International Society for Industrial Ecology

The Science & Culture of Industrial Ecology

Abstracts from the inaugural meeting

12-14 November 2001—The Netherlands

This document features abstracts from talks and posters presented at the inaugural meeting for the International Society for Industrial Ecology (ISIE). The abstracts clearly reflect the diversity and creativity inherent in industrial ecology. The November 2001 meeting was the first of ISIE's many anticipated outlets for encouraging scholars and practitioners to share their ideas and experiences.

If you would like more information about the ISIE, please see our website: www.yale.edu/is4ie

The abstract document is organized into three sections:

With each abstract is a notation as to whether the authors have a full paper available. If you would like a full paper and the notation indicates that "yes" there is one available, please contact the author directly.

This document reflects the program as of 19 October 2001.

Technical Program I

Social Framework I

Radical Reformism: Embedding Industrial Ecology into Modernity

Renato J. Orssatto

Full paper available: Yes

According to a specialised research area within environmental sociology - the ecological modernisation theory - industrial ecology practices are constituents of a broader emergent sociological phenomenon: the radicalisation of modernity. The understanding of the fundamentals of such phenomenon is, therefore, crucial for both the practice and theorisation of industrial ecology. This is the main reason for this paper to approximate the disciplines of environmental sociology and industrial ecology. By delving into the main sources of dynamism that *produced* modernity - the widespread trust in symbolic tokens and expert systems, and the reflexive appropriation of knowledge - the paper argues that industrial ecology practices depend on the creation of new types of expert systems within organisational fields. The paper anchors its main arguments in the research conducted in the European automobile industry - a socio-technical context undergoing ecological modernisation. The main conclusions of the paper relate to nature of reform required for industrial ecology practices to facilitate sustainable industrial development. While radical technological innovations may be necessary, such radicalism in technology may need, however, an incremental institutional reform of modern societies. Together, radical technological innovations and incremental institutional reform constitute the concept of *radical reformism*, which is suggested for enhancement of the ecological modernisation theory, as well as for the development of the normative programmes encompassed by industrial ecology practices.

Integrating Intelligent Trial and Error into Industrial Ecology

Edward Woodhouse, Jack Swearengen, and Jeff Howard

Full paper available: Yes

Industrial Ecology (IE) scholar-practitioners from engineering and the natural sciences tend to write as if clean production and greener design are largely matters of just making more sensible choices. In contrast, social scientists expect rampant disagreement about what constitutes "sensible," count on institutional bottlenecks and organizational dysfunction, and assume that unwelcome surprises and unanticipated side effects are inevitable in any complex new activity. Ought IE take better account of social science thinking in these regards? How?

Section I reviews recent IE literature to document what we see as the relative neglect of disagreement, organizational dynamics, and uncertainty. Section II summarizes social science research concerning a strategy of decision making known as Intelligent Trial and Error (ITE), which assumes that uncertainty and disagreement are inevitable and explains how to cope strategically rather than trying to ignore or banish the problems via analysis. Section III discusses how IE researchers and practitioners might utilize ITE to make their technical-managerial innovations more robust in the face of uncertainty and disagreement.

The analysis is illustrated with examples drawn from manufacturing engineering, industrial design, chemical engineering, and other arenas of technological practice.

Industrial Ecology: The Discipline and Its Relation to the Real World

Kjetil Røine and Martina Keitsch

Full paper available:Yes

Science and its different disciplines are about understanding and interpreting the "real world." Despite the fact that scientists are actors in that world and therefore contribute to the constitution and development of it, it is for analytical reasons appropriate to distinguish between a dis-

ciplinary scheme, based on theory of science, and a real world scheme, based on empirical evidence. This paper proposes to sketch out and connect these two schemes for the emerging discipline of industrial ecology.

In the disciplinary scheme we intend to place core literature of industrial ecology within a framework of theory of science. We will analyse the contributions of Frosch & Gallopoulos (1989), Ehrenfeld (1995) and Graedel & Allenby (1995). The analysis bases on the tripartition of ontology, epistemology and methodology, as one way of characterising and structuring a discipline. Ontology is defined as the theory of understanding the subject, i.e. what do we understand as the subject. Epistemology means the theory of our understanding, i.e. how do we understand the subject, while the methodology is knowledge about the tools we use to interpret, express or describe our understanding. The different approaches of industrial ecology mentioned above, will be positioned in relation to each other in the analysis.

The "real world" scheme will show how the ideas of Frosch & Gallopoulos, Ehrenfeld and Graedel &Allenby on industrial ecology can be located in an empirical framework of reality. Our empirical approach is based on the work of Giddens (1984). Giddens's structuration theory describes the relations and mutual influence between human actions and structures. The structuration theory is our analytical instrument for studying real world subjects.

Our case, the "real world" subject, will be the plastic packaging sector in Norway. The plastic packaging sector in Norway is subject to the implementation of the environmental policy principle, called extended producer responsibility. The analysis will be on the company level in this sector. This concerns the description of how selected companies adopted the implementation of extended producer responsibility regarding their reaction and development to this governmental policy. The selected companies are in different upstream phases of the life cycle and represent some of the largest economical contributors to the EPR system.

The intention of this paper is to develop a framework and a possible methodological tool for the combination of theory, methods and practice of industrial ecology and concrete problems and requirements in companies and administration. The goal is to bridge the gap between the disciplinary and the non-academic self-perception.

Literature

Ehrenfeld, J.R. 1995. Industrial ecology: A strategic framework for product policy and other sustainable practices. In Green Goods, edited by E. Rydén and J. Strahl. Kretsloppsdelegationens rapport 1995:5. Stockholm.

Frosch, R. and N. Gallopoulos (1989). Strategies for Manufacturing. Scientific American. 261 (3): 94 - 102.

Giddens, A. 1984. The constitution of society. Berkeley, CA, University of California Press

Graedel, T. and Allenby, B. 1995. Industrial Ecology, Prentice Hall, Englewood Cliffs, NJ, USA

Do Local Decision-Makers Ask for Substance Flow Analysis?

Annica Lindqvist and Mats Eklund

Full paper available: No

The framework of Industrial Ecology includes several tools (e.g. Material flow analysis (MFA), Substance flow analysis (SFA), Life Cycle Analysis (LCA), Design for Environment (DFE)) that aim to be supportive to environmental decision-making on different organisational levels, such as manufacturing companies, industrial networks and authorities. Seen from this perspective, this paper deals with the potential of SFA to be supportive to environmental decision-making in local authorities.

Being responsible for the overall planning of e.g. waste-treatment and energy in the local territory, Swedish local authorities play a vital role in management of different substance, material and energy flows. Since this includes management of complex societal systems that incorporates a large number of different actors such as citizens, industries and municipal owned companies, they are most likely benefited from information describing the overall interactions, both within these systems, and between the systems and the environment. However, SFA, or other flow-oriented approaches, are not yet com-

monly used as tools for strategic environmental decision-making in Swedish local authorities. Thus, one has to ask the question what information needs is actually identified for strategic environmental decision-making by the local authorities, and does the tool of SFA respond to these needs. Furthermore, another question is if SFA generate an improved basis for decision-making as compared to traditional environmental monitoring used in local authorities. If not, there is a risk of the methodology of SFA to become separated from the environmental decision-making process, and thus not supportive for the policy-makers.

