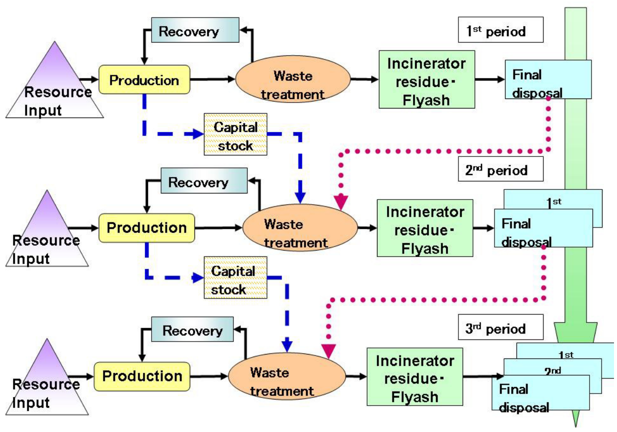

Fig.5: Material recovery from landfill model

Analysis

By using scenario analysis, the energy requirement for the relandfill activity and the life of remained landfill site capacity are evaluated. In the present work, three scenarios are taken into account. Scenario A is control, while all the municipal waste is received by gasification-melting furnace system, and relandfill activity is not assumed in scenario B. In scenario C, all the municipal waste is received by gasification-melting furnace system, and relandfill activity is assumed. A quantity of landfill waste which dug up is assumed as 5% of final disposal waste of a year, and it is assumed to be continued for ten years. In the summary of results, under scenario B, decreasing effects on the level of landfill volume were seen by 13.62% compared with Scenario A. Scenario C reduced landfill consumption by 17.13%.

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Applying the Socioeconomic Evaluation to Strategic Environmental Assessment of Municipal Solid Waste Management System

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Socioeconomic evaluation of environment was applied to strategic environmental assessment (SEA) of municipal solid waste (MSW) management system, and the system of recycling of plastics waste in blast furnaces was compared with that of incineration or direct landfilling of plastics waste in a holistic manner.

In a plan for MSW management, environmental impacts should be avoided as much as possible, but it is also important to think of amenity or disamenity for habitants.

Recycling of plastics waste in blast furnaces as replacement of coke has the advantage with respect to reduction of CO_2 emissions. When plastics are used as reducing agents, CO_2 emissions from blast furnaces are estimated at about two-thirds as much as those with coke as reducing agents, because hydrogen as well as carbon composing plastics works as reducing agents. In addition, CO_2 emissions in the process of making coke from coal are reduced.

On the other hand, recycling of plastics waste is more expensive than incineration or direct landfilling of plastics waste, and the system requires habitants to separate plastics waste at home. Decision-making process becomes more complex if air emissions other than GHG emissions and/or capacity of landfill site are taken into account.

It is desirable that various aspects of impacts be taken into account in a holistic manner and be weighted when alternatives are compared. Socioeconomic evaluation of environment is useful for this weighting. We proposed a new method using choice experiments, and applied this method to the MSW management system in Kawasaki City, on the south of Tokyo, Japan. The objective of this study is establishing a methodology for assessment of MSW management system through the application.

Three alternatives of MSW management system were assumed: (i) in the status quo, household wastes including combustibles, plastics, and incombustibles are collected and incinerated together, and energy is recovered as electricity, (ii) in the alternative I, plastics waste is separated at source (at home), collected separately from other wastes, and disposed of directly in the landfill site, whereas other wastes are incinerated, and (iii) in the alternative II, plastics waste is separated at source, and recycled as reducing agents in blast furnaces instead of coke, whereas other wastes are incinerated.

Environmental Impacts of the MSW management system in Kawasaki City, that is, the inventories such as air pollutants emissions, utility consumption, the amount of landfilling, and the cost for total system were estimated. Air pollutants include CO_2, CH_4, N_2O, SO_x, NO_x, and PM emissions. CO_2, CH_4, and N_2O emissions were integrated into greenhouse gases (GHG) emissions based on the global warming potential.

Some of the inventories were converted into impact categories. SO_x and NO_x, emission estimates were converted into human health damages in disability adjusted life year unit using damage functions. In each alternative, remaining landfill capacity was estimated using the amount of landfilling.

Questionnaire surveys were conducted in Kawasaki City using the framework of pair-wise conjoint analysis. Five attributes (health damages in loss of life expectancy unit, landfill capacity, CO_2 emissions, necessity of source separation of plastics waste, and the amount of payment) were included in each profile, and two profiles were presented in each question. Respondents were asked to state which they prefer and what extent. Through this procedure, weighting factors of health damage, landfill capacity, inconvenience of source separation of plastics waste, and payment were estimated.

Health damage, landfill capacity, and inconvenience of source separation were converted into monetary values using the weighting factors. In addition, social costs of GHG emissions and energy consumption were also estimated in a monetary unit using literature values. These five impact categories and the costs were aggregated into the single index, social benefits or costs, and the three alternatives were compared.

Intermodal Transport of Wastes and Recyclables in England and Wales – the 'STRAW' Project.

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Key words: Intermodal, Waste, Resources, Transport, BPEO, Life Cycle Analysis, Industrial Ecology, Eco-Industrial Parks, Systems, Clusters, Sustainable Waste Management, Synergies, Decision Support, Networks.

Aims

The paper will review developments in Intermodal Transport of Wastes and Recyclables, and present the outputs of a major research programmes, Sustainable Transport Resources and Waste (STRAW), funded by the Department of the Environment, Food and Rural Affairs (DEFRA), Biffaward, British Waterways, LaFarge, the Highways Agency and the Institution of Civil Engineers.

Methods

England and Wales faces a revolution in waste management practices in the coming decades as the demands of sustainable waste management policies drives the creation of a modern, integrated network of reprocessing, recycling, recovery and disposal facilities. The Sustainable Transport Resources and Waste Project (STRAW) offers the opportunity to think strategically about the scale and location of waste management infrastructure, while optimising transport of materials between facilities and regions using rail, inland waterways and coastal options. The challenge is the creation of a modern waste management and resource recovery system, effectively from 'scratch': the opportunity is to think creatively and strategically about how this system might be made as sustainable as possible. That is, how can this network of facilities be designed to optimise economies of scale in terms of facility location and scale and the intermodal transport of waste between these facilities.
The studies aim to integrate a range of converging concepts, including:-

- Regional Nodes;
- Environmental Technology Clusters;
- Industrial Ecology and Industrial Symbiosis; and
- Integrated Multi-Modal Transport.

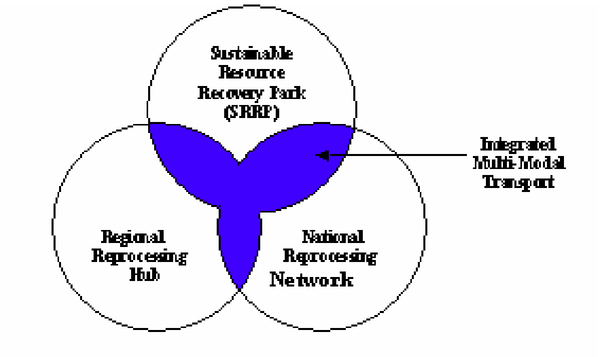

Figure 1. Schematic representation of the Project Concepts

In integrating the fields of Integrated Waste Management and Intermodal Transport, the project has identified the vital role of land use and spatial planning in encouraging a modal shift in the transport of wastes and recyclables.

Outputs of the Project

The outputs of the STRAW project will include:-

- A review of the current waste transportation and infrastructure;
- The projected waste and recovered material flows to 2020;
- Review of European and International Best Practice;
- Detailed regional scenarios, with applied Life-Cycle Assessment;
- Best Practice case studies and identification of barriers to wider implementation;
- Publication of Spatial Planning Guidance on waste infrastructure and intermodal transport; and
- Development of a GIS Decision Support Model for Intermodal Transport of Wastes.

Conclusions.

The challenges facing England and Wales in developing a modern integrated waste management system present the opportunity to assess flows of wastes and recyclables and develop synergies between infrastructure development, spatial planning and intermodal transport to highlight the opportunities presented by a strategic, systems approach to the development of a waste management and reprocessing network.

Dr Robin Curry, Project Director STRAW

STRAW www.straw.org.uk

Session C:
Eco-Industrial Parks and Networks

Chairmen: M. Cohen

Location: Lindstedtsvägen 17
Room: D1.

The Hinton Eco-Industrial Park – Integrating Ecology into Successful Eco- Industrial Park Design and Operation

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Natural ecosystems evolve over long periods of time to become reasonably stable and efficient. By applying an ecological approach to the design and operation of industrial parks, we can conserve natural resources, reduce production, raw material, treatment and energy costs, and improve operating efficiency, quality control and the health of surrounding ecosystems and populations[1].

An Eco-Industrial Park (EIP) represents the application of eco-industrial networking (EIN) within an industrial park. EIN is the application of the principles of industrial ecology, emphasizing systems, food chains, and life cycles to maximize resource efficiencies and minimize environmental impacts. EIN supports collaborative partnerships, or networks, between businesses, local governments, and the wider community resulting in more efficient and ecological resource use. In an EIP, businesses and their local government and community partners work together to incorporate the following features:

- ✓ Targeted economic development strategy: Businesses are attracted to fill product or service niches.
- ✓ By-product synergy: Businesses cycle material and energy (waste of one = feed for another), increasing efficiency and reducing environmental impact.
- ✓ Ecological design: Green buildings and sites are designed to minimize resource use. Green spaces and ecologically sensitive areas are preserved and integrated with the site design.
- ✓ Green infrastructure: Traditional infrastructure is replaced i.e., natural stormwater management or alternative energy systems.
- ✓ Networking around services: Businesses share services, such as marketing, transportation, research, and monitoring services.

Building on its success with the Hinton Government Centre, an energy-efficient, environmentally friendly, award–winning development, the Town of Hinton, Alberta, Canada is working to create a an EIP. The Park's strategy is based on three foundation principles: to be socially responsible, economically advantageous, and ecologically sensitive.

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[1] Côté, R. et al. 1994. *Designing and Operating Industrial Parks as Ecosystems*. Halifax, Nova Scotia: Dalhousie University, School for Resource and Environmental Studies.

The Conceptual Plan for Hinton's EIP was based on a thorough understanding of the site's community, industrial, and ecological context. Detailed community, industrial, and ecological profiles were completed which enabled the identification of EIN opportunities including suitable businesses and tenants, green energy systems, green buildings, ecological site design and green infrastructure. The Conceptual Plan was then developed, incorporating the EIN opportunities and integrating the profile information. Consultation with numerous stakeholder groups was completed as part of the profiling phase, and during the Conceptual Plan preparation. The Conceptual Plan included a Site Plan, which described the physical layout of the EIP, Business Plan, and Implementation Plan.

Unlike environmental site assessments, which often focus on the presence or absence of contamination, the ecological profile created for the Hinton EIP identified existing human and wildlife use; ecologically sensitive areas; rare plant and wildlife species; and other ecologically valuable features. Prior to site visits, aerial photos and existing documents and literature pertaining to the site were thoroughly reviewed and the surrounding area's vegetation and wildlife as well as ecological communities characteristic of the region were documented. Although this detailed overview of the EIP site has been prepared, further studies are necessary in order to accurately incorporate the ecological integrity of this natural site with the park design so that both function optimally. These studies should be completed before development proceeds.

This session will focus on the ecological profile and how it contributed to the development of the Hinton EIP Conceptual Plan. First, we will outline our ecological profile methods. Then we will detail how the ecological features of the site influenced the site layout, building and infrastructure designs and business development and marketing models. For example, a number of wildlife corridors have been included in the site design to preserve areas known as habitat for deer and elk. Also, natural wetlands were considered part of the stormwater management system, and provisions for constructed stormwater management and wastewater treatment wetlands were made.

We will also illustrate how ecological theory and principles have been incorporated in the planning process to create an efficient and environmentally friendly industrial ecosystem. For example we have planned for a diversity of businesses in terms of size and function, in order to create built-in resiliency in the 'ecosystem'.

Finally we will illustrate the social, environmental and economic benefits that can be generated by integrating the ecology into EIP design. In Hinton, the interpretive and recreational value of the site landscape will be maximized for area residents and Park workers through the creation of recreational walking trails, creating social and environmental benefits. Also, the Town will experience the economic benefit of green or sustainable municipal infrastructure on site (e.g. reduced costs of installation, operations and management).

Embedding Eco-Industrial Development in an Environmental Achievement and Recognition Program: Devens Eco Star

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Devens is a former army base located in North Central Massachusetts. It is comprised of 4400+/-Acres, of which only1800 acres are slated for development. The balance includes open space lands including 500 acres of grounds, an award winning sustainable certified golf course (Red Tail), land added on to the Oxbow National Wildlife Refuge and Mirror Lake. The Reuse Plan and redevelopment process placed a limit of 8.5 Million SF of redevelopment at Devens.

The base was selected for Base Realignment and Closure (BRAC) in 1991. As part of the screening process which occurs during base closure, federal agencies and homeless shelter providers screened the base; resulting in a Federal prison hospital, the Shriver Jobs Corps, Central Massachusetts Vietnam Veterans Assisted Housing and Sylvia's Haven (homeless women's shelter) locating at Devens. Redevelopment efforts to date have created 3000+/- jobs since 1996 when based was turned over to the State (Mass Development owns the property and the Devens Enterprise Commission or DEC serves as the permitting and regulatory authority for the redevelopment). Devens has approximately 4 Million SF of redevelopment at this date (July 2004) and utilizes a unique expedited permitting program (Unified Permit) to help maintain market niche. Devens is also listed as a Superfund Site, but is nearing the point where it will seek to be removed from the list, after years of successful remediation and clean up efforts.

Eco-Industrial Development at Devens:

What differentiates Devens from other sustainable developments is our commitment to eco-industrial development/industrial ecology. Eco-industrial development argues that a group of industries acting as part of a system will out perform an individual firm. This could look like one firm's waste stream being another firm's raw material source, or shared training and marketing endeavors. The DEC has conducted a number of baseline studies to assess the inputs and outputs of firms at Devens in order to assess by-product exchange potentials and has conducted on-going educational sessions about industrial ecology and eco-industrial development over the past five years. This has resulted in the development of an environmental achievement and branding program (EcoStar), which is being readied for launch in early 2005.

EcoStar was created to strengthen eco-industrial park concept; provide businesses with technical assistance; strengthen communications networks; create linkages among firms, and between the community and firms; and has as a goal to design a program that is both pro-business and pro-environment.

The program recognizes businesses that achieve ten core standards and five optional standards from a list of twenty five standards created by a steering committee comprised of business, community and environmental representatives. Once a firm is certified as an achiever, it may use the EcoStar logo on its products and services. Progress to date includes developing workbook using a standard template for each of the twenty-five standards. The workbook will be augmented by workshops intended to assist firms in achieving the standards. A workshop schedule has been agreed upon for 2005. The EcoStar logo was created in the Spring of 2003.The Steering Committee also developed a benefits package for participants and achievers. The committee's efforts to date have received funding from DEP and from Intel. A program brochure is being finalized, a kick-off event being planned for January 26, 2005.

For example, one standard actually developed contract language for ecological landscaping services requiring number of education contact hours about ecological landscaping and a plan from the contractor quantifying the lesser environmental impact resulting from this approach. The goal is to change the way landscapers deal with maintenance issues by making their practices more ecological. In this case, contracts are the vehicle for change.