The paper discusses results from interviews with officers at the environmental administrations and politicians on the local level in three structurally different municipalities in Sweden. With the aim of studying if there is a need for the kind of information from flow-oriented studies like SFA, the interviewees were asked about i) their need for information about the environmental situation ii) their need for information about interactions between different actors in the system being managed iii) if they experience a lack of information in environmental decision-making of the local authority iv) the information they required for prioritisation between different environmental issues etc. The results from the interviews are then compared to the results from previously performed SFA in these municipalities and the concept of SFA as described in literature.

Theory in Substance Flow Analysis

Integrating an Actor-Oriented Perspective into Regional Resource Management

Susanne Kytzia, Mireille Faist, and Peter Baccini

Full paper available: Yes

In the last decades a variety of tools have been developed to give an answer to the question which environmental problems are associated with which economic activity (e.g. Substance Flow Analysis or Life Cycle Assessment). Yet, they have failed to combine this investigation with an analysis of the system's economic driving forces. This paper introduces a method to combine both aspects in a joint analysis. It is based on a Substance Flow Analysis, which investigates material and energy flows in a functionally defined sub-system of a regional economy. A study of economic aspects is included by additionally gathering data on money flows, which correspond to the flows of material or energy. The processes of material transformation, transportation and storage are defined and interpreted as social systems within their institutional framework. The findings from both material, energy and money flow analyses are combined in a classification scheme according to their economic or ecological relevance.

This method is applied on the food production and consumption chain. It reveals two areas of improvement: (a) animal production and derived products and (b) refrigerating/sub-zero storage and responsible products. Economic actors in area (a) are very sensitive to changes because animal production and derived products dominate agricultural production as well as sales volumes in the food sector. Resource management strategies in area (b) will get much less attention if they focus on technological improvements because costs for cooling installations are comparatively low. But if the strategies focus on sales volumes of refrigerated or deep frozen products the reaction of economic actors will be stronger because they are likely to expect a continuing market growth. Based on the first application in the case study "food production and consumption" we conclude that our method is a first step towards a joint analysis of economic, technical and natural parameters in a material management system. Further development will focus on the money flow analysis and aims at a differentiated analysis which is more closely linked to economic theory.

Study on Development of Environmental Indicators for Evaluation of Organic Resource Cycle System

Toru Matsumoto and Hidefumi Imura

Full paper available: Yes

Economic development in Japan after World War II has brought about a number of dramatic changes in the lifestyle of the Japanese people in relation to their dietary habits. These changes have been associated with the changing production and consumption patterns of food, and have caused significant changes to the organic resource cycle. This paper attempts to discuss the environmental indicators that effectively represent the present organic-matter resource cycle of food origin. For this, material flow and environmental load pertinent to the complete chain of human activities related to food consumption and production are analyzed for the case of Fukuoka city, based on methodologies of Substance Flow Analysis (SFA) and Life Cycle Assessment (LCA). Activities include the agricultural sector, food processing industry, food distribution, equipment for food storage and preparation, food service, household activities of cooking and eating, and management of the disposal and recycling of food and packaging waste. The parameters that control the organic-matter resource cycle were defined, and a sensitivity analysis of the environmental indicators at the time of introducing countermeasures was performed.

Indicators for Chemical Product Input in Different Sectors: Possibilities to Include Chemical Products in Environmental Accounts

Viveka Palm and Kristina Jonsson

Full paper available: No

Environmental accounting is a system designed to combine environmental and economic data. Due to the complexity of chemical use, data covering issues on toxicity are normally not included in the systems. We would like to suggest some broad chemical product indicators, adapted to fit into environmental accounting. They give a picture of the national consumption of chemical products, divided between different branches. Depending on the choice of aggregation method and system boundary the magnitude of hazardous chemical products in Sweden lies between 30 and 40 million tonnes, approximately equivalent to 3 or 4 tonnes/ capita and year. Two different aggregation methods are chosen. The broadest method starts with the EU-classification of inherent risks. The other method is based on the companies' own risk labelling of products, according to the risk for chronic diseases. Major hazardous chemical product groups are petroleum based products with between 25 – 30 million tonnes per year, depending on method. Major groups are chemical products with cancerogenic and health hazardous properties, mainly petrol and diesel.

GREAT-ER—A New Decision Support Tool for Management and Risk Assessment of Chemicals in River Basins—Potential Applications for the EU Water Framework Directive

Diederik Schowanek and Tom C.J. Feijtel

Full paper available: No

The GREAT-ER (Geo-referenced Regional Exposure Assessment Tool for European Rivers) project team has developed and validated an accurate aquatic chemical exposure prediction tool for use within environmental risk assessment schemes. The software system GREAT-ER 1.0 calculates the distribution of predicted environmental concentrations (PECs) of consumer chemicals and industrial point sources in surface waters, for individual river stretches as well as for entire catchments. The system uses an ARC/INFO - ArcView (TM-ESRI) based Geographical Information System (GIS) for data storage and visualization, combined with simple mathematical models for prediction of chemical fate. At present, the system contains information for four catchments in Yorkshire, one catchment in Italy, one in Belgium and three in Germany, while other river basins are being added. GREAT-ER 1.0 is currently being expanded with models for the terrestrial (diffuse input), air and estuarine compartments to become a multi-environmental GIS-based chemical exposure assessment tool. The paper will illustrate a number of applications of the model in the context of chemical risk assessment and the EU Water Framework Directive.

Thermodynamics

Exergy, Emergy, and Life Cycle Assessment

Bhavik R. Bakshi, Jorge L. Hau, and Nandan U. Ukidwe

Full paper available: Yes

Life Cycle Assessment (LCA) has emerged as an important tool for incorporating environmental considerations in engineering. It expands the scope of typical engineering decision making beyond the traditional process or equipment scale to the global scale. Before LCA, many techniques have been developed for considering environmental aspects of processes at the equipment and process scale. These techniques are useful for pollution prevention and for enhancing process efficiency, and include, exergy analysis, energy integration, mass exchange networks, and pinch technology. Like other engineering methods, these methods are based on sound principles of thermodynamics. In contrast, methods for analysis at a global scale such as, LCA lack a thermodynamic framework. Although several researchers (Ayres et al., 1998; Connelly and Koshland, 1997) have identified the relevance of thermodynamics to LCA and industrial ecology, a framework for thermodynamically based analysis at the global scale is still missing.

This presentation will propose a rigorous thermodynamic framework for LCA and for including the contribution of ecological goods and services into engineering decision making. The framework is based on combining the methods of exergy analysis, emergy analysis and life cycle impact assessment. Exergy analysis is a popular approach for the analysis of individual equipment and processes, and has also been suggested as an approach for quantifying resource consumption and the impact of emissions in LCA. However, neither exergy analysis nor LCA account for the contribution of ecological products and services that are essential for any activity. Emergy analysis is another thermodynamic approach developed and used mainly by systems ecologists for analyzing ecosystems. Unlike exergy analysis and LCA, it accounts for the contribution of nature's products and services such as, rain, wind, photosynthesis, soil, petroleum, etc. However, emergy analysis does not consider the impact of emissions.

This presentation will discuss the relationship between exergy and emergy, and show that they are complementary properties. It will be shown that emergy is thermodynamically equivalent to the cumulative exergy of consumption calculated all the way to solar energy. Traditionally, exergy and cumulative exergy analysis consider all resources to be similar in terms of their ecological investment. Consequently, these methods do not consider the ecological services required to create different natural resources. Emergy analysis shows that this assumption is flawed, since the ecological investment in making a resource such as, coal can be significantly different from that for making limestone, wood or rain. Thus, emergy analysis can be used to extend exergy analysis beyond the scale of artificial (man-made) processes, all the way to the basic sources of energy and their flow through the ecosystem. The resulting approach can account for the fact that the ecological investment in natural resources can vary significantly. The relationship between terminology used in emergy and exergy analysis such as, transformity and cumulative degree of perfection will also be clarified. Establishing this link between exergy and emergy analysis allows the expansion of exergy based engineering approaches to include ecological products and services. The resulting analysis is more complete than that by existing methods, since it accounts for all the hidden flows or externalities.

A thermodynamic framework for LCA cannot be complete without thermodynamic methods for assessing the impact of emissions. From a thermodynamic point of view, the impact of emissions may be measured by the emergy required to absorb the impact or the exergy loss of the impacted system. For example, the impact of acid rain may be measured in terms of the emergy of the trees, forest, lakes, and organisms that are affected by the increase in acidity.

The practical challenges in implementing the proposed framework will be identified, and some approaches for meeting the challenges will be presented. Information about the exergy and emergy of inputs may be obtained from life cycle inventory databases or from economic input-output tables. Shortcomings of these approaches and benefits of using materials flow analysis at a

sectoral level will be discussed. For thermodynamic impact assessment, practical methods for converting the results of an impact assessment method such as, Ecoindicator-99, into corresponding emergy input will be presented. Finally, illustrative case studies based on the industrial chlor-alkali process, and the life cycle of soybean oil will demonstrate the synergy between exergy and emergy analysis, and the thermodynamic approach for impact assessment.

References

Ayres, R. U., Ayres, K., Martinas, L., Exergy, waste accounting, and life-cycle analysis, Energy, 23, 355, 1998.

Connelly L., Koshland C. P., Two aspects of consumption: Using an energy-based measure of degradation to advance the theory and implementation of industrial ecology

Resource Conservation and Recycling.19, 3, 199-217, 1997.

Entropy Production as a Measure for Resource Use Applied to Metallurgical Processes.

Stefan Goessling

Full paper available: Yes

One of the main components of evaluating industrial processes according to their ecological impact is measuring their overall use of natural resources. According to the second law of thermodynamics, 'use' or 'consumption' is really transformation of matter and energy to a physically less useful state. The physical measure for this transformation is the accompanying production of entropy. Therefore an obvious measure, although rarely used, for the resource use of a process is the associated entropy production.

When streams of matter and energy pass through an industrial process, they are transferred to a number of output streams, at least one of which is called a product. Considering a steady-state process, as are many industrial processes, the total entropy content of the output streams has to be higher than that of the input streams. The difference, the produced entropy, is a direct measure of how much the matter and energy passing through the process have been degraded. Degradation is to be understood in its physical meaning as loss of the ability to perform work. Applying an entropy balance to the inventory of any given process facilitates the calculation of the internal entropy production, thereby reducing the large amount of data to a single number proportional to the overall resource use. When comparing the entropy production of all steps within a process chain, one can pinpoint the location with highest resource use, indicating a good starting point for optimisation strategies. Comparing different process alternatives, one can identify the one with lower resource use, indicating a lesser ecological impact.

The method of entropy balancing has been applied to case studies in the metallurgical sector, namely primary and secondary copper production. The processes that have been studied in particular were the flash smelter, the converter, the anode furnace and the electrolytic refinery. It could be shown that the main entropy production during the production of one ton of refined copper takes place in the flash smelting unit, followed by the converter.

Nevertheless, comparing the entropy production with the 'service' of the process at hand (i.e. the increase in copper concentration), it was found that the converter and the falsh smelter also have the highest 'entropic efficiency'. On the contrary, anode furnace and electrolytic refinery contribute only little to the copper concentration increase but have an entropy production of the same order of magnitude as the other two processes which makes them significantly less efficient in the sense of overall resource use. Further investigating the main sources of entropy production resulted in the identification of possible starting points for optimisation.

Other key examples, like space heating and energy conversion, have been worked out. Entropy balancing has been compared to similar approaches which try to aggregate process inventories in order to yield a measure of resource use. These are cumulative energy consumption, the MIPS concept and exergy analysis. Comparing results with the complementary method of exergy analysis yields good agreement.

Thermodynamics Applied. Where? Why?

Gerard Hirs

Full paper available: Yes

In recent years thermodynamics has been applied in a number of new fields leading to a greater societal impact. The paper gives a survey of these new fields and the reasons why these applications are important. In addition it is shown that the number of fields could be even greater in the future and could lead to savings in human effort, use of land and water and of energy and natural resources. Achieving these savings is a contribution to a sustainable society.

Entropy as a Quality Measure for Industrial Metals Management

Helmut Rechberger

Full paper available: No

The objective of establishing material balances is to better understand industrial metabolism and to provide a basis for decision making in resource and environmental management. Industrial management of metals shows the following pattern: metals are extracted from ores and concentrated, refined, and shaped through several process steps. The resulting semi-finished products are used for the manufacturing and fabrication of a multitude of goods and products. These goods are consumed, used, and installed in infrastructure. Once they become obsolete, materials can be recycled, disposed of, or hibernate in the infrastructure.

Statistical entropy (SE) is introduced as a metric to evaluate the contribution of each process (e.g., milling of ores) to the whole systems' (e.g., Europe) overall metal management. Generally, SE is a tool to quantify the variance of a distribution of a property of any system. It can be shown that a substance balance can be defined by the properties "mass-flows of materials" and "substance concentrations". Applying SE to these properties yields a normalized metric in the range between [0,1], the relative statistical entropy (RSE). The RSE is zero (0) if the system or process maximally concentrates the investigated substance. The RSE is unity (1) if dilution or emission maximally dissipates the substance.

Today's metal management is characterized by the following RSE trends: Production of metal products with high purity (>99%) from ores (1-5%) decreases RSE-values from around 0.5 to <0.1. Manufacturing and fabrication of consumer goods increase entropy. Depending on the use pattern of the metal this increase can be moderate to high (0.2<RSE<0.4). Installing goods in the infrastructure results in another entropy increase (0.4<RSE<0.6). Waste management can reduce the entropy again by concentrating metals. It is shown that today this is not efficient since recycling rates could be higher. However, even the contribution of an optimized waste management is limited. This is due to the fact that the still growing stock in the infrastructure serves as a buffer for waste management. Once the residence time of the stock has expired waste management will have to accept greater amounts of wastes. Then an optimized system can reduce the RSE to levels below 0.2.

The overall trend in the RSE from ore extraction to landfilling of wastes varies among different metals. First results indicate that copper shows a decreasing trend across its life cycle and may serve as a model for future metals management. On the other hand zinc clearly shows an increasing trend marking non-sustainable management. This is mainly due to dissipative use of zinc in products (chemicals, pharmaceuticals, etc.) and galvanizing of steel. Also emissions from galvanized products have the potential to increase entropy significantly.

Statistical entropy reinforces a better understanding of industrial metabolism. Material balances of complex systems are quantified by a single metric. Hence scenarios and alternatives can be easily compared. In combination with other criteria optimized systems can be designed. The results show that entropy is a useful and accurate indicator for the quality of substance management by any system.

Theory in Corporate Integration

Environmental Communication of Japanese Industry

Midori Aoyagi-Usui

Full paper available: No

We investigated the Environmental communication strategies of Japanese industry. Our respondents are Japanese companies, who published or planned to publish "The environmental report". We focus on the relationship between stakeholders' response and changing strategies of companies' environmental information disclosure. We found the companies who received objections from stakeholders about their environmental countermeasures are more likely to disclose their environmental information.