The DEC and EcoStar are committed to evaluation. . Mr. Lowitt currently serves on the board of the Eco-Industrial Development Council. The EcoStar program is being touted internationally and has become the basis for a similar program run by the Industrial Estates Authority of Thailand. EcoStar and the DEC are committed to continuous environmental improvement.

At this point in time, our Sustainable Development programs such as EcoStar have reduced the mental distance between firms at Devens. Many of the firms now see themselves as part of a system of industries. While we have a small number of by-product exchanges but no major process exchanges have been created at this point. We will be concluding a solid waste master plan shortly which is examining providing collective waste disposal, by-product exchange facilitation, reuse/recycling services to all firms and residents at Devens, expandable to businesses in the region.

Industrial Symbiosis: Finding the Real Opportunities

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In the past few decades, there have been efforts to improve resource use efficiency through system wide linkages in many industrial areas. These are referred in the literature as "industrial symbiosis", "by-product synergy"," by-product exchange", "eco-industrial park", "eco-industrial network" or "industrial ecosystem". Depending on the system boundaries, specifics of the project, its management umbrella, or even the geographical location, the above expressions may vary but generally they are used interchangeably. There are many examples, Australian and international, and although each one is unique, responding to local circumstances and needs, these networks usually involve some material, by-product or waste exchange; cogeneration or energy from waste or other energy sharing infrastructure; some form of eco-industrial park management; shared emergency response, information access, environmental monitoring or employee training; shared supporting utilities (e.g. laboratories, storage); or even shared environmental staff.

Successful symbiotic relationships in industrial networks require an in-depth understanding of material and energy flows. The analysis of such inter-industry and inter-sector flows often poses significant challenges, due to the magnified complexity and number of potential network links and the greater distances involved, as compared to process optimisation within one operation. Physical and economical concepts are available to model the throughput of materials and energy in a region or economy, such as material and substance flow analysis, life-cycle assessment, physical input/output analysis, material product chain analysis, economic input/output models and others.

The Centre for Sustainable Resource Processing (CSRP) launched a research project on engineering tools and technologies for industrial symbiosis. The primary aim of the research is to develop tools to find realistic synergy opportunities from the often very complex resource flow diagrams of heavy industrial areas. The application of such area-wide eco-efficiency assessment tool would augment currently used synergy identification practices, such as inter-industry workshops and database matching of company inputs and wastes.
Review of existing engineering tools and methodologies for regional synergies development based on the available information is presented, featuring tools that

have been used in a number of eco-industrial projects in the last decade with different degrees of success.
Furthermore, a comparative review of international examples is presented with primary focus on heavy industrial areas. The 17 case studies selected cover variety of programs, research and consultancy projects, where at least one of the participating companies can be associated with the resource processing industry. The review focuses on the types of technological solutions implemented and the ways these have been identified and engineered.

These case studies have been compared and categorised based on the type of the network and the nature of the program or project as well as years of development. A comparative overview of the industries involved in eco-industrial projects, and existing as well as potential synergies is presented. The collection of these documented synergies will to become a starting point for further development of a database of typical/proven synergy options that could be useful in the process of synergy identification for emerging industrial symbiosis projects.

Drivers and barriers having implication to the identification and implementation of specific synergies between industrial partners are identified in a limited number of case studies. The primary driver behind the development of any industrial partnership is reported to be economics. Regulatory barriers toward implementation of synergies are identified in all of the individual reports as a major obstacle for progressing with viable synergies.
Throughout the available information applicable to the 17 industrial symbiosis examples, there is little indication of an engineering tool that has been specifically used for the generation of ideas for synergy opportunities. Many of the case studies have followed a similar methodology or a step-by-step approach that has resulted in a number of synergies.

The majority of the documented case studies have no emphasis on technologies needed for the implementation of the synergies. In some of the reports available technologies that were used are briefly mentioned, and only in two occasions the need for a specific and innovative technology is identified.

The outcomes of the industrial synergy projects review has confirmed the need for more systematic approach to integrated material and energy flow analysis in industrial areas, need for collaboration with local and state authorities to ease the burden of the regulatory constraints on reusable waste streams, and to assess the role that technology plays in developing viable inter-industry synergies.

Keywords: Input/output analysis, by-product synergy, industrial symbiosis

Note:

The research on engineering tools and technologies for regional synergies feeds into two Australian regional pilot projects with high concentration of mineral processing industries (Gladstone and Kwinana). It also runs in parallel with research into enabling mechanisms to facilitate inter-industry collaboration for industrial symbiosis.

Acknowledgements:

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Agent-based Model: A Tool for Defining Sustainable Eco-industrial Parks

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Both scientific and policy implications for a sustainable industrial park are obvious. However, how to define a sustainable industrial park is usually difficult and lack of common judgment. This is especially true because every agent within the industrial park may behave environmentally unfriendly by maximizing its economic return. In this paper, the agent theory is applied to analyze the newly developed eco-industrial parks (EIP) in China. First, based on the analysis of structure and functions of EIP, objective functions and indexes are developed to measure the environmental performance of the enterprises and EIP. Characteristics of enterprises, EIP and neighbor regions, as well as the multi-scale relationships between them will be qualitatively and quantitatively analyzed. Secondly, an agent-based model will be established to dynamically simulate the performance of enterprises and EIP under different scenarios. The simulation will also target the keynote nodes and determining factors that can be manipulated to achieve the maximum socio-economic and environmental benefits. Finally, an agent-based decision-making model will be developed to target the overall goal of EIP in terms of sustainable development. Suzhou Industrial Park will be taken as a case study to adopt, verify and modify the models developed above. Such a research will contribute to the micro-dynamics of industrial ecosystem on the one hand, and help the practice of EIP development in China on the other hand.

Keywords: agent-based Model; dynamic simulation; Eco-Industrial Park; regional sustainable development

Industrial Symbiosis: What Makes it Happen

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This paper presents the results of a global review of the current application of industrial symbiosis strategies in heavy industrial areas with high concentrations of minerals, metals, energy and chemicals production. The review forms the first part of a comprehensive research effort to foster the greater application of industrial symbiosis in Australian heavy industrial areas such as Kwinana (WA) and Gladstone (Qld). The research was initiated from the desire to better understand why applications of industrial symbiosis still appear to be comparatively scarce and patchy, despite the compelling logic of the industrial symbiosis concept.

The principal aim of the review was to assess the current contribution of industrial symbiosis to sustainable development (i.e. economic, environmental and social outcomes) at the local level and understand barriers and ways these have been addressed in the individual areas. The review attempted to identify mechanisms that have assisted industry to establish long-term material, energy and water exchange partnerships. A body of academic, environmental management and land development literature on industrial symbiosis is starting to form, (which may appear to some) to have come from limited field studies of industrial networking and partnerships, and a larger body of theory. This review could 'test' this literature against practical examples, and vice versa. The results will be used to assist industry to form long-term partnerships for the exchange of materials, water and energy, either as products by-products or waste.

Two complementary research methods were used for the baseline assessment:

- Review of scientific literature and other publications dealing with industrial symbiosis applied to heavy industrial areas. This review was broadly scoped to develop a comprehensive picture as to the current contribution to, and application of, industrial symbiosis to sustainable development.
- Survey of industry, government and other stakeholders in short-listed industrial areas and interviewing industry within the heavy industrial areas. The research identified and targeted twenty two industrial networks implementing industrial symbiosis or establishing Eco-Industrial Parks from fifteen countries. A detailed questionnaire was prepared for an in depth review of these areas, focussing on the underlying success or failure factors for industrial symbiosis in these areas. The questionnaire was accompanied by a short description of each area, and a list of current and potential exchanges within the area. The questionnaire was in three main sections: the

history and motivation for participation of individual businesses in industrial symbiosis and, in Eco-Industrial Park; benefits and arrangements on each ‘implemented’ synergy; and barriers and incentives for ‘potential’ synergies.

The literature review justified scoping of the research around three major categories of enabling mechanisms:

1. Facilitating structures: the networks and mechanisms that have been set up to facilitate collaboration and exchange between industries in the area, to better track and understand the collective area-wide resource flows (in particular energy, materials, waste, water, products and by-products), and encourage collective analysis and creative opportunity identification.
2. Operational and contractual arrangements: the way in which the costs, benefits and risks for the implementation of industrial symbiosis opportunities, involving multiple companies, have been shared between those participating companies, so that the necessary funding, technology and management skills were freed up to actually realise the opportunity. Possible types of arrangements are for instance: long-term take or pay contracts, performance based contracts, joint venture companies etc.
3. Evaluation methods: the manner by which environmental, social and economic impacts of synergies on the heavy industrial area were identified, measured and reported.

The literature review was also used to compile a sample of industrial symbiosis examples, covering North America, Europe, Asia and Oceania. The sample was constructed to achieve regional diversity, which leads into different socio-cultural, economic and legislative environments for industrial symbiosis, and targets heavy industrial areas, ie. those with maximum relevance for the Australian industry partners. Available information on each area was summarised using a standard semi-structured format. These draft case studies were circulated to industry, government and other stakeholders in the area, as a starting point for the detailed study.

The detailed survey sought to deepen the understanding of the management and evolution of the industrial symbiosis process, and collect detailed information on both ‘implemented’ and ‘potential’ synergies.

- The review of ‘implemented’ synergies served to consolidate data on achievements (economic, environmental and social) and understand where and how the three categories of enabling mechanisms were deployed. Facilitation turned out to be the common enabling mechanism, with varying models being used to provide this function.
- The review of potential synergies focused on barriers and enablers for their realisation. A common problem appears to be that the industrial symbiosis

efforts plateau upon successful implementation of few comparatively straightforward synergies ('low-hanging fruits'). As an illustration of this, the average number of synergies for the 22 networks was 10 implemented, 8 potential and under 'active' investigation and 57 'potential but not under active investigation'. It turned out to be difficult to ascertain on the basis of the survey exactly why potential synergies failed, either for technical reasons (no technical means available to realise the potential synergy, ie. the potential synergy is not a 'real' opportunity) and/or for organisational reasons (unable to obtain approval and/or finance to make it happen).

The review findings are currently being utilised to develop comprehensive web-accessible case studies for each industrial symbiosis network. Moreover the findings are also used to develop and trial innovative approaches in the three key enabling mechanisms currently identified; ie facilitation structure, organisational arrangements and evaluation tools.

Acknowledgements
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Environmental technology innovations and value creation processes in eco-industrial parks

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Over the last decade, the European Union, as well as some of its member states individually, have launched and supported initiatives towards eco-industrial development in the form of eco-industrial parks (EIP). These industrial systems of interconnected organizations have been initiated by different context-specific objectives and evolved into industrial areas with different structural characteristics as far as the nature, scale and form of relations among participating organizations are concerned.

Technology is one of the enablers of EIP and is a determinant factor of their level of economic and environmental performance. In such settings, technology plays an important role not only in the products and processes of the participant organisations, but also in the ways these organizations are interconnected and their residues are treated. Accordingly, environmental technologies that refer to the technological inputs required for either enhancing the environmental characteristics of products and processes *per se*, or for supporting compensating activities to reduce their environmental impact have been developed by a diverse range of technology providers. Overall, however, the question of whether their environmental benefits are accompanied by direct and/or indirect economic benefits is still to be answered. Much of this gap in research can be attributed to the lack of consistent frameworks for accomplishing their economic assessment beside their environmental one.

In addressing the above question, this paper attempts an assessment of the European environmental technology output from independent providers (universities, research laboratories, SMEs etc.) with respect to the value creation processes in eco-industrial parks. More specifically, it examines whether innovative environmental technologies target the value-creation resources of specific industrial sectors which are present in the different forms of eco-industrial park implementations.

Towards this end, after studying a number of existing EIP implementations in Europe, we have developed the *environmental strategic initiatives matrix*. This matrix provides an instrument for mapping and recording the impact of environmental technologies, concerning the inputs of the park, its processes and its products, to specific operational initiatives and improvements (e.g. to an initiative that results in a firm A to use the byproducts of firm B as inputs). Then, by building on the resource-based view of the firm, we have identified the generic strategic resources of ten industries which are frequently present in EIPs (ranging from energy production to food processing) and whose contribution to competitive advantage stems from technological innovation. These resources were distinguished as supply-side, transformational and demand-side to correspond with the input, process and product categories of the environmental strategic initiatives matrix. In this way, an environmental technology which addresses a specific area of initiatives that coincides with the area that provides the source of value creation for the industry is considered to contribute to the later, in addition to the improvement of environmental performance.

To assess the alignment of environmental technologies with the value creation innovations for the ten EIP-related industries, a database with more than five hundred cases of environmental technology innovations was built. The data has been extracted from two thousand five hundred technological innovations produced in thirty European countries for the period 2002-2004. The source of data was the national Innovation Relay Centers. The environmental strategic initiatives matrix and the resource framework were used to position each technological innovation in terms of environmental performance and industry value creation. Overall, a significant misalignment was observed indicating that a more coherent technological innovation strategy for supporting eco-industrial development is required at the European and national levels.

Evaluation of the Kitakyushu Eco-town Project based on Life Cycle Assessment and Environmental Accounting

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1. Outline of Kitakyushu Eco-town project

The Eco-town Project was created in fiscal 1997 under Japan's Ministry of Economy, Trade and Industry (METI) and the Ministry of Environment (MOE). It was founded on the basic concept of "zero-emissions." In essence, this concept is about ultimately reducing waste generation to zero, by taking the "waste" arising in citizen lifestyles and industrial activities, and utilizing it to the greatest extent possible as raw materials in other industries. The Eco-town project has two objectives: (1) to stimulate local economies by nurturing the growth of environmental industries that take advantage of the industrial capabilities in each region, and (2) to create integrated systems that are in harmony with the environment, and to involve industry, the public sector, and consumers, with the aim of creating a resource-recycling society in a given region. To date (spring of 2004) 19 areas in Japan have been approved by the government as Eco-town projects.

City of Kitakyushu prepared the Kitakyushu Eco-town Plan, with the stimulation of environmental and recycling industries as its main pillar, and it was approved by the national government in July 1997. The Kitakyushu Eco-town is consisted of three zones: the Comprehensive Environmental Industrial Complex, the Practical Research Area, and the Recycling Area.

2. Environmental evaluation of Kitakyushu Eco-town project by using material flow analysis (MFA), life cycle assessment (LCA), and environmental accounting (EA)

2.1 Overview

this study aims to construct a comprehensive assessment system that can inclusively measure increases/decreases in environmental load and understand its manifestation structure in order to quantitatively and fundamentally understand the relationship between a resource recycling policy and the resulting transitions in environmental load by linking the environmental accounting method with the LCA method and utilizing the features of both these methods.

First, material flow in the Kitakyushu Eco-town is examined. Statistical data issued publicly by individual enterprises and business organizations and data from the oral survey conducted for each enterprise are utilized in the calculation process. Based on the aforementioned data, material flow and the amount of material in each of three different economic section groups (Eco-town, within Kitakyushu and outside of Kitakyushu) are calculated.

Next, life cycle assessment is implementing for each recycling project of the individual enterprises located in the Eco-town area. This data is also based on publicly issued data and the data extracted from the questionnaires in the same fashion as the material flow calculation. As a result, environmental load and any increases/decreases caused by the recycling projects conducted by the enterprises in the Eco-town area are understood.

Finally, the data obtained from the methods described above is expressed utilizing the framework of the environmental accounting method. Even though the purpose of LCA is to provide information regarding the materials that are to be described in the environmental accounting table, this study utilizes this method to inclusively understand material flow, especially in the recycling projects, and to fully state the impact of these projects without the exclusion of any data.