Organisational Challenges to Industrial Ecology—A Comparative Analysis of Three Companies' Efforts to Develop Environmentally Responsible Corporate Cultures

Thomas Dahl, Øivind Hagen and Stig Larssæther

Full paper available: Yes

The concept of Industrial Ecology represents a holistic view on industrial systems' impact on the environment. At the same time there seems to be a trend in industry to expand the system borders of production units and to view each unit as a part of a bigger value chain.

This paper presents a study of three manufacturing companies' efforts to develop their production-processes and marketing in line with principles of industrial ecology. The companies represent a variety of product spectres and have their factories and sales offices in several countries, mostly Europe, but also the US. All have their main quarters in Norway.

The companies have been concerned with finding methods for recycling and to integrate their products into larger recycling loops. While technical solutions to problems in some of the recycling systems can easily be found, it seems more difficult to work with the organisational issues connected to introducing industrial ecology. One major challenge for all three companies has been to include proactive environmental thinking in production processes and strategic actions. Handling environmental aspects is in general not seen as the core activity, and is often regarded as an extra burden instead of a business opportunity. One explanation is that the reward systems of the companies are not stimulating environmental thinking to the extent necessary in order to compete with other pressing interests. This might be a symptom indicating that green issues have not been integrated into the deeper levels of the organisational culture, although the environment holds a rather central position in the images these companies project to their markets. Our findings also indicate that we in all three companies find internal forces with slightly different value systems and stronger ambitions towards a proactive environmental strategy than the dominating positions. The actual environmental performance of the companies can thus be seen as the result of an ongoing negotiation between different meanings on core competence and strategic importance of environmental issues in product development and market communication.

Innovation Strategies – Impacts on Economic, Ecological and Social Co-Management

Raimund Schwendner

Full paper available: Yes

This paper will be dealing with the integration of technological and organizational innovation strategies, creating a variety of processes, instruments and quality criteria for economic, ecological and social co-development. These strategies are expected to meet sharp management requirements for effective system integration and mutual learning. They have to support both human resource and organizational development.

As a counterpart to incremental co-evolution, the *co-management* of economic, ecological and social development has to create and speed up

"triple-win-strategies". They are designed to add high level value to economic development and to serve ecological and cultural diversity as well. This will affect a number of issues:

1) Evaluation of Economic Perspectives:
   a) Comprehense "innovation-based value" and "sustainable quality"
   b) Redesign reward systems within peer groups and organizational networks
   c) Master heterogeneous problem solving strategies
2) Process of Ecological-Economic Goal Setting:
   a) Analyse multi-focal effectors, indicators, ambiguous factors and meta factors
   b) Implement mutual learning and negotiation strategies
   c) Initiate interactive paradigm management on both regional and organizational levels
3) Leadership capabilities:
   a) Improve integrated leadership within organizational networks
   b) Redesign network information and communication
   c) Link shareholder-, stakeholder- and sustainable value management

Interactive innovation strategies are helpful to establish and link both economic and ecological sustainability, coping with a variety of social challenges. As a model, this may be helpful to improve economic, ecological and social co-development in general.

The paper will offer a variety of analytical and methodological procedures such as effector analysis, mutual value analysis, interactive scenario learning and multi-project management. To meet the challenge of comprehensive sustainability, such instruments have to be adapted to technological, organizational and regional utilization. They are useful to amalgamate many-sided efforts of co-development. In order to gain excellent results, this approach will involve different styles of creativity and problem solving strategies. This includes corporate as well as customer oriented coaching and network-based „self-controlling". Further more, the "trilogy of capability" will be of crucial importance, including

1) the evaluation of relevant criteria which are associated with the subtext (meaning), context (circumstances) and supratext (transformability) of innovation strategies,
2) initiative management, and
3) preventive risk and conflict management.

Theory in Life Cycle Assessment

Towards a More Credible Handling of Environmental Values in LCA Studies.

Magnus Bengtsson

Full paper available: Yes

In many life cycle studies, impact assessment methods that include weighting between environmental issues are used to make sense of the results of the inventory analysis. The way in which this value laden element of LCA is handled can be important for the credibility of the conclusions drawn, especially when these are communicated to people who have not been involved in the life cycle study in question. The present research study can be seen as a test of how the results of some existing and widely used LCA weighting methods are received by different kinds of actors (e.g. people working for environmental authorities, industrial companies, NGOs and fund managers). The research approach is qualitative: reactions and discussions of weighting and weighting methods are recorded through group interviews. Issues dealt with include: the acceptance for weighting of different environmental changes as such, the parameters included in (and not included in) different methods, the underlying principle of the methods, the outcome of different methods when these are applied to product cases. Statistical significance is not the aim of this kind of studies. The purpose is rather to investigate whether qualitatively different "logics," i.e. ways of thinking and reasoning about environmental weighting, can be discerned. Knowledge of such mental or cultural patterns is important when life cycle studies are carried out and when results are communicated to various actors. Hence, the study is expected to give enhanced understanding of how weighting can be handled in a more credible manner in life cycle studies. These results will be useful both for further methods development, for the

work of LCA practitioners and for the various audiences for LCA results.

Life Cycle Activity Analysis: An Optimizing Approach to Industrial Ecology

Fausto Freire and Sten Thore

Full paper available: Yes

Life Cycle Activity Analysis (LCAA); a mathematical programming decision support model for the optimization of the entire life cycle of products; is presented. LCAA is a new tool for the mapping of hierarchical production and recovery chains, their impact on the environment, and for a holistic evaluation of new technologies, environmental strategies or policies. LCAA involves three successive stages of analysis: i) a description of all participating activities (processing, transport, use, recovery) as a product travels from its "cradle" to its "grave", including the inventory of ancillary materials and energy supplied to each activity, economic costs and environmental burdens; ii) the formulation and numerical solution of a linear or nonlinear mathematical programming model and iii) the evaluation of a set of environmental scenarios of interest to policy-makers or stake-holders.

The application of LCAA is illustrated using case studies brought from the Portuguese and European market for bottles, tires and plastic components. The potential of LCAA, the type of problems to be addressed, and its relevance to environmental policy in the context of industrial ecology are further explored.

Risk Trade-off Analysis of Demand-side Management: Combining Life-Cycle Assessment and Risk Assessment

Yurika Nishioka, Jonathan I. Levy, Gregory A. Norris, Andrew Wilson, Patrick Hofstetter, and John D. Spengler

Full paper available: No

Increased residential insulation can potentially provide environmental and public health benefits, given reduced emissions from power plants and residential fuel combustion. Quantification of these benefits could assist in developing energy codes that are socially optimal, considering both economic and environmental endpoints. Within this study, we construct a combined life cycle assessment and risk assessment, with the goal of estimating the public health benefits of increasing residential insulation for new housing from current practice to the latest International Energy Conservation Code. We model state-by-state residential energy savings and evaluate particulate matter (PM2.5), NOx, and SO2 emission reductions. To estimate public health benefits, we use regional dispersion models coupled with exposure efficiency concepts to estimate exposure. We determine concentration-response functions for premature mortality and selected morbidity outcomes using current epidemiological knowledge of effects of PM2.5 (primary and secondary). Our analysis of the population risks associated with the reduced end-use energy consumption shows that the concentration reduction of air pollutants is not necessarily proportional to the health benefits. One unit of pollutant concentration reduction is more effective in reducing health effects in areas that are more densely populated than where there is less population density. As the next step, in order to assess the net benefits of this policy decision, we consider three impact pathways in addition to the population risk reduction from the reduced end-use energy consumption; (1) a decrease in the processing of fuel sources, leading to a decrease in population and worker exposure to air pollutants from the upstream process chains of fuel source processing activities; (2) an increase in the processing of insulation, leading to an increase in population and worker exposure to air pollutants from the upstream process chains of insulation manufacturing activities; and (3) changes in indoor quality associated with increased insulation in the building envelope, leading to changes in exposure of occupants to indoor pollutants. For the analysis of population risks associated with the upstream impact pathways, we propose combining economic input-output LCA with exposure efficiency concepts to estimate population risks. Economic input-output LCA may be complemented by information from the process-based LCA to disaggregate sectors into sub-sectors that

produce more specific commodities. For the calculation of risks to workers, we propose using industrial injury and fatality statistics within the input-output LCA for the short-term occupational health effects. For the long-term health effects to workers and home occupants, we propose using epidemiological studies and estimates of production changes to estimate risks. By aggregating the health endpoints of each impact pathway in terms of disability-adjusted life years (DALYs) and the monetized values, these public health benefits are compared with the cost implications for homeowners (i.e., installation and operating costs) to determine the influence of external costs on benefit-cost calculations.

Spatial Economics

The Evolution of Industrial Symbiotic Networks - The Case of Kalundborg

Noel Brings Jacobsen and Stefan Anderberg

Full paper available: Yes

The concept of "industrial symbiosis" has during the last decade attracted increasing attention in many countries in all parts of the world. The eco-industrial park in Kalundborg is one of the most internationally well-known examples of a local network for exchanging waste products between industrial producers. It is an example of a spontaneous network, which have evolved over a period of several decades. Inspired by network theory, this paper presents an analysis of the evolution of the Kalundborg symbiosis and discusses what can be learned from this case, that is of general value for the realization of local industrial-symbiotic networks. The aim is to improve the understanding of the complex local development dynamics behind industrial symbiotic networks. The analysis includes physical preconditions and possibilities as well local economic and environmental effects of the realizations, but focusses particularly here on identifying central mechanisms, including technological, institutional, organizational, economic and mental elements, behind the development of the symbiotic network of Kalundborg. A framework for different mechanisms, which both shape opportunities and create barriers to the development of industrial symbiosis will be presented and discussed. Even if the Kalundborg symbiosis in many respects is quite particular, insights in this case should definitely be able to contribute with new dimensions to the planning of eco-industrial parks.

Self-organization, Cooperation and Industrial Symbiosis

Marco A. Janssen and Frank Boons

Full paper available: Yes

Industrial symbiosis engages separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water and/or by-products (Chertow, 2000). The concept of industrial symbiosis is inspired from concrete realizations of eco-industrial parks, such as in Kalundborg, Denmark. The few examples of success have been evolved spontaneously. In various countries governmental policy is focuses on creating industrial symbiosis. However, these policies fail to stimulate required long-term cooperation between firms. In this paper we will try to understand why current policies are doomed to fail. To address this question we will discuss recent concepts on self-organization and cooperation. This will provide insights under which conditions cooperation can emerge and persist. Furthermore, by translating these insights to industrial parks can extract suggestions for improving policy.

Waste Management Policies: An Applied General Equilibrium Analysis

Heleen Bartelings, Ekko C. van Ierland, and Rob Dellink

Full paper available: Yes

Current waste management policies are not sufficient to obtain a significant reduction in waste generation of both industries and households. Waste generation is too high due to certain characteristics of the waste market, for instance flat assessment pricing for treatment of

solid waste and regulations that indirectly promote the use of virgin materials in the waste market. This paper presents an empirical modeling analysis of the efficiency of current waste management policies and calculates the social costs of waste generation. The goal of this paper is to show that social costs of waste management are inefficiently high and that these costs can be reduced by changing certain characteristics in the waste market.

An applied general equilibrium model is developed to simulate the waste market. The model describes a national economy with three (ordinary) production sectors, an extraction sector, a recycling sector, a municipality as collector of solid waste, three waste treatment sectors (i.e. composting, incineration and landfilling) and two consumer sectors. Some attention will be given to the spatial aspects of waste treatment by introducing transportation costs for transporting waste from the municipality to the waste treatment sector. The model is applied on the waste market in The Netherlands. The results show that the specific characteristics of the waste market cause a sub-optimal level of waste generation and hence significantly higher social costs for waste treatment.

Recycling, International Trade and the Environment: An Empirical Analysis

Pieter J.H. van Beukering

Full paper available: Yes

Over the last decades of the 20th century a large number of countries have experiences a substantial increase in materials recycling. During the same period, the international trade of recyclable materials between developed countries and developing countries has grown as well. A specific trade pattern gas emerged: waste materials recovered in developing countries are exported to developing countries for recycling.

This contribution will discuss the economic and environmental significance of the simultaneous increase in trade and recycling of recyclable materials.

Technical Program II

Social Framework II

The Social and Political Context of Industrial Ecology: Extrapolations on the Theory of Ecological Modernization

Maurie J. Cohen

Full paper available: Yes

The social and political theory of ecological modernization seeks to situate industrial ecology and current developments pertaining to the sphere of social-environmental reform within a broader social scientific context. Theorists have sought to use ecological modernization to understand new political configurations moving environmental policymaking away from conventional reactive command-and-control regulatory measures toward proactive engagement and a fuller appreciation of notions of sustainability. During most of the past decade researchers have focussed their attention primarily on the political and economic realignments that will be necessary to facilitate ecological modernity and more complete acceptance of the principles of industrial ecology. This paper will provide a historical overview of the theory of ecological modernization and highlight recent attempts to address the cultural underpinnings that are likely prerequisites for the enthusiastic embrace of industrial ecology and its allied fields.

Ecological Modernisation

Yasuhiko Hotta

Full paper available: Yes

Along the development of environmental politics school in 1990s, environmental political discourse of Ecological Modernisation has become one of the most important focuses of study of environmental politics in industrialised society. Ecological Modernisation represents the idea that economic growth and environmental protection are essentially complementary (J. Dryzek, "The Politics of the Earth", Oxford: Oxford, 1997: 15). And environmental problems are considered as

opportunities rather than troubles to a restructuring of the capitalist political economy along more environmentally sound lines (ibid.: 141). From this point of view, industrial ecology is an expression of Ecological Modernisation whose main focus is on restructuring of industrial system.

This paper tries to situate concept of industrial ecology in ecological modernisation discourse. At the same time, this paper argues that ecological modernisation initiatives including industrial ecology promotes the idea of eco-efficiency and voluntary regulation to encourage the active participation from private industrial sector in environmental policy making. These initiatives have a very similar character promoted transnationally. Domestic environmental initiatives are incorporated with transnational environmental initiatives. This trend represents a legitimisation process of shift of private industrial and corporate sector into playing a significant role in a transnational political arena. This paper emphasizes the significant role of this legitimisation process by transnational discourse coalitions among international organizations, private business entities, network of academia, national agencies and NGOs in transnational environmental policy making.