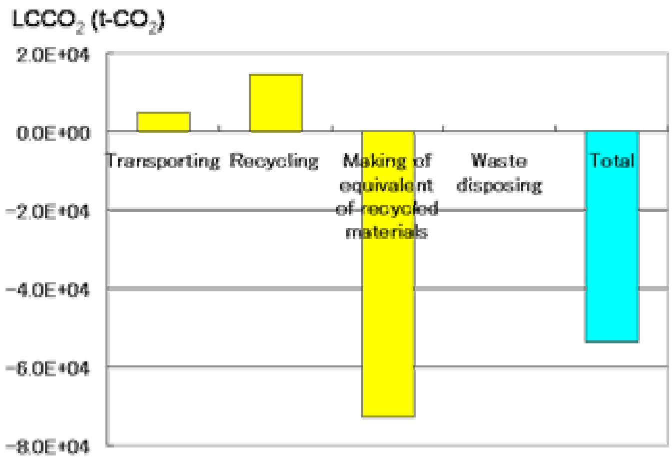
In this study, assessments are implemented on the fluorescent tube recycling business, the end-of-life vehicle (ELV) recycling business, PET bottle recycling business, OA equipments recycling business, used paper recycling business, cooking oil recycling business and organic solvent recycling business.

2.2 Results of MFA and LCA

Fig.1 shows the MFA results of accumulated data from seven enterprises and Fig.2 shows the LCA results. According to LCA, while energy of 2.2×105 GJ generated by the recycling activities is discharged, an energy reduction of 1.1×106 GJ by waste resource is seen and a reduction of 8.0×105 GJ by total recycling activities. For CO2, it can be assessed that there is a reduction of 5.4×104 t-C.

2.3 Environmental accounting of the Kitakyushu Eco-town project

Table 1 indicates results with the discharge of carbon expressed in positive values and the reduction expressed in negative values. For the impact on the environmental sections, the LCA results on processing, recycling, distribute ion and disposal are displayed for each grouping, Eco-town, within Kitakyushu and outside of Kitakyushu. Environmental load of 7,940 t-C generated by disposal from the Eco-town area and fuel consumption in recycling activities in the area, as well as new resource mining of 10,232 t-C in the areas within Kitakyushu and outside of Kitakyushu are input, and as an impact of recycling activities, a decrease in new resource mining of -72,027t-C is output. Based on this data, it is assessed that 53,856 t-C in reductions occurs annually as an environmental impact imposed by the Eco-town project.



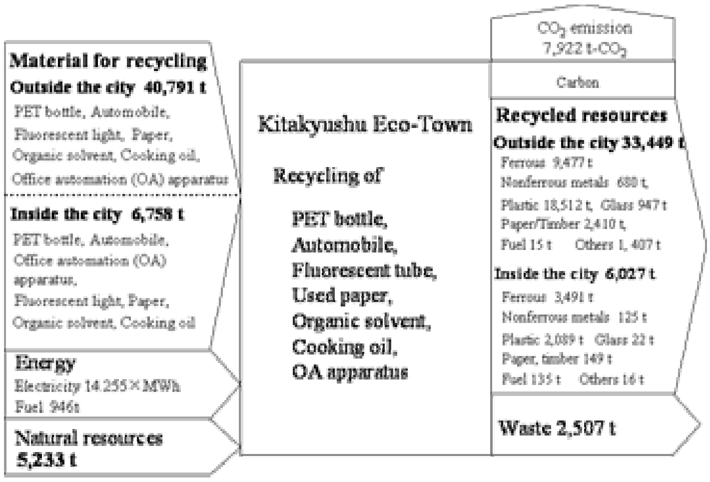


Fig.1 Material flow of Kitakyushu. Eco-town project
Fig.2 LCA results by life stages

t/year	Eco-Town	In Kitakyushu	Outside Kitakyushu	Environment	Total
Eco-Town	Internal linkage 36 t	Ferrous 3,491 t Nonferrous metals 125 t Plastic 2,089 t Glass 22 t Paper and Timber 149 t Fuel 135 t Others 16 t	Ferrous 9,477 t Nonferrous metals 680 t Plastic 18,512 t Glass 947 t Paper and Timber 2,410 t Fuel 15 t Others 1,407 t	7,940 t-CO2 Waste generation 2,507 t Waste disposing 18 t-CO2 Fuel burning 7,922 t-CO2	7,940 t-CO2
In Kitakyushu	Recycled materials 6,758 t Electricity 14,255 MWh			1,085 t-CO2 Indirect environmental load 1,085 t-CO2	1,085 t-CO2
Outside Kitakyushu	Recycled materials 40,791 t Fuels 946 t Natural resources 5,233 t			10,147 t-CO2 Indirect environmental load 10,147 t-CO2	10,147 t-CO2
Environment	-0 t-CO2 Internal linkage -0 t-CO2	-11,106 t-CO2 Primary resources reduction -11,106 t-CO2	-61,881 t-CO2 Primary resources reduction -61,881 t-CO2		-72,987 t-CO2
Total	-0 t-CO2	-11,106 t-CO2	-61,881 t-CO2	19,172 t-CO2	-53,815 t-CO2

Table 1. Environmental Accounting of Kitakyushu Eco-Town Project

Session D:

Sustainable Cities and Regional Matabolism

Chairmen: R. Isenmann

Location: Lindstedtsvägen 3
Room: E2.

The Design Approach to Urban Metabolism

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A framework for the integrated assessment and simulation of urban metabolism is presented here with a regional geographical focus around Melbourne, Australia. Part of our approach has been a comprehensive inclusion of all data sets relating to the current and historical physical identity of the Melbourne Region. Concurrently, we have constructed the Melbourne Region Stocks and Flows Framework (MRSFF) using the Design Approach[1] embodied in the "*whatIf*" software[2] to integrate this data into a self consistent whole.

Calculators in the framework represent sectors such as demography, land use, energy, water, transport, emissions and so on. These calculators deal with data relating directly to a particular sector, but they also operate on any outputs from other sector calculators that could relate over the long-term. The framework thus has a wealth of physical data that is also richly integrated and is able to simulate long-range effects between sectors. The validity of outputs from the framework rests on a calibration to 40 years of historical data and the transparent construction principles of the Design Approach.

The Design Approach deliberately avoids equilibrating algorithms and feedbacks, so the user can openly explore the simulated implications of planning and policy scenarios as represented by chosen values for control variables in the framework. Indeed, the user is an essential part of the system as an agent that can assess potentially undesirable outcomes and also provide innovation to remedy such 'tensions' through alternative policy choices.

The MRSFF is a spatially explicit computational tool to analyse the multi-sectoral impacts of contemporary and future urban growth, transport, energy, water, waste and pollution, housing and other policies and planning options for the Melbourne Region over 25 to100 years. Over this time scale, long-range, indirect effects become significant and may expose the aforementioned 'tensions' i.e. differences between the physical needs of the economy and the limitations of supplying to those needs. Such indirect effects or externalities might otherwise appear as negligible over shorter time scales.

The comprehensive geographic scope of the MRSFF accommodates the potential expansion of Melbourne's population and its material and energy catchment beyond current natural and demographic borders. Recognising that the Melbourne Region itself should not be considered in isolation, there is also the intention to integrate the MRSFF urban metabolism model with state and national level frameworks to allow a truly holistic analysis of future sustainability issues for the Melbourne Region, the State of Victoria and Australia.

While the full framework is yet to be completed, recent results exploring scenarios suggested by the Victorian State Government have direct policy implications for future sustainable planning for the region.

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Informed Decision Making towards a More Sustainable Urban Development

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An interdisciplinary team of researchers at Arizona State University (ASU) has set out to estimate the environmental impact of growth in the Phoenix metropolitan area and assess the sustainability of current decision-making trends in the region. The research team intends to study two components: (1) the effect of social and political decision-making on growth patterns in the region and (2) the effects of this urban sprawl on the environment. The ultimate goal of the project is to educate the public and policy makers in an effort to promote more efficient decision-making in terms of material use and emissions to air, water, and land.

Between 1990 and 2000, the population of the Phoenix metropolitan area increased by almost 50% from 2.1 million to 3.1 million people. The tremendous influx of people from Mexico, California, and other regions in the United States has managed to sustain this growth over the past four years as well. Although this population growth is beneficial to the state's economy, this increase in population also leads to increases in water consumption, energy consumption, and air pollution.

Unfortunately, these problems are exacerbated by the geography and climate of an already resource-scarce desert ecosystem. Rather than allowing for the dispersion of pollutants, the mountains surrounding the Phoenix metropolitan area effectively contain most of the pollution emitted in the urban areas. As a result, the valley is basically an "incubator" in which intense ultraviolet radiation, nitrogen oxides, volatile organic carbons, carbon monoxide, and several other precursors react to form dangerously high levels of tropospheric ozone. Furthermore, the intense heat coupled with the public desire to landscape with nonnative vegetation places a tremendous strain on the limited water resources. Energy consumption also rises sharply each summer as temperatures consistently exceeding 110°F (44°C) require extensive use of air conditioners. Each of these characteristics combined with the city's relative isolation from other urban centers allows the region to be viewed as a metaphorical “test tube” for sustainability and regional metabolism. Therefore, this urban center is an ideal subject for studying the effects of urban growth on natural environment and ecosystem.

There are four primary components to the methodology of the project: social decision-making, urban development, urban metabolism metrics, and urban air quality. The project team will be adjusting and calibrating an agent-based model known as UrbanSim, which was originally developed by the University of Washington, for the Phoenix metropolitan area. UrbanSim uses complexity models to examine social decision-making, land development, and transportation activities based on household and employment growth, household and employment mobility, location choices for households and employment, development choices determined by policy and market-based incentives, and land price modeling. Once the development scenario has been generated and projected to the year 2020, the output will be used to estimate material quantities, such as lumber, steel, concrete, and glass, for residential, commercial, industrial, and infrastructure construction. A “cradle to grave” life cycle analysis will then be performed to develop a regional inventory for a variety of metrics, including water consumption, solid waste generation, energy consumption, and greenhouse gas emissions. A regional air quality analysis will also be performed to estimate the formation of tropospheric ozone resulting from the increased development and population. The results from these analyses will be combined to prepare a life cycle impact analysis as a measure of the quality of life, ecological health, and sustainability of the Phoenix metropolitan area. In order to account for potential ideological changes, regulations or policies, and demographic transitions, multiple scenarios will be modeled and analyzed; possible solutions to sustainability concerns may also be modeled in these additional scenarios. The information flow for the project is illustrated in the diagram below.

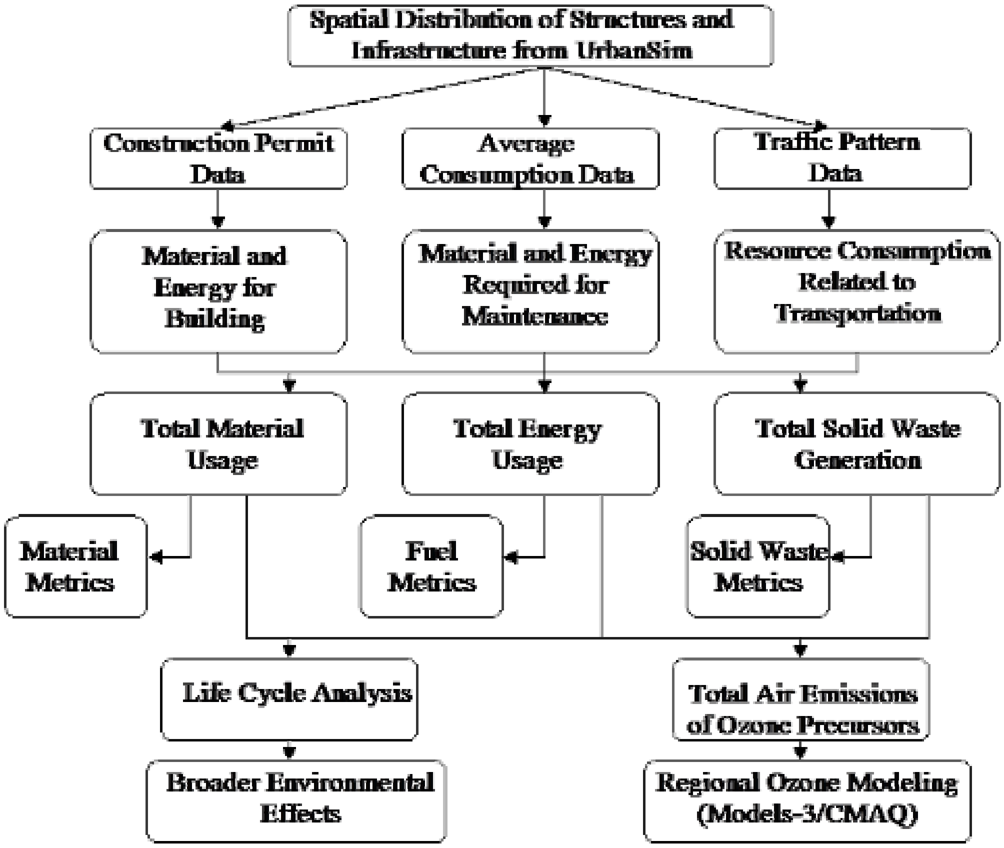

Figure 1. The Information Flow for the Study of Informed Decision Making towards a More Sustainable Urban Development

The results from this study will act as a policy and decision-making tool for the region and will aid in the effort to promote sustainable growth in the fragile desert ecosystem. By forecasting future development and the environmental impacts of that growth, the MUSES project will provide valuable insight into the economic and social viability of the Phoenix metropolitan area.

Model-Integration Based Evaluation of Technologies to Promote Sustainability in the Building, Electricity, and Transportation Sectors of Tokyo, Japan

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Introduction

In response to calls for development of numerical modeling methods and tools in Industrial Ecology (IE), recent research contributions to IE have included a wide range of computer simulations and analytical models. These computer models provide a form of published information that is more dynamic, generalized, interactive and multi-faceted than traditional document-type publications. We have been studying methods to use technologies for exchange and integration of knowledge over the Internet, to draw more effectively on this potential knowledge source (Kraines et al. to be published). As a component of this research, we have been conducting several case studies on integration of computer models from different disciplines for supporting comprehensive studies of complex IE system problems. Some of these studies are described in other abstracts presented in this conference. Here, we describe a case study to integrate five computer models for evaluating technologies to realize more sustainable building, electricity and transportation industrial sectors in Tokyo, Japan.