Material Culture – A Critical Missing Dimension in Industrial Ecology

Chris Ryan

From the framework of Industrial Ecology the critical (and productive) points to intervene in the current industrial eco-system seem clear. In the author's research institution, four approaches to changing current systems of production and consumption have been identified. These approaches do not define new systems, they reflect a mix of pragmatic and theoretical/conceptual starting points for system change. These approaches raise important questions about the conceptualisation of the 'system' which is the subject of analysis and action. This is particularly clear when it comes to the issue of consumption and most evident in those approaches which seek to significantly reduce material flows by 'dematerialisation' ('servicisation' etc). It is apparent that the 'system' cannot be adequately described in terms of technical, material, logistic and economic aspects. The value of material things, as one aspect of the system which significantly affects the consumption of products cannot effectively be reduced to attributes of function, cost, availability, material flow. The value of things incorporates aspects of human behaviour and perception, opening up what economists like to portray as the irrational within the system. Attempts to deal with real systems change have to engage with complex issues of why things are consumed, invariably leading to a search for 'underlying' causes and the all too easy simplification of ascribing outcomes to biophysical 'needs', or manipulated 'wants', or displaced 'desires'. This paper will examine some characteristic examples of such thinking encountered in the context of approaches to systems change. It proposes a broad framework to build up knowledge in this critical area, bringing together work in a number of areas/disciplines around a new 'field' referred to as Material Culture, building on work from design studies.

Postindustrial Ecology

Gregory Unruh

Successful industrial ecology experiments and public policy efforts are creating interconnected technological systems that minimize currently recognized environmental disutilities. This paper argues, however, that combined institutional frameworks and technological systems are subject to numerous sources of "irreversibility" which can lock-in these systems for extended periods of time. Designers of industrial ecosystems naturally focus on solving current problems and, because of the complexity of the natural world, are largely unaware of potential future problems these systems may create. There are numerous historic examples of technological "solutions" that solve one environmental problem only to create another: the automobile as the turn-of the-century solution to horse wastes being an infamous example. Recognition of this tendency requires industrial ecologists and policy makers to design evolution, both technological and institutional, into their industrial ecosystems and policies.

Corporate Integration in Practice

"Resource Management" (RM) Contracting

Paul Ligon and Tom Votta

Full paper available: No

Contracts are pervasive in the solid waste field and directly influence the way in which approximately two-thirds of the US waste stream is managed. In addition to municipal solid waste, hundreds of millions of tons of construction and demolition, nonhazardous industrial waste, and hazardous wastes are managed through contractual arrangements. Although widespread, contractual relationships have generally not been viewed as a mechanism for advancing pollution prevention or "resource efficiency." An emerging concept called "resource management" (RM) contracting seeks to address this issue.

Typical organizational disposal contracts send exactly the wrong economic signal to waste management contractors: more waste equals more profit. RM contracts cap disposal compensation and provide direct financial incentives to contractors that identify and implement cost-effective, resource efficient source reduction and recovery options. Thus, if a contractor identifies new or improved markets for disposed materials, or options for preventing waste altogether, they receive a portion of the savings resulting from the innovation. This arrangement enhances recovery of readily recyclable materials such as corrugated cardboard and wood pallets, while producing tangible source reduction and market development for difficult to recover materials such as paint sludge and solvents.

The concept of using contractual relationships to reduce, not just handle, waste is a novel idea that is attracting increasing attention in both industry and government. The General Motors (GM) corporation, for example, a leader in the development and use of RM contracting, has realized substantial benefits as a result of RM contracting. One year after implementing RM contracts at most of its North American Plants, GM realized a 20% reduction in overall waste generation (30,000 tons), a 65% increase in recycling (from 50,000 tons to over 82,000 tons), and a 30% decrease in waste management costs. Total disposal at GM plants that have implemented RM to date has declined by more 50% as a result of RM contracting. Similar results are expected at other Midwest organizations that are pursuing development of RM contracts, including the City of Omaha, ConAgra, Inc., West Des Moines School District, and various others. Based on this experience.

By changing the ways in which organizations demand and incentivize integrated waste management services, RM has the potential to transform the waste disposal industry into an industry that profits from mutually beneficial resource efficiency gains, rather than ever increasing quantities of waste. Widespread diffusion of RM promises to be one of the single most important drivers to source reduction, recycling, and recovery in the next decade.

The proposed presentation will address RM contracting practices and present RM results and techniques from diverse demonstration organizations throughout the nation that are participating in the Tellus Institute's national initiative to advance RM contracting.

Environmental-Economic Supply Chain Management of Suppliers, Contract Manufacturers and Recyclers: The Big Challenge of an Original Equipment Manufacturer (OEM)

Menno Nagel

Full paper available: No

The supply chain of an OEM contains much diversity. It contains semiconductors, printed boards etc., but also recyclers and contract manufacturers. The life cycle of products contains the Component Realization Process (CRP), Product Realization Process (PRP), Product Use Process (PUP) and Product End-of-Life Process (PEP). From a supply chain approach the CRP is managed with global applicable Environmental Performance Tools, which generate a performance per supplier. Based on the performance suppliers can be ranked, compared, classified etc. and a proposed price reduction can be derived. The linkage and balance between a bad performance and a big proposed price reduction and vice versa is the environmental-economic cornerstone in

suppliers' negotiations. This linkage transfers environmental quality into the scope of Total Cost of Ownership (TCO). In this scope the result of a worldwide assessment of 25 printed board production facilities will be shown. Currently, the OEMs are outsourcing the product assembly to contract manufacturers. The contract manufacturers are a part of the PRP and should be managed from a supply chain approach. They are service providers to the OEM. For the owning of the service the TCO-elements as product quality, delivery and price have been integrated into the negotiations, but not the environmental performance of the assembly site. Other service providers are recyclers, which are a part of the PEP should be managed as well. For the owning of this service the TCO-elements as product mass, the material content and price are a part of the negotiations, but not the environmental performance of the recycler itself. In both supply chains the ranking, comparison etc. from an environmental perspective and the linkage to proposed price reductions is not investigated. This problem is researched from the experience in the CRP supply chain. This paper will outline the new challenges from a strategic view.

STABIS—An Integrated Environmental Management Tool

Alfred Posch

Full paper available: No

Environmental management is no longer a voluntary minor matter but is rather becoming a critical executive function. Although many organizations have already implemented an environmental management system (EMS) according to international standards, in particular the ISO 14000 series and the EMAS regulation, the integration of the EMS in their conventional managerial decision support systems is usually lacking. However, focussing only on monetary objectives can easily lead to negative environmental impact while actions concentrating exclusively on sustainability may lack acceptance because of high costs or other negative economic consequences. In order to make economically and ecologically efficient decisions a common database is necessary. This is the starting-point of our R&D-project STABIS. STABIS stands for the German term "Stoffstromanalyse-, Bewertungs- und InformationsSystem". This means that an integrated managerial information system based on the analysis of material flows as well as on the economic and ecological assessment of clearly defined systems is to be developed. The objective of STABIS is to provide a tool that enables industry to achieve a holistic knowledge-based environmental management approach. First questions concerning the overall vision and mission, the environmental objectives and targets of the company, existing legal and other requirements and restrictions, need to be answered. On the basis of this first analysis a customized configuration of STABIS can be undertaken. A core function of this tool is to analyse technical-physical as well as economic data of identified critical processes or materials. It is crucial that STABIS must not be a stand alone solution.

Hence, data-gathering has to start in the existing enterprise-resource-planning system (ERP) of the specific organization. Only data that is not contained in the ERP has to be provided additionally, e.g. by manual data-entry or other existing stand alone applications. Data redundancy in different information systems within the same organization should thus be avoided, data integrity and compatibility reached.

Concerning the possibilities for data-retrieval, the user interface has to support changing demands without requiring modification of the environmental management tool. The database of STABIS has to be edited and processed in a way that different levels of analytical detail can easily be required. While top management is likely to prefer highly aggregated information lower management levels might have more detailed output needs.

The most critical success factor of developing STABIS is the transformation of the environmental targets into a comprehensive set of performance measures that provides the framework for a continual environmental evaluation of the organisation's activities. Since STABIS claims to be an integrated environmental management tool it is crucial to combine environmental and economic performance measures in a way that provides decision makers with an appropriate set of measures.

This integration in existing management information and decision support systems depends strongly on the tools applied in the specific organization and can be reached for example by extending any existing Balanced Scorecard Management Program (Kaplan/Norton) or as part of so-called benchmarking activities.

Case Study: "Green" Construction and Environmental Management System Implementation at a Small Parts Manufacturing Facility Using the Concepts of Industrial Ecology

James Russell and Walter H. Peters

Full paper available: No

During the last 400 years, human knowledge and the concurrent use of power have developed exponentially. The fruits of this labor can be summed up as modern life and modern conveniences in the developed world. However, these conveniences have come at a cost. Human systems have grown so large that they are at risk of overwhelming the biological systems in which they are embedded. As scientific knowledge and understanding has increased, the realization that the earth is a complex system full of interactions and interrelationships among the biota, land, atmosphere, and oceans has developed along with the realization that human activities are intimately tied into these systems. Even though they play an ever-increasing role in earth systems, human activities are currently not coordinated with or integrated into earth systems in a coherent manner. This research intends to explore the interactions between industrial activities (including the built environment and manufacturing activities) and earth systems in order to devise decision-making and design methodologies that help create solutions which bring industrial activity into coherence with earth systems.

This case study describes the process including necessary requirements and major problems associated with constructing and operating a small parts manufacturing facility in the midlands of South Carolina using the concepts of industrial ecology. Major areas of discussion include:

- Facility Siting
- Facility Design
- Facility Construction
- Environmental Management System Implementation
- Input output analysis using IE concepts
- Identifying aspects and impacts using IE concepts
- Setting and carrying out goals

Modeling

Substance Flow Normalisation

Anders Grimvall and Erik Löfving

Full paper available: No

Substance flow analyses are normally carried out to detect or elucidate long-term trends in the human impact on the environment. However, the data collected for such purposes can be strongly influenced by short- and medium-term fluctuations. Temporal variation in weather conditions can cause spurious trends in substance fluxes in the natural environment, and production and consumption levels vary with the business cycles. This raises the question of how comparisons over time or across populations can be facilitated by some kind of data pre-treatment aimed at suppressing irrelevant variation. In several sciences, different types of normalization or standardization techniques have long been used. For example, there is a strong tradition of using indices to suppress irrelevant variation in economic time series of data. In the environmental sciences, regression-based normalization techniques predominate. Several authors have demonstrated that a substantial part of the temporal fluctuations in the deposition of atmospheric pollutants can be explained by variation in wind direction, temperature and the amount of precipitation. A few scientists have normalized substance flows in rivers to a given water discharge. In this paper we first review the major principles of normalizing time series of data, and then we discuss in what respects existing procedures need to be modified to the meet the demands on such procedures for the analysis of temporal trends in substance flows. More precisely, we show that

the normalization techniques used in economics and the environmental sciences have a common theoretical framework that can be given a simple probabilistic interpretation. Furthermore, we discuss how normalization of substance flow data can be accomplished without violating fundamental mass balances. The methods proposed are illustrated with empirical data regarding nitrogen fluxes in the biosphere and the technosphere.

MFA Modelling

Ruben Huele, Ester van der Voet, and René Kleijn

Full paper available: Yes

The quantity of emissions from an economic system is determined by both the size of the flows involved and by the technological infrastructure through which the materials are flowing. Emissions can be reduced either by volume based policies (?), which reduce the size of the flows, or by transforming the technological infrastructure, reducing the leakage from the system into the environment. The distinction is reflected in the mathematical representation of the technological infrastructure as a Markov chain and the flows as an initial state of the system. The approach assumes a dynamic model, for which the static model is a special case. By standard linear algebra elegant measures can be derived to describe the system.

Based on data from a simplified case of nitrogen flows in the Netherlands, the method is illustrated.

Infrastructure Ecology

G.P.J. Dijkema, J.R. Ehrenfeld, E.V.Verhoef, and M.A. Reuter

Full paper available: Yes

Infrastructures represent a special class of integrated complex systems. We conjecture that design and management of infrastructures can greatly benefit from the concepts developed by industrial ecologists.

Industrial Ecology is a newly emerged multidisciplinary discipline, which launch was marked by the books of Allenby, Graedel and others. It is seen by its advocates both as a mechanism to support sustainability in industry, and as a novel paradigm or toolkit that will help to establish integrated complexes of industrial plants.

The ecology analogy not only involves complex structures, however, but also the concept of systems that incorporate mechanism that enable effective response to a dynamic environment. Indeed, in a number of infrastructures a major concern is whether the relatively inflexible hardware in the infrastructure sectors can be adequately designed and managed to keep up with increasing external dynamics. Liberalisation, market forces, shifting regulation and new business strategy models have initiated changes in the companies and public bodies that own parts of these infrastructures. At the same time vertical unbundling of integrated companies is in progress, whilst new forms of horizontal bundling emerge that lead to convergence of infrastructures. Per company, production and service activity portfolios are being reshuffled, separated, demerged or outsourced. The new relationships established in the infrastructure sectors must been enabled by new and existing infrastructure hardware.

In our contribution, an overview is given on the R&D into the application of Industrial Ecology to infrastructure analysis, design and management that we label ‘Infrastructure Ecology’. The validity of the ecology analogy is tested for a number of important infrastructures. Some infrastructure developments identified by using the Infrastructure Ecology analogy will be described. Finally, a set of issues to be addressed in Infrastructure Ecology will be formulated as elements of a research agenda.

Ecology provides a rich source of inspiration for the elucidation of man-made systems, and we give examples of he analogies largely fall into three classes.

1) the analogy in system structure between our industrial society and nature (eco)-systems provides a useful insight into the position of infrastructures in our industrial system
2) as an example in analogy of complex system operation we addressed different modes of competition.
3) we addressed sustainability a desirable characteristic of ecosystems desirable for industrial systems

As the body of knowledge of Ecology is vast, and the application to infrastructures appears to be limited, it is to early for a research agenda, other than one that says: explore the body-of-knowledge of ecology. Notably the notion of Evolutionary Ecology, and the concepts developed therein appear promising for some Infrastructure Ecology, as extensive infrastructure systems evolve, largely in response to the regulatory and market conditions prevailing. Thus by learning from the mechanisms and drivers of evolution of populations and communities and their interrelationships we may be able to learn something useful to develop the proper conditions for stakeholders interaction that lead to sustainable infrastructure development.

MFA in National Economies I

Key Questions to MFA for National Economies

Marina Fischer-Kowalski

Full paper available: No

For the first time now we are in the favourable situation of seeing a large number of countries presenting their "material flow accounts" on a national level, often for longer time series, done on the basis of similar accounting methods. Indicators like "direct material input" (DMI), "total material requirement" (TMR), "domestic material consumption" (DMC) and "domestic material output" (DPO) have been calculated for a number of countries, and have been related to population numbers and economic performance. EUROSTAT, the European Statistical Office, has recently issued guidelines on how to calculate these indicators, and OECD has established a workgroup for a similar purpose. It is now high time for the scientists involved in this field to critically review their achievements, to see what substantive, methodological and political lessons can be learned from this broad spectrum of national experiences.