Component models

Our model integration case study includes the following component models:

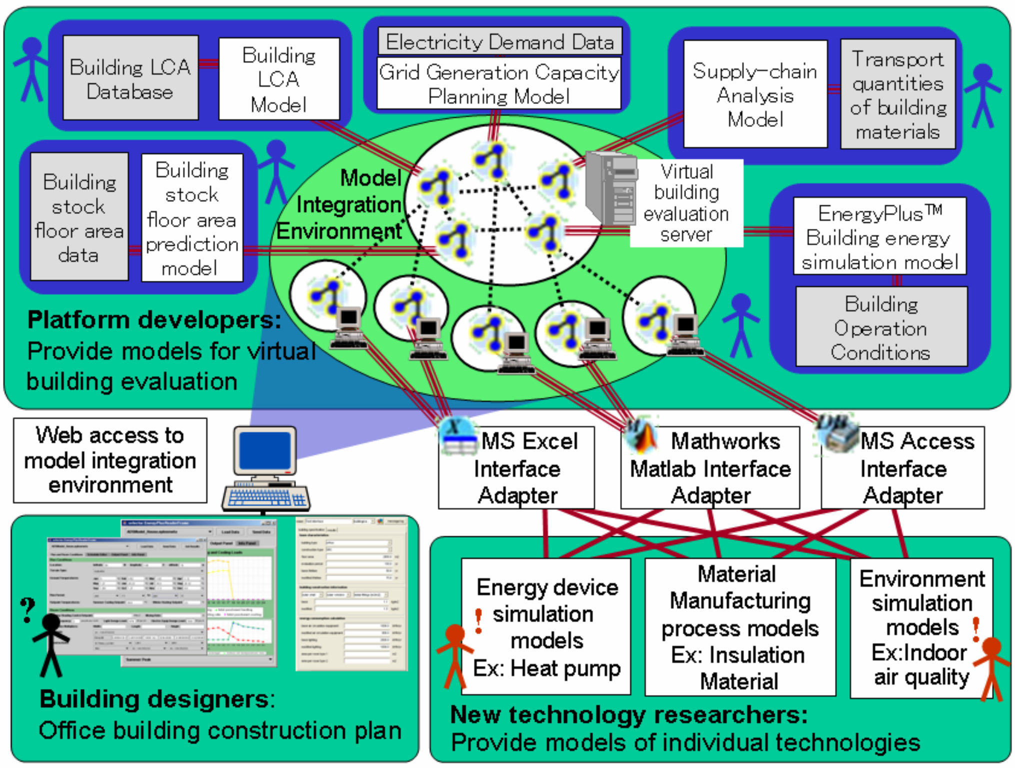
1. A building life cycle assessment database model that quantitatively compares cost, energy consumption, and environmental impacts of a baseline and a modified building design
2. A grid generation capacity planning model using linear optimization to allocate generation capacity among power generation types for the central grid, including a new option for a solid oxide fuel cell and gas turbine combined cycle, based on cost minimization, the electricity demand profile, and capacity constraints (Koyama et al. 2004)
3. A building energy simulation model to calculate energy requirements for annual building heating and cooling using the EnergyPlus simulation software (Crawley et al. 2001)
4. A supply-chain analysis model using network analysis to calculate the minimum cost routing of material transport for building material supply chain
5. A building floor area demand model for estimating spatial distributions of

the required floor area for different building types

All of the component models are based on computer models developed by experts in each related field of research. The work presented here represents a case study of how these dynamic representations of diverse expertise related to building LCA can be flexibly integrated to construct a platform for comprehensive evaluation of building technologies.

Model integration results

Using the Distributed Object-based Modeling Environment, DOME, under development by some of us at the CAD laboratory, MIT, we have integrated interfaces that we developed for the five component models described above. A schematic diagram of the integrated system model is shown in the figure. The resulting DOME integrated system model can be solved over the Internet using the server component of the third generation DOME software prototype, DOME[3]. Furthermore, the integrated system model can be combined with global optimization tools, such as the Queuing Multi-objective Optimizer (QMOO) that is available as a solver tool in the DOME[3] software prototype, in order to search the optimal criteria performance space of the integrated system model.



We present results of applications of the integrated model platform to different scenarios based on three designs for office buildings in Tokyo, Japan. The first design is for a conventional energy efficient building. The second design uses building materials with low environmental impact such as wood and recycled concrete to construct a relatively short-lived building. The third design is for a building that uses newly available highly durable building materials in order to realize a building structure lifetime of more than 100 years and energy efficiency higher than the conventional building with possibly higher upstream lifecycle costs.

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A Review of Urban Metabolism Studies

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Since Wolman's analysis of the urban metabolism of a hypothetical US city in 1965, metabolism studies have been conducted for a handful of cities around the world. The studies differ in terms of their terminology, scope of analysis, and results. This paper reviews the development of the urban metabolism concept, compares the previous studies and discusses current and future possible directions for urban metabolism research.

Urban metabolism studies have been undertaken by a diversity of academics, ranging from civil and chemical engineers to urban planners and ecologists. Consequently these studies have been published in an eclectic set of books and journals, and have used differing terminology. The metabolism of an ecosystem has been defined by ecologists as the production (via photosynthesis) and consumption (by respiration) of organic matter; and is typically expressed in terms of energy. While a few studies have focused on quantifying the embodied energy in cities, other urban metabolism studies have more broadly included fluxes of nutrients and materials, and the urban hydrologic cycle.

Metabolism studies have been conducted for a few cities around the world, over several decades. One of the earliest and most comprehensive studies was that of Brussels, Belgium by ecologists Duvigneaud and Denaeyer-De Smet, which included quantification of urban biomass. In studying the city state of Hong Kong, Newcombe et al. were able to determine inflows and outflows of construction materials and finished goods. An update of the Hong Kong study by Warren-Rhodes and Koenig showed that per capita food, water and materials consumption had increased by 20%, 40% and 149%, respectively from 1971 to 1997. Upward trends in per capita resource inputs and waste outputs were also reported in a study of Sydney, Australia. In a rare study of a North American city, Sahely *et al*. found that while most inputs to Toronto's metabolism were constant or increasing, some per capita outputs, notably residential solid waste, had decreased between 1987 and 1999. Metabolism studies of other cities include those for Tokyo, Vienna, Greater London and part of the Swiss Lowlands. Not all studies have quantified urban metabolisms as comprehensively as others. Bohle considers the urban metabolism perspective to examine urban food systems in developing countries. A few studies of nutrient flows in urban systems have been undertaken, while others have specifically investigated metals or plastics in the urban metabolism. Collectively these metabolism studies provide a quantitative appraisal of the way that cities are changing worldwide.

On-going and possible future urban metabolism research includes: more in-depth analysis of metabolic processes, in particular accumulation / storage processes; development of mechanistic urban metabolism models for sustainable city planning; life cycle analysis of metabolic processes with possible links to urban ecological footprints; impacts of climate change on urban metabolism; classification of different types of metabolism; and greater understanding of socio-economic processes that drive/regulate urban metabolism.

Evaluating Life-cycle Environmental Implications of Water Supply Systems

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Meeting water demand is a key economic and political issue in California. The U.S. government and other sources predict that there will be a water crisis in the state in the next two decades unless substantial changes in water conservation and provision are instituted [1,2]. In response, water utilities are exploring new water sources and policies. Alternative water sources under evaluation often include importing, recycling, and, for coastal cities, desalinating water.

However, the environmental effects of these systems are not considered in the decision-making process, in spite of the fact that energy and material consumption in water systems are significant and are increasing as systems become more complex[3-5]. These effects could be estimated using life-cycle assessment (LCA) and subsequently inform supply priorities, infrastructure investments, and other water system decisions. Though LCAs of water systems have been conducted in other countries, a comprehensive LCA of U.S. water systems has not previously been done.

To inform sustainable water supply decision-making, an analytical tool, the Water-Energy Sustainability Tool (WEST), has been created at UC Berkeley to evaluate the impact of construction, operation, and maintenance of water supply systems using LCA [cites of prior publications]. The tool uses a hybrid approach combining elements of process-based LCA and economic input-output analysis-based LCA (EIO-LCA). The tool evaluates material production and delivery, construction and maintenance equipment use, and energy production through the life-cycle of a candidate water supply system based on information provided by the user. Examples of necessary information include: the pipeline materials cost (in dollars), excavator use in construction (in hours), and energy consumption of water treatment plant equipment (in kilowatt-hours). Drop-down menus and default values are included for many parameters to assist the user in data entry.

This presentation will demonstrate the capabilities of WEST by describing and evaluating a case study system located in Oceanside, a California town located in northern San Diego County. The City of Oceanside Water Utilities Department (OWD) obtains water from each of the considered sources. The majority of their water (92%) is imported from either the Colorado River or

Northern California via the State Water Project. The imported water system includes hundreds of miles of pipelines, tunnels, and canals, numerous pump stations, and many dams and reservoirs. Another 7% of OWD's water is obtained by desalinating brackish groundwater using a reverse osmosis (RO) process. Finally, less than 1% of the water is filtered effluent from a wastewater treatment plant which is used for non-potable applications.

Energy use, global warming potential, and air emissions of nitrogen oxides, particulate matter, sulfur oxides, and volatile organic compounds were estimated over a 50 year time frame and reported in terms of average annual emissions for a given volume of water produced.

The results were reported both deterministically and probabilistically using Monte Carlo analysis. The results showed that desalination had twice the energy demand and caused significantly more air emissions (as much as 18 times higher) than the other alternatives. The energy-intensity of the RO process caused the majority of the emissions. The energy demands of recycling and importation were similar. For all alternatives, the energy consumed during system operation contributed most to the results, but maintenance was also found to be significant. Four activities were analyzed: materials production and delivery, equipment use, and energy production. Energy production was found to be the largest contributor in all alternatives, followed by materials production. The other two activities were relatively insignificant.

The environmental effects of the system through its life-cycle should be considered when making water supply decisions. The impact of energy, equipment, and material production and use in the process should be evaluated and included in the decision-making process. The WEST tool makes such assessments possible, and allows utilities to make more environmentally-friendly water supply decisions.

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[5] J. Stokes and A. Horvath. "Life-cycle Assessment of Alternative Water Supply Systems." Unpublished manuscript. (In review for publication). 2004.

Urban metabolism – Can Hammarby Sjöstad serve as an example of applied industrial ecology?

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Hammarby Sjöstad is the largest urban development project in Scandinavia. A former industrial and docking district is transformed into an environmentally advanced residential area. Construction work started in 1993 and when completed in 2010 more than 30 000 people are expected to work or live in the district. 8 000 eco-friendly apartments will be built and an additional 10 000 workspaces. The area will house 20 000 people. The estimated emissions from Hammarby Sjöstad will be 50 percent lower compared to housing areas built in the early 1990s. All subsystems from building materials to infrastructure construction to soil decontamination are part of the improvement. An environmental programme has been developed with the aim of focusing on environmental issues at the planning and implementation stages. The so called Hammarby Model is an eco-cycle system for managing energy, waste and water. In this model sewage processing and energy provision interact, and it shows how refuse is handled and the added-values society gains from modern sewage and waste processing systems.

Urban metabolism is a growing and crucial problem worldwide. In cities the magnitude and impact of resource use and waste disposal are most striking and the potential for beneficial action is greatest. The topic of urban metabolism is close to the purview of industrial ecology [1]. Can the concept of industrial ecology represent a scientific model for minimizing energy and material flows also in urban development projects? To what extent are similar models developed and taken into use today? In this paper we try to discuss to what extent the concept of industrial ecology can be adopted in urban development and in what way Hammarby Sjöstad can serve as an example of applied industrial ecology.

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Session E:
Managing Energy and Greenhouse Gases

Chairmen: B. Davidsdottir

Location: Lindstedtsvägen 5
Room: D3.

PowerPlay – Developing Strategies to Promote Energy Efficiency

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Computer models are widely used to analyze decisions about energy efficiency improvements in the residential and commercial sector. Few models exist that can actually be run interactively by decision makers to play out alternative future scenarios. None are available that interactively capture the dynamics, subtleties and complexities of interdependent decisions by utilities, households and firms in an ever-changing technological and economic environment. PowerPlay fills that gap and does more: it is a game to be played by at least a dozen player groups who interact with each other, make deals (or break them), plan for the future and revise decisions. The computer model functions like a game board to trace actions and offer choices. The observed behaviors can be analyzed to advance understanding of investment strategies and consumer choices.

Playing the game provides a unique opportunity for decision makers to appreciate time-delayed ripple effects of their choices for the choices and behaviors of others in the energy field. Playing the game also generates experimentally-based data on energy efficiency changes. Analyses of those data offer an alternative to historical, time-series driven specifications of energy models.

In this presentation we offer an introduction into PowerPlay – its development and game rules – and summarize findings from past games which were played by a diverse set of actors from government agencies, think-tanks, research institutions and non-governmental organizations in the energy field. We describe the data generated by those games and present insights into opportunities for, and constraints on the development and implementation of strategies to promote energy efficiency.

Managing Energy Futures and Greenhouse Gas Emissions with the Help of Agent-Based Simulation

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During the last two decades, electricity industries have been undergoing deregulatory reform worldwide. There are contradictory conclusions about the performance of these restructured electricity markets. For example, the Australian power market is dominated by large, cheap, coal-based generation, with limited forms of renewable energy such as hydro, wind and solar power. Although the market was deregulated in 1998, it has since demonstrated high levels of price volatility and market power and is still responsible for about 60% of Australia's unacceptably high greenhouse gas emissions.

In this paper, we model the market and physical network as a complex adaptive system (or CAS). Technically speaking, we use agent-based simulation to explore alternative energy futures. On the human side, we show that generators respond strategically to changes in market conditions (e.g. load changes), adapting their behaviour in profit-driven ways that tend to exacerbate air pollution. On the physical side, we show that strategically located clusters of distributed generation (less than 11kV) could produce significant reductions in greenhouse gas emissions, enhance security of energy supply and serve as anchor tenants for local communities that could lead to eco-efficient supply and demand-side management practices.

Serious uptake of distributed generation requires new market structures, new clusters of small generation units, new grid systems, new participants (e.g. aggregators) and new rules. To see if various clusters of distributed generation would work in advance of their creation, we evolve "would-be worlds" of new agents, microgrids and rules using agent-based simulation. With the help of evolutionary computation, we can discover those configurations that may be more eco-efficient in the sense that they can play a role in more efficient recycling of solid, liquid and gaseous resources.

Industrial ecology, complex systems theory and adaptive management are intimately related, in the sense that they are concerned with subtle interdependencies between system elements and flow dynamics on networks of various kinds. Given energy's important place in industrial ecology, and vice versa, the time seems ripe for the tools and techniques of complex systems science to be brought to bear on eco-industrial research involving complex energy and material flows and recycling networks. This paper takes a small step in that direction.

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Material Flow Analysis for CO_2 Emission Accounting in the (Petro-) Chemical Industry in Germany

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Background

All parties of the Kyoto Protocol have committed themselves to report their national greenhouse gas emissions on a yearly basis. In this context, most attention has been paid so far to CO_2 emissions from fossil fuel combustion for energy purposes. However, parts of the fossil resources are not used for energy purposes but as feedstock in the petro-chemical industry or for the production of final non-energy refinery products such as bitumen or lubricants. The consumption of these fossil fuels is generally referred to as non-energy use (NEU). One part of the NEU is emitted as CO_2 during the production and the use phase of products, while the other part remains incorporated in the chemical commodities. The latter is stored in the economy during the life span of those products. At the end of their life cycle, the waste treatment technology applied, determines the amount of carbon released to the atmosphere.

To gain deeper insight into the CO_2 emissions originating from non-energy use, an international network was established, which brings together experts in emission inventories and from the chemical/petrochemical industry. Within the NEU-CO_2 Network, a spreadsheet-based model (NEAT - Non-Energy use emissions Accounting Tables) was developed, to estimate a country's CO_2 emissions from non-energy use. NEAT is based on a material flow analysis (MFA) of the chemical and petro-chemical sector. The model follows a bottom-up carbon flow and mass balance approach. It estimates CO_2 emissions separately for different source categories such as solvent and product use, industrial processes, and steam cracking independently from official energy statistics. The model therefore serves as a valuable cross check for official inventory data prepared according to the guidelines of the Intergovernmental Panel on Climate Change (IPCC).

Objective

The objective of this research project is to apply the NEAT model to Germany for the period of 1990 - 2003. In Germany, non-energy use of fossil fuels account for 7.2% of the total primary energy supply and for 11.1% of the final energy consumption. The use of fossil fuels for non-energy purposes is therefore clearly above EU average (6.5% and 9.0% respectively) in the year 2002 (IEA 2004).

The NEU-share at the total fossil fuel consumption is expected to rise in upcoming years due to increasing energy efficiency on the one hand, and growing demand for polymer applications and chemicals on the other hand. This trend is likely to cause CO_2 emissions from non-energy use to become a '*key source*' in the German *Greenhouse Gas Emission Inventory*. However, the most recent German inventory of 2004 assumes the non-energy use, as stated in the national energy balances, not to be CO_2 effective (UBA 2004). The total German CO_2 emissions are therefore likely to be underestimated by 1-2% in the current approach (Patel et al. 2003). The deficits of the current German inventory have also been recognized during the international quality assessment of German greenhouse gas inventories and are well known by the German Federal Environmental Agency.

The following results from our study on non-energy use in Germany will be given in the presentation:

1. We start with a definition of non-energy use in the German energy balance and discuss its implications on CO_2 emission reporting in the national greenhouse gas inventories.
2. We show the results of NEAT calculations for non-energy use CO_2 emissions for the period of 1990 - 2003.
3. We discuss the results and the methodology chosen with respect to current calculations of non-energy use in the German inventory according to *national approach* and IPCC *reference approach*.
4. We draw final conclusion and recommendations to improve CO_2 emission accounting in Germany.

This research project is funded by the UBA until April 2005. We are currently conducting our model runs and will have first results by the end of this year. The final results will be presented at the ISIE conference.

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Leveraging Non-Renewable Fuels for Renewable Electricity Generation

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Electricity is a key energy carrier for residential, commercial and industrial activities, particularly in developed countries. In the United States, electricity generation accounts for 39% of total primary energy consumption with renewable sources providing only 9% of the total [1]. This reliance on fossil and nuclear fuels is not sustainable on a long term basis and is a major contributor to environmental challenges such as global climate change, acidification, smog formation, and radioactive waste disposal. Transition to renewable technologies provides an opportunity for enhancing the sustainability of electricity generation.

The objectives of this paper are to compare the life cycle energy performance of competing renewable technologies through the use of net energy ratio (NER) and to examine alternative life cycle assessment (LCA) methods for evaluating the NER. The net energy ratio as defined here is the total life cycle electrical energy output of a system relative to the total life cycle primary energy input from non-renewable sources and is used to discuss the non-renewable energy leveraging capacity of electricity generation. NER values can be calculated using either a process-based LCA approach or an input-output based LCA approach.

Examination of NER values for alternative technologies is extremely complex. Materials of construction, processing systems, operating parameters, durability, and other factors all affect technology performance. In the case of many renewable energy technologies, location factors such as solar radiation levels, wind speeds, and crop yields directly impact NER values. Examples that demonstrate these factors for select renewable technologies are shown in Table 1. Not surprisingly, the identification and examination of key technology parameters is an important component of understanding energy performance. This paper highlights critical factors included in energy analyses, and provides NER values for the major electricity generation technologies available in the US.

Table 1. Net energy ratio for renewable electricity generation under various conditions, Source: [2]

Technology	Location	NER
Building integrated amorphous silicon photovoltaic	Detroit, MI	3.9
Building integrated amorphous silicon photovoltaic	Phoenix, AZ	5.9
Building integrated amorphous silicon photovoltaic	Portland, OR	3.6
Wind turbine technology composite with advanced airfoil	Class 4 Wind	47
Wind turbine technology composite with advanced airfoil	Class 6 Wind	65
Willow biomass in a direct-fired stoker-grate boiler	N/A	9.9
Willow biomass in a high pressure direct-heat gasifier	N/A	13
Willow biomass in a low pressure indirectly heated gasifier	N/A	13

Process-based LCA studies require detailed information regarding a well-defined system and the associated processes. EIOLCA requires information regarding economic transactions and environmental impacts associated with broad industrial sectors within a specified economy (e.g. the US national economy). The resulting analyses provide a detailed understanding of individual system components in the case of process-based LCA or a comprehensive view based on a more extensive system boundary in the case of EIOLCA.

Figure 1 compares the NER of a wind farm using the two LCA methods studied. The electrical output of the facility at any point on the figure is identical for both methods, however, differences in the amount of life cycle energy input captured by the two methods results in different NER values. EIOLCA tends to be more comprehensive and inclusive than process based approaches, which yields a larger denominator for the computation of the NER. Consequently, EIOLCA based NER values are smaller than process based LCA results. Two key system parameters, the lifetime of the facility and the capacity factor, affect the NER regardless of the LCA method used.

Overall results from EIOLCA and process-based LCA methods indicate that the greatest leveraging of non-renewable energy occurs with wind turbines and hydroelectric plants followed by biomass and photovoltaics.

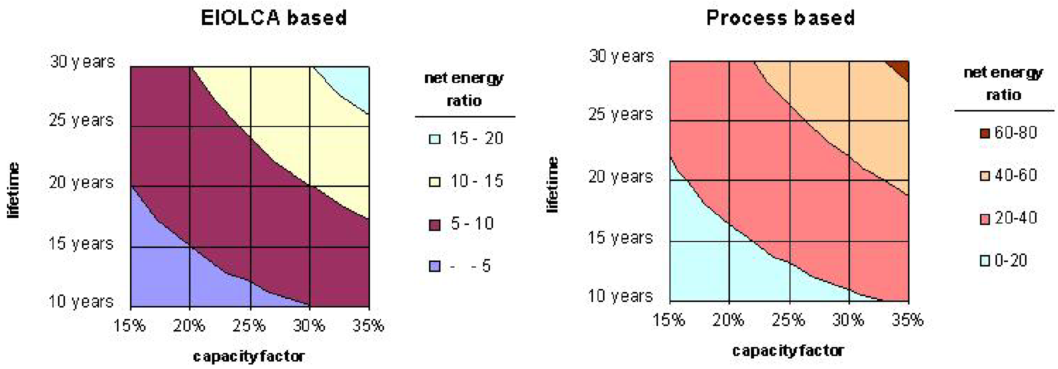

Figure 1: Net energy analysis of wind farms using process based and input-output based life cycle assessments as a function of facility's lifetime and capacity factor

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Incorporation of Life Cycle Assessment in Future Energy Scenario Analysis

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The U.S. electricity industry is currently experiencing and adapting to enormous change, driven by concerns related to fuel cost, security, reliability, competition and environmental impacts. Decisions made over the next decade will be critical in determining how economically and environmentally sustainable the industry will be in the next 50 to 100 years. For this reason, it is imperative to look at investment and policy decisions from a holistic perspective, considering various time horizons, the technical constraints within the system and the environmental impacts of each technology option from an economic and environmental life cycle perspective.

While there is a large body of literature which investigates future energy scenarios, very few of these studies focus on a framework for incorporating the life cycle impacts of these scenarios. The current framework for conducting life cycle assessment does not focus on the range of possible technology futures and therefore must be used in conjunction with scenarios in order to incorporate life cycle impacts into future choices.

In this paper, we develop a framework to evaluate the cost and environmental tradeoffs of future electricity options from a life cycle perspective. This framework builds on basic energy scenarios developed using an energy planning optimization model (MARKAL). Within each of these scenarios we focus on exploring various possibilities for the upstream component of the technology and fuel choices within the model. For example, in a high demand scenario requiring a large investment in coal infrastructure, the upstream impacts would look very different, depending on the technologies that are chosen. In particular, technology (pulverized coal versus gasification), efficiencies achieved, coal type, mining method, and whether the carbon is captured and sequestered all change the overall environmental impact of fuel and technology choice in both the generation phase and the upstream impacts. In addition to the generation technology and fuel, decisions must be made about whether to transport the coal by rail, transmit as electricity or convert the coal to natural gas and transmit by pipeline. Each of these choices have different infrastructure, economic and environmental tradeoffs.

Most studies of fossil fueled power generation studies show that the generation phase produces emissions that are greater by at least an order of magnitude over the rest of the life cycle. However, in this analysis we find that under certain future energy scenarios, the upstream environmental discharges from producing an increased amount of electricity have impacts that must be considered when making infrastructure investment decisions.

Another scenario is that of high penetration of renewable technologies. Wind and solar are particularly interesting case studies in that they have unique infrastructure requirements (e.g. backup, storage, long distance transmission etc.). In addition, there is a wide range of solar technologies that have quite different life cycle and cost implications. These choices will have to balance the level of toxicity of material chosen, scarcity of those materials, energy penalty to manufacture the technology and the net efficiency obtained.

Energy Use in the Food Processing Chain of 13 European Countries.

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Energy use in agriculture and food processing has been an issue since the 1970s. Most early studies were driven by the fear that increasing oil prices would push up production costs which could affect considerably food prices and even more important, that limited reserves of fossil fuels were likely one day to prove limiting in the agricultural system. Since 1990, the main driver for energy studies of the agricultural and food processing systems is not so much the fear of limited fossil fuel reserves as concerns related with climate change. It is in this context that answers to questions such as what are the trends in energy demand? Where are the main critical points? What is the role of consumer demand and energy efficiency? are important inputs into the ongoing debate of which and where policies are necessary to reduce greenhouse emissions. In this paper we examine energy use in the food processing chain and we take a look at the factors that have influenced energy demand in the last three decades.

Data

All data are gathered at the country level and then aggregated to obtain values for what we have defined as Europe13 (Austria, Belgium, France, Germany, Greece, Italy, Luxemburg, the Netherlands, Norway, Portugal, Spain, Sweden and the United Kingdom). The analysis is conducted for the food production chain; hence retail and households are not included The time period studied is 1970-2002. Energy flows have been estimated using data from the International Energy Agency, Eurostat, the Odyssee database and own estimations. Output is expressed in energy values (calories). It was estimated by gathering data in physical terms (e.g. each crop in tonnes) and transforming them into energy values by using FAO nutritional factors (i.e. calories per 100g product). For a complete description of how each stream was calculated please contact the authors.

Results

Energy use in the food processing chain in Europe 13 was of 3960 PJ of primary energy in 2002. We found that the only part of the chain showing a decrease in energy use (about 2% p.a.) is the indirect energy allocated to the manufacture of fertilizers. While in 1970 energy for fertilizer manufacture accounted for 26% of the total energy, the share has decreased to 9% in 2002. About 90% of this decrease can be explained by energy efficiency improvements in the manufacture of fertilizers in the last 30 years. Agriculture increased its primary energy demand by about 1.6% p.a. in the period studied while the increase in the food processing sector was of 1.8% p.a. The highest increase is shown by the transportation of food, with about 2.1% p.a. for transportation of agricultural goods and 2.5% p.a. for the transportation of foodstuffs and fodder.

To understand the increasing energy demand of the whole system and the impact of energy efficiency developments, we examined different factors that influence energy efficiency in each step of the food processing chain. Two main conclusions can be drawn: first, increased activity (agricultural output, food processing output and amounts of tonne-kilometer transported) has been the main driver in the rising energy demand shown by the food processing chain. Secondly, changes in energy efficiency have not been able to offset the increasing demand due to activity growth, on the contrary, some of the developments in physical energy efficiency (energy per calorie) have helped to boost energy demand. These are important results since they show that current trends do not point towards a decrease in energy demand in the whole system, and that stronger efforts will have to be made if expectations on energy efficiency as a main factor on reducing total energy consumption are to be fulfilled.

Possibilities of Multi-functional Biomass Systems for an Efficient Greenhouse Gas Emission Reduction

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Biomass may play an important role in mitigating greenhouse gas emissions by substituting conventional materials and supplying biomass based fuels. However, currently, a modest amount of biomass is used in industrialised countries. Main reasons for the low share of biomass applications in Europe (about 6 EJ in the EU-15) are their often-high production costs due to a.o. the relative low availability of agricultural land. Therefore, in the short to medium term more efficient and cost effective routes for the introduction of biomass, e.g. multi-functional biomass systems, are needed. Multi-functional biomass systems use the concepts of 'multi-product use' and 'cascading'. Multi-product use is defined as using biomass for different applications, while cascading is the subsequent use of biomass for a number of applications. Important parameters for the efficiency of multi-functional biomass systems are savings of non-renewable energy consumption, GHG emission reduction, (agricultural) land use and total costs of the system. However, only very few studies have explicitly addressed multi-functional biomass systems analysing these parameters quantitatively. Therefore, the central research question of this study is: *What is the potential of multi-functional biomass systems to improve the costs and the land use efficiency of saving non-renewable energy consumption and reducing GHG emissions in quantitative terms?* Several case studies of multi-functional biomass systems that appeared promising after a first review are carried out. The case studies are situated in Europe and concentrate on Poland.

Results for the different systems vary considerable from plain benefits to no perceptible advantage of multi-functional biomass use. The performance of multi-functional biomass systems is influenced by many factors, which depend (1) on the type and structure of the biomass systems and (2) on circumstances such as material markets and reference systems. Most multi-functional biomass systems regarded in this study, however, increase the potential benefits of biomass use in terms of costs, GHG emission reductions and agricultural land use. Of course, the evaluation of multi-functional biomass systems depends strongly on the alternative reference systems. In the case of biomaterials that have a relatively long lifetime, time dimensions of temporary carbon storage in these materials can play an important role, too. Market prices of land, materials and energy carriers also influence the economic benefits of multi-functional biomass systems strongly. The results indicate that with a growing use of biomass for materials and energy, GHG mitigation costs of options may increase. While many multi-functional biomass systems already have quite high GHG emission mitigation costs, the economic potential of these systems to mitigate GHG emissions might even be further limited by these market effects. This is especially the case for biomaterials that have comparably small markets.

In conclusion, to use biomass efficiently in terms of GHG emission reduction, (agricultural) land use and total costs of the system, multifunctional biomass systems may be an attractive option if carefully designed. The best multi-functional biomass systems analysed in this study, increased the GHG emission reduction per unit of agricultural land used and decreased the total systems costs by up to a factor of 5 compared to single biomass uses. However, for the performance of biomass systems at a large scale of biomass use, the interactions of biomass use with land, material and energy markets need to be understood. Therefore, further research on optimal biomass systems for GHG emission mitigation, should combine bottom-up information of biomass system with knowledge on market mechanisms from top-down analyses.

The Link Between Energy Efficiency, Carbon Intensity and Carbon Emissions: State Level Decomposition Analysis of President Bush's Greenhouse Gas Reduction Proposal

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On February 14th, 2002, President Bush announced the following: "*My administration is committed to cutting our nation's greenhouse gas intensity -- how much we emit per unit of economic activity -- by 18 percent over the next 10 years. This will set America on a path to slow the growth of our greenhouse gas emissions and, as science justifies, to stop and then reverse the growth of emissions*."

Carbon dioxide accounts for approximately 92.6% of net greenhouse gas emissions in the United States, and thus to fulfill the president's proposal the carbon dioxide intensity of economic activity needs to decline. More specifically, since the combustion of fossil fuels is responsible for over 97% of all anthropogenic carbon dioxide emissions in the United States, changes in energy consumption per value of economic activity needs to decline. Such changes occur as a function of (1) structural change, (2) changes in energy efficiency or (3) shifts between carbon rich and other fuels. An understanding of the relative importance of each component is important when planning for future reductions, and when analyzing differences between sectors and states when it comes to past performance and future reduction potentials.

The objective of this paper is to decompose carbon emissions economic intensity in the United States, to analyze the following questions.

- What is the relative importance of the three different contributing components between 1980 and 2000 to reduction in carbon intensity?
- How do states differ in both their performance and the relative importance of each contributing component?

The analysis of those three questions is then used to infer on the potential for future reductions in carbon intensity, and to analyze if the president's proposal is realistic, and if it is likely to result in reducing total carbon emissions from the United States.

The data used for this study is derived from EIA's state level energy database, economic activity data from the Bureau of Economic Analysis, vehicle miles from the Department of Transportation in addition to data from the US Census Bureau. The choice of decomposition is crucial to the accurate identification of the various effects that determine changes in aggregate energy intensity. For this analysis two different methods are used, the Laspeyres and logarithmic mean weight Divisia indices. The Laspeyres indexes are chosen due to their ease of interpretation, which an important feature of any index to be used in a policy context, and the Divisia method since it leaves the smallest most stable residual (Greening et al. 1997, Ang 2004).

Results are presented on both end-use and primary use basis. On a primary use basis for example, the industrial sector contributes approximately 18% to total carbon emissions, but substantial state-level differences exist, ranging from 5.46% in Nevada to 5.8% in Rhode Island, to almost 50% in Louisiana. Change in carbon intensity across states varies as much as the contributing share of the industrial sector. For example carbon intensity increased by 31% in Maine, 13.7% in Louisiana and 3.4% in Rhode Island, but declined by 67% in New Mexico and 43% in Nevada. The reasons for change within the industrial sector vary across states, ranging from almost solely being the result of fuel switching in Massachusetts to mostly being the result of efficiency change in New Mexico. The results indicate the varying importance of contributing sectors in reducing overall carbon emissions and carbon intensity, and demonstrate much state variation in the potential for further change.

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T4 PM

Session A: **Tools in IE**

Chairmen: R. Cockerill

Location: Lindstedtsvägen 3
Room: E1.

Towards a sustainability assessment of technologies - integrating tools and concepts of Industrial Ecology

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Until a point of widely acceptable clear and measurable vision for sustainable development is reached, the work with sustainability metrics would continue to evolve as a relative measure of ecological, social and economic performance of human activities including technologies. This can be done by both comparing the relative performance of different alternative paths of providing the same well defined function or service or by characterizing technologies that enjoy different level of societal priorities using different absolute performance indicators. In both case tools and methods of industrial ecology can be used for different portions of the issues, in different ways and for different purposes.

In combining tools and methods, a list of features are crystallized out accounting, among other things, for the type of information processed and the knowledge required. Here, Industrial Ecology, manifested in the mapping and assessment of material and energy flows associated with technical solutions is a key aspect. In this paper, this will be illustrated by the experiences gained from researches carried out at two divisions in the Royal Institute of Technology in Stockholm namely the Division of Industrial Ecology and the Division of Built Environmental Analysis. This illustration will focus on application of two tools (ORWARE and EcoEffect) in three different areas, waste management technologies, energy technologies and the built environment.

Concepts and ideas from material flow analysis (MFA), life cycle assessment (LCA), life cycle costing (LCC) and social impact assessment (SIA) are used to a varying extent in ORWARE and EcoEffect. SIA is gradually being incorporated in ORWARE.
In the modelling approach adopted in ORWARE, a big picture composed of four arrays of technologies unfolds into the scene. These are:

- the technologies under assessment making up the core system
- the technologies for producing inputs, utilities and others
- the technologies for producing additional magnitude of the existing functions for *quantitative equivalence*.
- the technologies for producing additional function for *in-kind equivalence*.

Modularity as the degree to which a system's components can be separated and recombined, as well as the degree to which the "rules" of the system architecture enable or prohibit the interchanging of components is considered as important aspect of the ORWARE model.
It is necessary to emphasise that understanding the whole implication of a technology chain composed of different components requires knowledge to understand the components (component knowledge) and the knowledge to understand the linkage (architectural knowledge).
Both ORWARE and EcoEffect are expected to serve as learning tools for the actors in the waste management system, energy system and building sector. The active participation of the different stakeholders from the building sectors in the development and implementation of EcoEffect have facilitated the possibility to build the learning loops into a modelling structure.
The inclusion of social dimension within the same definition of sustainability within the framework of the ORWARE models undermines the variety and diversity of social values across the global and between current and future generations. Thus a postmodernism approach is required where different scales and metrics can be used to generate various layers of information.

Industrial Ecology Tools for the Built Environment – Part 1: Analysis of Environmental and Economic Impact of Technology and Metabolism in the Norwegian Built Environment

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[2] Yale University, Centre for Industrial Ecology, School FES.

Built environment is one of the most important sectors in society with respect to materials and energy demand, and waste generation. Numerous projects in research and practice have searched opportunities for reduced environmental and economic impacts from the built environment stock itself, as well as from upstream material production and construction activities or downstream waste management activities.

However, the dynamic behaviour of the built environment system is yet weakly understood, including changes in material and energy inputs to the stocks of buildings and infrastructure, as well as the waste outputs. Also, we need a better understanding of how technologies and strategies in waste management may influence the overall environmental and economic life cycle performance in the system.

We claim that research on such issues is important. Earlier studies indicate that stocks are still growing, and that the inputs and outputs from built environment structures will change a lot in coming decades, particularly with much higher waste outputs. Another argument is the growing concern for environmental and economic efficiency in the construction and demolition activities, both due to changing governmental regulation and consolidation in industry itself.

Industrial ecology offers a promising analytical framework and tools well suited to perform dynamic analysis of built environment. We have applied this to develop a novel simulation model, so far applied to analyse the concrete and gravel system in Norwegian built environment. The model takes advantage of Matlab programming, linking three model elements; a scenario analysis, an MFA simulation model, and an Input-Output LCA analysis.

The scenarios analysis defines pathways for future stock demand, and typologies for buildings and infrastructure including lifetime distribution parameters and material intensity coefficients. Defined are also pathways for solutions in the downstream waste management system, including technologies and material transfer coefficients. These assumptions give input to the MFA model, designed in Matlab Simulink, where stocks and flows in the concrete and gravel system are examined. The IO-LCA analysis is then used to examine the environmental impacts over time, as a result of physical flows and different waste management strategies, combining a process LCA on a foreground system and IOA on the background system.

The presentation gives an overview of the overall simulation model, its elements and assumptions, including matrix algebra structure for calculations and process layout for the Norwegian built environment. Results are shown for an evaluation of the concrete and gravel subsystem, on the basis of best available empirical data in Norway. It is shown that future waste management strategies will have a very large influence on the cyclic behaviour and the environmental and economic performance in the Norwegian built environment system. First of all, the use of waste management technologies with potentials for high concrete reuse and recycling ratios will strongly influence the mix of primary versus secondary inputs to the future built environment stock. This change is partly a consequence of growing waste outputs and improved transfer coefficients for recycle, providing much more secondary materials to the markets of the construction industry than today. This growth will again strongly influence the reduced need for primary resources. The analysis also demonstrates the important environmental and economic benefits of improved waste management technologies, which become particularly dominant in a long term perspective. There is a large gap between current construction and demolition waste management practices and what we might call sustainable practices in future.

Furthermore, the analysis gives direction for important research and development work in this industry. Finally, the generic and logic structure in our model design, combined with its favourable analytical methodology, suggest that the approach we have applied should be easily transferable to other material subsystems in built environment systems, and applicable to other countries. A separate presentation (Part 2) is offered, with detailed information of the dynamic MFA analysis of the Norwegian dwelling stock.

Session B:
Waste Management

Chairmen: C.Binder

Location: Lindstedtsvägen 5
Room: D2.

An Environmental System Analysis of the Solid Waste Management in Managua, Nicaragua

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Björn Frostell[3]
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Most of the solid waste in Nicaragua is landfilled without any special treatment, such as composting, anaerobic digestion or incineration. In the municipality of Managua, the capital city of Nicaragua, hazardous and non-hazardous wastes are disposed of and mixed in a major landfill on the shore of the Managua Lake. The landfill is a dump without any measures to reduce leachate, gases and dust to the surroundings. Therefore, this landfill is considered as a potential contamination source to the lake. Recycling of materials is mainly carried by scavengers at the landfill site. The present situation of the solid waste management in Managua has been summarized in Pomares and Flyhammar (2004).

Outside Managua, a few municipalities have taken into account alternative treatment methods like composting. Composting is mostly regarded as a small scale method to reduce the amount of waste sent to the landfills and as a method to recycle organic waste and nutrients. The demand of compost is limited among farmers due to lack of prior experience on use compost and poor knowledge about alternative soil improvers and fertilizers. The legal framework controlling the waste management is weak. There is no special law on waste management, but some basis to create a new legal framework has been established. In addition, a new national policy on waste management was approved by the parliament in June 2004. Moreover, municipalities are technically no efficient; technical analytical tools to optimize the waste management system are missing. Poor economic resources of the municipalities further complicate improvements of the management of solid waste.

The aim of this study is to perform an environmental system analysis of the waste management system of Managua city. Different scenarios will be analyzed by the system analysis simulation model ORWARE (Organic Waste Research). This approach has earlier been used to analyze different waste management systems in Sweden (e.g. Björklund. 2000; Liunggren. 1997; Lindqvist. 2002) and in Jakarta, Indonesia (Trisyanti, 2004). However, it is important to mention that LCA (Life Cycle Assessment) is also a basis for

ORWARE. The choice of scenarios is based on the present situation, a recent proposal of a new waste management strategy of Nicaragua (Melendez, 2002) and different solutions and treatment technologies considered as adequate for Nicaragua.

The following management scenarios have been suggested to handle the waste generated: (i) The present MSW management system in Managua, (ii) The present system with increased source separation and recycling of materials, (iii) The present system with treatment of organic waste (methane extraction from the landfill), (iv) The present system with a mixture of different treatment methods (biological treatment: composting or anaerobic digestion, and incineration)

The results of this study could be used to improve and upgrade the waste management system of Managua as well as the national policy on municipal solid waste management in Nicaragua. In addition, our experience during this study allowed us to conclude that the development of national policies and legal frameworks of solid waste is simplified by an LCA approach.

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Study on the Traits of Recycling Industrialization —What Are the Differences from the Traditional Way?

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Although municipal solid waste now is regarded as an important resource for industrial development, it is still out of the traditional economic system. To make the waste recycling be a new industry is crucial way to integrate the waste stream with the product stream. However, being complex and diversified in composition, dispersed in distribution and low in quality makes waste recycling industrialization different in management and production from the traditional industry which uses the raw material directly from the environment. To figure out the differences will be of important significance, especially to the policy makers.

Waste recycling can be divided into 3 stages: collecting (including concentrating and transferring), reclamation (or reuse, remanufacturing) and marketing. The paper studied the anterior 2 stages by following the waste paper stream in Beijing and it's vicinity by doing structural and semi-structural interview with the various partners involved in the industrialization. Also field works have been done to investigate the life cycle of waste paper including discharging, collecting, transferring and reclamation.

Based on the survey, the paper pictured the mechanism of the waste paper management system in Haidian district of Beijing. And the social and economic traits of recycling industrialization in this regard were analyzed. Finally, suggestions for policy makers were put up.

How Beneficial is a Regional Concentration of Waste Treatment and Disposal?: An Application of the WIO-LP Model to Japanese Interregional Input-Output Table

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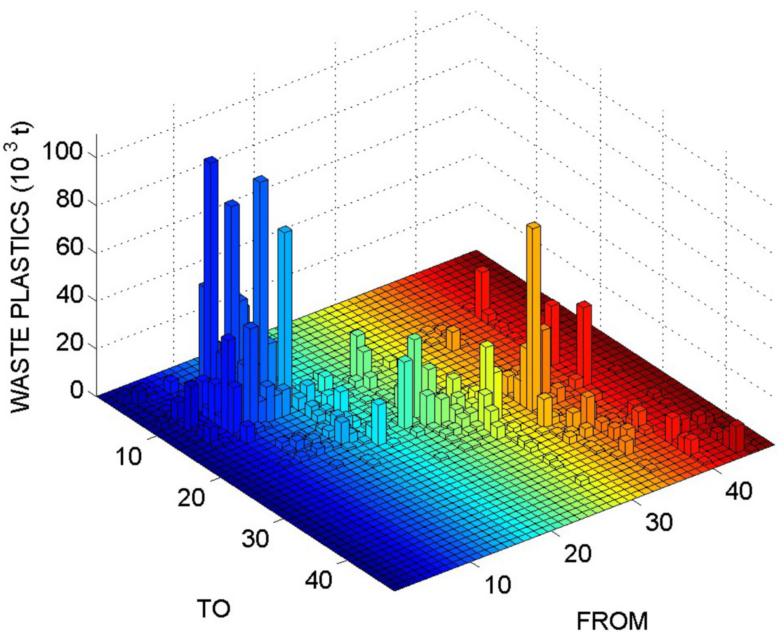
The Japanese law provides that most waste of municipal and industrial origin should, in principle, be treated or disposed of within the region in which it is generated. On the one hand, this principle is closely related to fairness and NIMBY issues and may be supported from a social point of view. On the other hand, the principle might cause economic and/or environmental loss because a regional concentration of waste management possibly improves its eco-efficiency. For example, there are 20 eco-industrial parks (or eco-town) in Japan in April 2004 [1]; they are expected to promote regional economies and their expansion inevitably needs to collect waste and recycled materials from over a wider area. In reality, about 30% of the total industrial waste plastics are transported to other prefectures in 2001 [2] (Figure 1). It is thus quite important to understand how beneficial a regional concentration of waste treatment and disposal is. We present an empirical analysis of this issue by applying the waste input-output linear programming (WIO-LP) model [3] to a Japanese 9-region interregional input-output table.



01 Hokkaido, 02 Aomori, 03 Iwate, 04 Miyagi, 05 Akita, 06 Yamagata, 07 Fukushima, 08 Ibaraki, 09 Tochigi, 10 Gunma, 11 Saitama, 12 Chiba, 13 Tokyo, 14 Kanagawa, 15 Niigata, 16 Toyama, 17 Ishikawa, 18 Fukui, 19 Yamanashi, 20 Nagano, 21 Gifu, 22 Shizuoka, 23 Aichi, 24 Mie, 25 Shiga, 26 Kyoto, 27 Osaka, 28 Hyogo, 29 Nara, 30 Wakayama, 31 Tottori, 32 Shimane, 33 Okayama, 34 Hiroshima, 35 Yamaguchi, 36 Tokushima, 37 Kagawa, 38 Ehime, 39 Kochi, 40 Fukuoka, 41 Saga, 42 Nagasaki, 43 Kumamoto, 44 Oita, 45 Miyazaki, 46 Kagoshima, 47 Okinawa

Figure 1. Industrial waste plastics transported to other prefectures [3]

The WIO model [4] is an extension of the conventional input-output model so that it can properly deal with the interdependence between the flow of goods and the associated waste stream and it can be used for evaluating economic and environmental effect of waste management options. The WIO-LP model is a decision analytic extension of the WIO model. Namely, the WIO-LP model can be used to search for an “optimal” waste management option with regard to a given objective function (e.g., the amount of GHG emission) from among a given set of feasible alternatives while the WIO model is a framework for evaluating a given waste management option. The decision analytic extension is useful particularly for analyzing waste management options because possible combinations of waste treatment and recycling technologies are quite complicated.

We apply the WIO-LP model to a Japanese 9-region interregional input-output table for understanding how beneficial a regional concentration of waste treatment and disposal is. Given the scarce nature of landfill site capacity in Japan, we choose the minimization of required landfill capacity as the criterion of optimality. Other environmental, economic, and social aspects are also considered by laying upper bounds on several variables such as the amount of GHG emission, unemployment rate, and the degree of regional concentration which corresponds to the capacities of existing treatment plants and landfill sites.

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Session C:

Eco- Industrial parks and Networks

Chairmen: A. Horvath

Location: Lindstedtsvägen 17
Room: D1.

Harjavalta industrial park as an industrial ecosystem

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Koskenkari, Tuomo Eka Chemicals Oy, Oulu, Finland (alphabetical order)

Industrial ecology provides the scientific and technological understanding upon which the increased environmental, economic and social efficiencies necessary to progress towards sustainability can be based. Industrial ecosystem is the creation of synergies between various industries, agriculture, and communities to profitably convert waste into valuable products or feedstock. By working together, the community of businesses seeks a collective benefit that is greater than the sum of individual benefits.

The metallurgical industry is very fruitful application field to industrial ecology. The total load of the nature has lead to the more strict use of raw materials through recycling the main and side products. Further processing for utilization and disposal of wastes and elimination of harmful impurities have needed and will demand great efforts, the costs at which being at least partly directed to the primary process thus forming an essential boundary condition for process selection. But this has been and will be a great change, which can be utilized by developing industrial ecosystems to improve raw material efficiency.

Copper and nickel flash smelters developed by Outokumpu form the heart of the Harjavalta industrial park, which consists of thirteen different firms. The main five process industry companies, the products and the material and energy change between the firms are shown in Figure 1.

Regarding the main companies the most important advantages of the Harjavalta industrial park are the environmental, recycling, marketing and logistic advantages and imago factors. Also the networking and the better co-operation has been very positive development actor. The safety actions have also improved because of the co-operation. To the city of Harjavalta the most important advantages of the industrial area are employment, international dimension, intellectual capital and imago because of the famous firms.

Considering the Harjavalta industrial park as an industrial ecosystem three of the four ecosystem principles (roundput, diversity, locality and gradual change) by Jouni Korhonen are fulfilled. There are also plans and research work going on to further improve friendliness to the environment. The low temperature waste energy will be used as an energy source of green house park. The research work to improve and add the utilization of the copper and nickel slags has been started. So, the industrial system should rely even more on sustainable use of renewable natural resources as well as on the use of waste material and waste energy flows. Also the local natural resources based on the wood are one potential energy source.

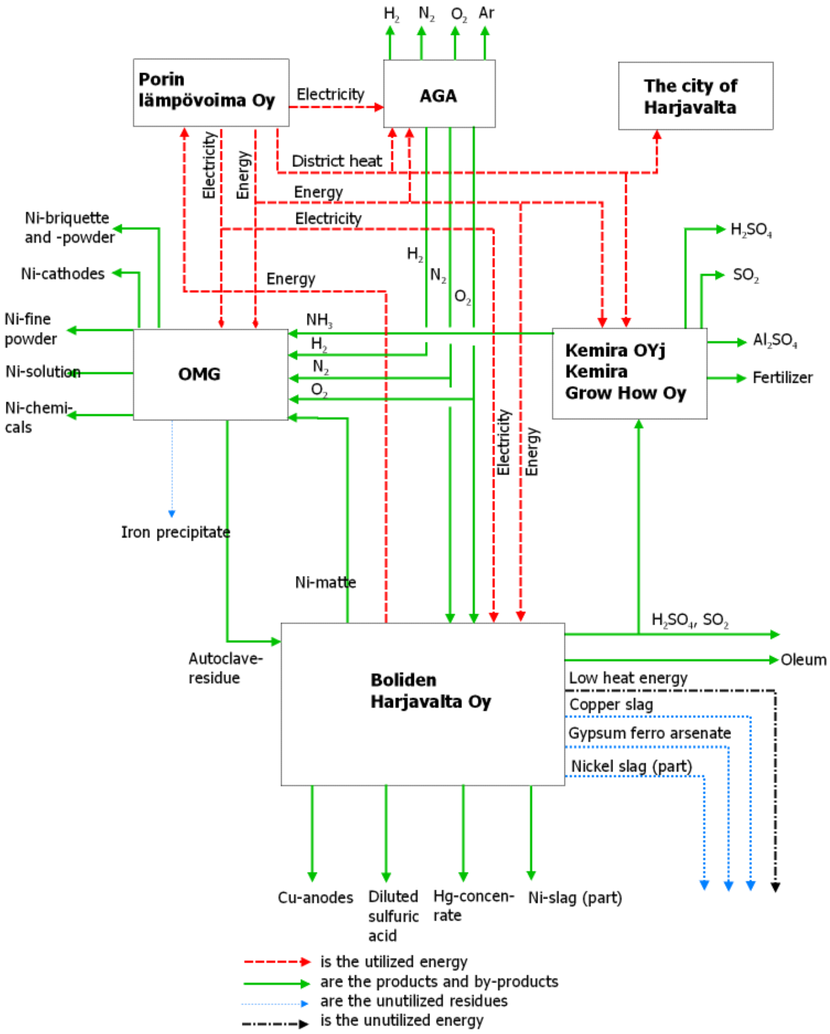

Figure 1. The products and the material and energy change between the firms in the Harjavalta industrial park.

Implementation and Management of Sustainable Eco-industrial Networks in the Region of Oldenburger Münsterland (Germany) and Styria (Austria)

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The paper delivers a contribution to the theoretical side of industrial ecology as well as to the practical side. In the first part an evolution model of Eco-industrial networks will be presented and five conditions for their longlasting existence will be proposed. Afterwards this framework will be used to describe the installation of two Eco-industrial networks in the German Region of Oldenburger Münsterland and in the Austrian Region of Styria.

Sustainable Development was defined as an overall concept of society in the Brundtlandt Report in 1987 (World Commission on Environment and Development 1987, p. 43). Ten years later it was written down in Article B of the EC Treaty (Möller, L. 2003, 236 ff.).
This aim can be approached by a long-lasting cycling of resources in economy corresponding to the principle of natural ecosystems (Strebel, H. 2002, p. 107. The realization of industrial closed loop economy will lead to the model of Eco-industrial networks. (Strebel, H. 1998, p. 3 f., Schwarz, E. J. 1996, p. 358 f., and Sterr, T. 2003, p. 269 ff.), if the reuse of waste materials in the same company is not intented or possible (Strebel, H. 1995, p. 49).

By networking companies are enabled to cope with increasing complexity of their environment (Kappelhoff, P. 1999, p. 376), which is caused by a growing number of environmental laws in order to enforce sustainable development.

The dynamics and self-organizational potential of Eco-industrial networks will be described by using a system theory model. This process-orientated model was developed by Mildenberger to describe the evolution of production networks (Mildenberger, U. 1998, p. 103). The networking model synthesizes the autopoietic Concept of Gradual Autonomy which Teubner created to describe social systems (Teubner, G. 1987) and the scientific Synergetic System Analysis developed by Haken (Haken 1990).

Based on this networking model five essential conditions for sustainable Eco-industrial networks will be proposed and described:

- Selection of networking companies and their waste material streams
- Information and knowledge transfer between the networking companies

- Inter-organizational recycling activities
- System trust (confidence) into the Eco-industrial network
- Strategic guidance of the network by a central institution

Next the environmental situation of the future networking companies at the beginning of the two Eco-industrial network projects in the Austrian Region of Styria (start in 1996) and in the German Region of Oldenburger Münsterland (start in 1997) will be analyzed with reference to the described five conditions. After the selection of the networking companies and their material flows the specific information channels and existing recycling and disposal solutions will be focused as well as the trust between the companies and their waste management partners. Finally the preconditions in both regions for the installation of a central network agency will be highlighted.

The results of this analysis were used for the development of the information and knowledge transfer between the companies in the Eco-industrial networks of (Upper-)Styria and Oldenburger Münsterland.
Therefore a networking centre was installed in the Region of Styria in 1999 and in the Region of Oldenburger Münsterland in 2001. The planning and management activities of these centres were supported by the development of specific REGional Recycling Information Systems (REGRIS) which functions will be decribed.
Both network institutions generated recycling orientated co-operations between the network companies and raised personal trust between the networking managers. As a consequence of the recycling initiatives a network identity was established and system trust (confidence) into the networks as sustainable systems was created.
The long-lasting experiences out of the recycling initiatives supported the development of a service concept for the network agency of the Eco-industrial Network of Oldenburger Münsterland. Afterwards a financing plan for the network centre will be presented which proposes that the income of the agency will be derived mostly from the generated cost saving potentials within the networking members. Finally a communication concept will be described which aims at the promotion of network membership to the companies in the Region of Oldenburger Münsterland.
The presented model of a network centre and the related financial and communication concepts support the institutionlization of Eco-industrial networks to become autopoietic systems. These structures will foster sustainable development on a regional level.

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Asian Model of EIP Developmental Stages

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The environmental conditions at Asia Pacific have been deteriorating through the years of industrialization. The national governments of many economies earlier implemented Command and Control instruments and set up emission standards to monitor the pollution management programs of the industries. New concept of firm-level preventive approach has been successful in gradually replacing the old conventional corrective approaches. The industries, however, realized that the firm-level strategy is quite slow and small in scope. Eco-industrial development (EID) for clustered industry becomes popular in the 1997, with Japan's ecotown program. Thailand and Philippines followed the EID approach in 1998 and promoted the concept throughout Asia during the 1st regional EID conference held in Manila 2001. Each economy then searches for their own fit model in the process of development, converting their conventional industrial park into eco-industrial park (EIP), or building a brand new EIP.

This paper collects the cases, lessons, and mindsets of the projects in Japan, Thailand, Philippines, Korea, Taiwan, China, Vietnam, Australia, Singapore, India, Indonesia, Sri Lanka, and Fiji. This paper adopts a value-adding framework in the utilization of resources within a system, and introduces the four stages of development of eco-industrial park.

The development model attempts to define the scope of the resource management at various levels (e.g. firm, park, community) within and around the system, which can be defined as the industrial park or even a cluster of industrial parks. Often than not, a bigger system boundary will provide an opportunity to achieve higher development stage.

Keyword: eco-industrial development, eco-industrial park, value-added

Session D:
Transition and Societal Change

Chairmen: B. Frostell

Location: Lindstedtsvägen 3
Room: E2.

Physical Principles to Guide Australia's Transition to Sustainability

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The challenge of gaining traction for sustainability science in political, business and institutional settings is bedevilled by an excess of good intention and fine sounding phrases such as 'sustainable growth' and 'sustainable consumption' and a lack of appropriately scaled analyses that present an economy wide view of the environmental content of goods, services and economic activities. There is also the issue of complexity in public policy and the need to give simple but meaningful statements that can guide both corporate planning and public debate. In common with many developed economies, Australia has accepted the concept of sustainability but is struggling with its implementation. This paper will present two streams of enabling process for the sustainability transition. The first proposes six principles of physical sustainability that regions may need to implement at governance, industry and household levels. The second is a boundaryless lifecycle analysis of key resource issues such as energy use, water use and land disturbance.

The first stream proposes high level guidance for the sustainability transition with six key principles that could be implemented over 50 years, at national and regional scales. These are distilled from issues highlighted in nationally scaled 'physical economy' models as well as the international literature. They are currently proposals without full review and testing in traditional science terms. Instead, they represent active responses to national sustainability issues and requests for policy guidance. In addition, they are characterised as dealing with the primary or immediate drivers of environmental change. In the paper, each principle is characterised by five short statements, the first of which describes its function with the rest being technological or institutional elaborations of the principle's intent. The six principles are as follows:

1. Stabilise human population number and age structure
2. Constrain the flows of essential global elements (C, N, P, S, 'H_20')
3. Base society and economy on accessing 'flows' rather than 'stocks'
4. Shorten the supply chain where possible
5. Engineer society for durability and resilience
6. Develop an improved economics where taxes 'tell the truth'

The need to develop such principles is based on life cycle analyses that allow us to quantify the environmental content of all goods and services in an economy without imposing artificial boundaries. This allows the tension between a modern consumption driven economy and physical resource use to be clearly displayed (Figure 1). This graph shows the relationship between per capita spending and the amount of primary energy required that enables this volume and pattern of consumption to occur. The graph depicts a life cycle analysis of the consumption patterns, expressed in energy terms, for several thousand households in Sydney. Three issues challenge current concepts of sustainability policy. The first is that direct energy use, the electricity and gas for our homes and the petrol for our cars, increases only slowly across this range of personal consumption patterns. By comparison, the total energy requirement (direct energy use plus indirect energy use embodied in the full production chain of consumption) rises more rapidly as expenditure rises. There is a 30 fold difference between the lowest and highest spenders in Sydney. The third issue is that while the energy intensity of personal consumption is 50% lower for each dollar spent by more affluent consumers, this seemingly large efficiency gain makes little difference to the total energy required i.e. there is little saturation or plateauing effect across the entire expenditure range in a typical Australian regional area.

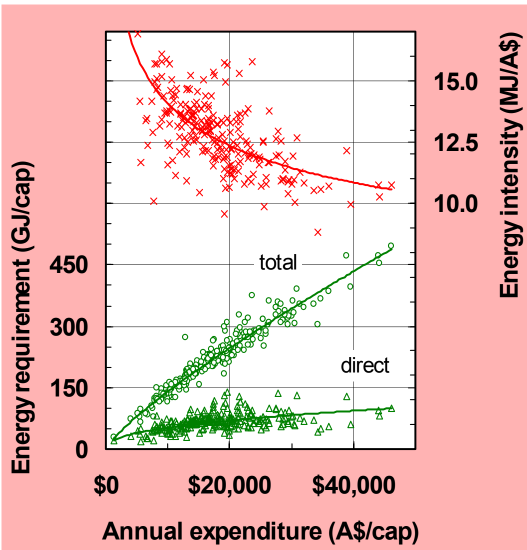

Figure 1. The relationship between per capita discretionary expenditure and the embodied energy in the full life cycle of that expenditure. The figure shows direct requirement (bottom graph), the total requirement for primary energy (middle graph) and the energy intensity (top graph) across the per capita expenditure range collected in the household consumption survey undertaken by the Australian Bureau of Statistics.

In guiding Australia's sustainability transition, it is unclear how the six principles and the nation-wide life cycle analytical techniques can be implemented within institutional settings that have the mandate and power to change the manner in which society operates. Each principle has the potential to disrupt and offend nationally dominant concepts and influential institutions. To date, the implications of the analysis shown in Figure 1 do not find cognition space with any important decision maker. Simply put, it seems to be too challenging for any modern society. Whether good analysis can breach the gap between this presentation of physical reality and institutional change is currently quite unclear.

Socio-technical Transitions and Public Controversy

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Sustainable Development can only be achieved by radical socio-technical change, i.e. changes in technological systems and changes in behavior and institutions. These change processes are called transitions. A delicate issue remains whether we are able to influence transitions or even manage transitions. Managing technology in society (Rip, Schot, Misa, 1995) is an issue that emerged in the 1970s. Many attempts that have been made thus far have not produced eminent results. The CFC ban might be considered one of the few exceptions as it led to a rather successful transition in some industries (Mulder, forthcoming).

Transition management implies an attempt for conscious orchestration of a socio-technical change process at a systems level. In general, costs and benefits of a transition process will not be distributed equally among stakeholders. Moreover, cost and benefits will not all be clearly identifiable, or even quantifiable. In transition processes, consensus on the standards by which to evaluate the costs and benefits of the changes is often even lacking. Transitions often necessitate debates on moral standards in regard to new issues that are raised. Whether a transition is perceived as a positive sum game is therefore far from being a priori clear.

This uncertainty exists at every transition process, no matter if it is managed or spontaneous. Nevertheless, spontaneous transition processes can take place even if negative judgements are almost omnipresent among the stakeholders. If the mechanisms that (seem to) propel a transition process are conceived as beyond individual, group or national control (like Scientific Progress, World economy, etc.) negative judgments are often disregarded. An important factor seems to be that an address for objections is not present. Objecting without an addressee is like Don Quichote's battle against windmill sails. No serious debate can emerge as there is no focal point for decision making.

In transition management, this addressee for objections is present, it is the transition manager. In transition management approaches, various alternatives are generally pursued for prolonged in order not to create sharp conflict. However, it is probably an illusion to presume that transition processes aimed at Sustainable Development will always end up in solutions that are regarded as positive sum games at every level of society. Objections will focus upon the transition manager.

Controversy is will probably heat up as the transition process is perceived as more threatening and more successful.

The transition manager might be trapped in a split: objections cannot be neglected as it will lead to sharper conflict and is contrary to the aim of

Sustainable Development. However, giving in to objections might easily endanger the transition goals and the political legitimacy of the whole process as it will probably endanger its pace.
This paper will give an overview of controversy studies regarding socio-technical change and the factors they identify as leading to the emergence and closure of socio-technical controversy. It will evaluate the occurrence of these factors in transitions related to Sustainable Development such as the introduction of renewable energy, landscape preservation and the replacement of CFCs.

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Social Pressure - A Main Driver for Recycling Paths in Resource Scarce Societies:The Case of Santiago de Cuba

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Goal. This paper analyzes the municipal solid waste sector of Santiago de Cuba. The main issues analyzed are the current consumption and waste disposal patterns of short-lived materials, such as glass, aluminum, organic material and PET.

Methods. We applied the method of material flux analysis (Baccini & Brunner, 1996). The necessary data were gathered with personal interviews using a standardized questionnaire. The sample of households was drawn by a random-route procedure where the interviewers were sent to randomly selected crossroads all over the city. The questionnaires of 1171 households could be used for the analysis. The questionnaire contained questions about socio-demographic variables such as age, sex, education, income, and occupation. The households were asked about how many PET bottles, containers of aluminum (cans, tubes of toothpaste), and containers of glass they use per month and how they dispose of the different kinds of garbage.

System analysis. The consumption/waste disposal system can be described as follows: The goods are delivered from dollar shops, distribution stores for food, and markets for vegetables and fruits. All shops are state-run, no supply from the private sector exists. Households consume the delivered goods. Once consumed households have at least five options to deal with the residues. (i) they can keep and reuse them; e.g. keep a glass bottle to fill it with self made juice; (ii) they can throw them away (trash can), burn them, throw them on the road or in wild garbage dumps; (iii) they can give them to the CDR (Comité de Defensa de la Revolución, revolution defense committee), which is the main collection entity in the city; (iv) they can give them away as a present to relatives or friends; and (v) they can sell them in the "casas de compra", where they will receive for example for twenty empty bottles a filled one.

Results. Regarding weight, glass is the mostly used packaging material with a yearly consumption of 22 kg/cap, followed by PET with 3.3 kg/cap and Aluminum with 1.3 kg/cap. About 75% of the glass packaging is used for beverages (with rum bottles taking a share of over 20%), the rest are hygiene and medicinal goods. PET packaging has the highest share of beverage use

(96%) with an average monthly per capita consumption of about 8 liters. Aluminum packaging is also used mostly for beverages (51%). In addition food (30%) and also hygiene goods, e.g. toothpaste (19%), are still packaged in aluminum.

About 20% of the consumed glass is thrown away, the same share is reused within the household, 4% is given away to relatives or friends. The largest share, 55%, is given to CDR. This is quite remarkable as people would receive filled beverage bottles if they bring the empty bottles to the "casas de compra". Still they choose not to do so but to give their waste bottles to CDR.

Compared to other countries, the recycling rates in Cuba are relatively high, ranging from 50% for PET to 68% for glass. As a comparison, the recycling rates for Germany are 64% for PET and 83% for glass (Deutsches Bundesamt, 2004), the ones of France 1.6% for PET and 16% for glass (Defeuilly & Lupton, 1998).

Comparisons between the "rich" people (highest income quartile) and "poor" people (lowest income quartile) show that consumption of goods increases with increasing income. For glass, the rich consume about 3.5 times more glass then the poor do. However, the waste disposal behavior of both groups does not differ significantly. The largest share of the waste materials (around 50% for all goods) is picked up by CDR. Poor people tend to "sell" a larger share of their waste bottles than rich do. However, even though their share of "to sell" for glass is significantly higher than the one of the high-income group, with 27% it is still much smaller than the one delivered to CDR (52%). One of the main reasons for this behavior is the role that CDR plays beyond collecting the materials. CDR organizes social events in form of regular meetings, parties and demonstrations and it controls social life by informing higher institutions about improper conduct of neighbors. As CDR is organized at the city section level, social control, leads to an incentive to not sell the materials to the "casas de compra" but to give them to CDR and so to benefit from the other activities delivered by CDR.

Conclusions:

- The recycling rates for short-lived goods in Santiago de Cuba are high (50-68%).
- Even though income plays a role determining the amount of consumed material, it does not affect the waste disposal behavior.
- Most of the recyclable goods are not sold but given to CDR, a social organization working at city section level.
- Social control is an important driver determining the recycling paths.

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Session E:
Design for Environment

Chairmen: R. Ramaswamy

Location: Lindstedtsvägen 5
Room:D3

Evaluation Of The Environmental Impact Of Products

An ESTO project for EU/DG Research/IPTS and DG ENTR/DG IND

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In order to identify areas where measures in the context of Integrated Product Policy may be desirable, it is necessary to find out which are the products or product groups that have the greatest environmental impacts. On the initiative of the Institute for Prospective Technological Studies (IPTS) the European Science and Technology Observatory (ESTO) is now executing a study into this issue, called Environmental Impacts of Products (EIPRO). The following ESTO members participate in the study:

- the TNO-CML Centre for Chain Analysis (the Netherlands - Operating Agent/Project Manager) ,
- VITO, Belgium, and
- the Technical University of Denmark

The EIPRO study is based on two pillars:

1. The first pillar is a thorough evaluation and comparison of about 7 relevant studies analysing the environmental impact at European level. This has the advantage that truly European data are used and compared, but the disadvantage that probably not the desired resolution needed in EIPRO can be reached (the final impact of consumption will be allocated to about 50 sub-consumption domains).
2. The second pillar is to transform an Input-Output model for the US, called CEDA 3.0, to a database that reflects the EU-25. This implies the application of several transformation and ‘forcing’ steps that transforms the existing database in such a way that its outcomes comply with known data on total EU-consumption, -emissions, EU-production data in specific sectors, etc. Furthermore, several general deficiencies of Input-Output models have to be solved, such as use- and waste stage emissions. This allows to present results at a high level of resolution (500 product groupings).

Comparison of CEDAEU25 results with those of the existing studies will allow for an assessment of robustness of results. The study will be fully completed at the end of 2004. It will present one of the first EU-wide detailed E-IOA analyses for product policy.

Note: due to the abstract submission deadline, this abstract was quickly submitted by the project manager. It may be that we feel in the end that another person from the team will be more appropriate to present this work. Note as well that his paper could fit under SCP, Product-services and other topics

Determination of Critical Factors That Affect DfE Implementation of Taiwanese Companies by Analytic Hierarchy Process

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Recently, product-oriented regulations, such as the European Union's WEEE Directive (Waste Electronics and Electrical Equipment), RoHS Directive (Restriction of the Use of Certain Hazardous Substance), ELV Directive (End of Life Directive) and others - although not yet in effect - have already put great pressure on multinational enterprises, especially those that manufacture electrical and electronics products. Companies must not only invest in the research and development of greener products to satisfy these regulations, but also require their suppliers to comply with the directives through effective supply chain management. With regard to global supply chains, the EU, the second largest economy in the world, is establishing green product norms for all manufacturers to follow. As original equipment manufacturers (OEMs) and original design manufacturers (ODMs) for various name brand companies worldwide, Taiwanese companies must find innovative ways of maintaining their "license to operate". Taiwanese companies must apply the Design for Environment (DfE) approach to avert this threat. A recent survey revealed that approximately 65% of Taiwan's 3C product manufactures have been asked to provide certification for their products, and the rest (35%) expect to do so in the near future.

Although the situation is serious, "green" issues have never been of priority concern among Taiwanese companies. The factors that cause them to be reluctant in dealing with such issues must be identified. Correspondingly, this work examines the critical factors that most affect Taiwanese companies' attitudes to implementing DfE. A questionnaire was designed from four aspects, i.e., environmental significance, manufacturing costs, product design, and value-added, each containing five sub-factors. Next, questionnaires are mailed to the

top 500 manufacturers in Taiwan and, then, an Analytic Hierarchy Process (AHP) technique is applied to determine the critical factors. Results of this study indicate that the critical factors considered by companies when introducing DfE are as follows: the safety of the products, end-of-life considerations for products, customer demand, time required for research and development and invested capital. Studied companies are divided into two groups - those who have implemented and those that have not implemented DfE. The DfE issue largely concerns firms that are implementing DfE and are in the computer industry (34.2%), followed by those who have not implemented DfE are in the metal and chemistry industries (35%). Results of this study indicate sector discrepancy.

Keyword: Design for Environment, Analytic Hierarchy Process, Critical Factors

Recycling Potential Index (RPI) of materials and parts in End-of-Life vehicle for Design for Recycling

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Every year, end of life vehicles(ELVs) generate about 0.6 million cars and trucks in South Korea. More than 75wt% of the materials and parts from end-of-life vehicles are profitably recovered and recycled by the private sector. In 1997, the European Commission adopted a Proposal for a Directive which aims at making vehicle dismantling and recycling more environmentally friendly, sets clear quantified targets for reuse, recycling and recovery of vehicles and their components and pushes producers to manufacture new vehicles also with a view to their recyclability. In the European Commission, they set the recycling regulation taget value; 85% in 2005, 95% in 2015. For attainment of this goal, it will be needed reducing about the Automatic Shredder Residue, infrastructure and technical development for using effective resources.

The purpose of this research is to construct a materials and parts database using environmental and economic assessessment in the recycling system of end-of-life vehicles (ELVs). This research is about issues and technologies in recycling, both current and future, with a focus on end-of-life vehicles (ELVs). Furthermore, this study includes the issues involved in design for recycling and the existing scrap recycling system.

In this study, the Life cycle assessment (LCA) method was used to evaluate the environmental load in the recycling process of End-of-life vehicles (ELVs). A static economic evaluation method was used in this study. In this method, present market price is employed and future change of technology and market is not taken into account. Total economic value for the material and parts recovery can be calculated using equation (1)

$$\textit{Economic value}_{total} = \underbrace{(C_C - C_D - C_M - C_R + C_S)}_{\text{Dismantler process}} + \underbrace{(-C_C - C_D - C_M - C_R + C_S)}_{\text{Shredder process}} \text{ ------ (1)}$$

C_F: *Collection fee*
C_D: *Disassembly cost*
C_M: *Maintenance cost*
C_R: *Residue disposal cost*
P_S: *Selling price*

We set the system boundary to the end-of-life vehicles (ELVs) recycling system. Fig. 1 shows the recycling process of End-of-life vehicles (ELVs) and the boundary of this research.

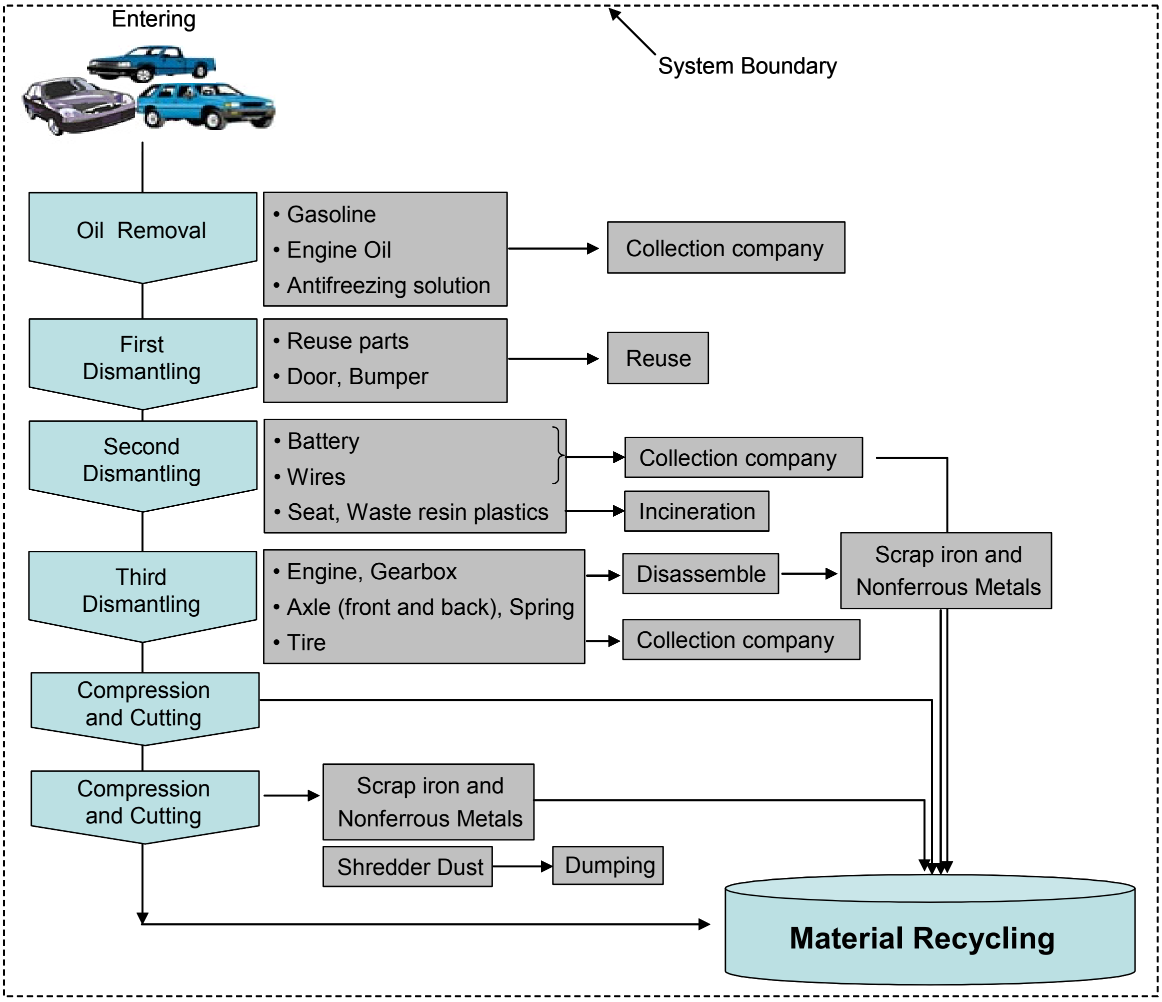

Fig. 1 End-of-life vehicles (ELVs) recycling system

The recycling potential of each material and part can calculate by adding up the environmental score (S_{Env}) and the economic score (S_{Eco}) (equation 2). In equation 2, the weighted value of α and β will be determined by a questionnaire survey.

$$S_{RP} = \alpha S_{Env} + \beta S_{Eco} \quad \text{--------} \ (2)$$

Keywords; End-of-life vehicles (ELVs), Recycling Potential Index, LCA, Design for Recycling

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