My contribution shall serve as an introductory framework to this series of panels on "bulk MFA"; this is why I will concentrate on posing questions that should invite answers from the part of the panelists, rather than attempting to give these answers myself.

1) In doing (bulk) material flow analysis for national economies, have we by now arrived at sound methods? Do national MFAs generate comparable results? Where are the key weaknesses of our methods? What are the most important, and the most promising directions of methodological improvements?
2) Do we operate with adequate concepts and indicators? Do we properly understand their meaning? Do we position these concepts within appropriate frameworks? (Frameworks such as environmental impacts, green accounting, physical scale of economies, modes of subsistence and life styles, material intensity and efficiency…)
3) Do we, with the help of our basic model and our indicators, properly understand the dynamics of socio-economic metabolism, and do we understand ongoing change? Can we deal with the role of technological change? Can we analyse problems of intragenerational equity (such as North-South exchanges), and problems of intergenerational equity? Ho well do we understand the metabolic impact of affluence and economic growth, and how well do we understand the impact of population dynamics?

Are we able to provide actors with an appropriate understanding of environmental risk and sustainability problems? What relevant intervention strategies are we able to propose, and to which actors? What are the major problems we should be able to contribute in finding solutions?

I shall confine myself to options, to pros and cons, how these questions could possibly be answered, and hope for the other panelists to pick up some of them and contribute their own answers.

The Role of MFA Indicators in the EU Sustainable Development Strategy

Anton Steuer

Abstract unavailable

Material Flow Analysis for the European Union and Beyond —Implications for Statistics and Policy

Stefan Bringezu,

Full paper available: No

The metabolism of the EU-15 was analyzed to provide indicators on the volume and composition of total inputs and outputs, on the efficiency of resource use, and the balance of inputs and outputs was used to measure the physical growth of the economy. Three major results are of special concern for policy and future accounting practices. (1) Resource requirements are increasingly being shifted to foreign regions which limits the value of pure (supra-)national accounts; the use of Direct Material Input (DMI) as a proxy for Total Material Requirement (TMR) will be discussed based on regression analysis. (2) There is a shift of outflows to the environment from deposition on land towards emission into the atmosphere which reveals the limits of traditional waste accounting and policy. (3) The physical growth of the technosphere represents an increasing threat to sustainability, and linkages are required to land use accounts and management. In all cases, results and interpretation critically depend on accounting conventions. Obstacles and possibilities for improved international harmonization will be discussed.

Lessons from Japanese MFA

Yuichi Moriguchi

Full paper available: No

Japan highly depends on imported natural resources, which are often accompanied by environmental significance. Intensive import of timbers harvested from tropical rainforest has been a typical issue. Japan's participation to an OECD's pilot study on natural resource accounting in the beginning of 1990s was driven by such context. On the other hand, material flow analysis/accounting (MFA) was studied mainly to respond to the domestic issues of increasing solid wastes. A schematic chart describing Japan's macroscopic material flow balance has been published on the annual 'Quality of the Environment' report, what we call 'White Paper' since its 1992 edition. Dissemination of an English edition of the report created the opportunities for European MFA experts to involve Japan to international collaborative efforts in this field.

The main focus of international joint MFA studies, of which outcomes were published twice by WRI, was put on the development of indicators and the comparison of their numbers/historical trends. The results were disseminated to broader Japanese audiences through another mandated 'White Paper' on material cycles, of which first edition was just published in the summer 2001. A key phrase "mass-production, mass-consumption and mass-disposal" is often used to characterize the society today with material-intensive production-consumption pattern and life-style. The nation- wide MFA meets the needs to quantitatively describe the state of such situation.

Beside this mainstream of the nation-wide MFA, there are considerable existing stock and future potential of other inter-related studies; those on environmentally extended economic input-output analysis, emission inventories of Green house gases and other pollutants, waste prevention and recycling indicators, consideration of 'hidden flows (or ecological rucksacks)' within life-cycle assessment, and so on.

However, there still remain many issues to be solved. The most critical problem is data availability; in particular, poor availability for estimating imported hidden flows. Institutional/statistical backing for data gathering and compilation is not sufficient. To meet the policy needs for MFA from waste prevention and recycling, many detailed technical issues have to be discussed. Disaggregation of MFA by industrial sectors and by type of materials is another challenging research subject, in order to link indicators and policy measures for improving environmental efficiency of industrial activities. If this disaggregation of MFA is made consistently with economic input-output tables, it will provide us with further opportunity of integrated analysis of material cycles and the economy. We may also have to learn from the experiences of analogous studies at more microscopic levels, such as material flow cost accounting at a corporate level, material flow analysis within the Zero-Emission initiative.

Industrial Symbiosis I

Building Partnerships for Sustainable Development

Phillip E. Barnes

Full paper available: No

A model for symbiotic partnerships is built through utilizing a geographic information system (GIS) database to design an ecological approach to economic development. Based on an open systems concept where organisms interact with their environment and change according to external events or stimuli, planned economic development can be better controlled by utilizing tools that provide organizational leaders with information to measure the influence of these events or stimuli on their ecosystems.

As living ecosystems, all organizations: government, industry, NGOs, municipalities, interact in a dynamic environment. The organizations feed, (input) produce waste (output) multiply (through expansion and growth) and die (mergers, takeovers, failing) Through sustainable planning and partnerships, the organization, such as an industrial site or company operating within a community, can utilize technologies to strengthen partnership information flows, which enhance sustainable growth and development.

The GIS database model presented in this paper demonstrates the effectiveness of partnerships in the development of waste exchanges, brownfield inventories, resource requirements, entrepreneurial development, and organized communication flows. Shown on various scales of networks, the database builds a foundation for decision-making that will benefit economic development efforts within a defined area, e.g., municipality, county, state, region, etc.

The GIS database model will accomplish three main objectives for sustainable development initiatives:

1) Provide information necessary for proper sustainable development planning within identified areas
2) Enhance entrepreneurial activity in regard to abandon site redevelopment through business incubators based on sustainable business design
3) Establish networks intended to create a symbiosis effective, which will propagate the ecological benefits of partnership development

Sustainability in an Eco-Industrial Park

Jane Powell

Full paper available: Yes

Lifecycle assessment has traditionally been used to determine the environmental impacts of products, but there has been a move to expand this concept to services such as waste management. This paper will examine if it is feasible and appropriate to extend the LCA concept even further to assess the environmental consequences of an eco-industrial park. This will also involve concepts such as eco-design, industrial ecology and materials flow analysis.

An eco-industrial park is a group of industries that seek to maximise their use of resources and minimise their impact on the environment. This is achieved through collaboration and inter-company partnering. In addition to the minimisation of individual uses of energy and material resources, collaboration between the companies can lead to closed loops of material and energy use. Where a particular waste stream does not have a re-use value it may be used as an energy resource, recovering both heat and electricity.

This paper will introduce a new EC funded project; to design an integrated industrial system for the optimisation of energy and materials for a new eco-industrial park in Langhe, Northern Italy. The project includes the layout and building design, the use of alternative building materials, the development of an integrated information system, and the use of LCA and related methodologies to establish the environmental impacts resource and energy flows and the design of alternative technologies.

The main topic of this paper is if and how LCA, and other related techniques, can be used in such a broad, holistic study. Can the various assessment techniques be integrated and used to determine if an eco-industrial park can truly meet the mandate of sustainability?

Building a New Eco-Park in Santa Perpètua de Mogoda (Catalonia)

Xavier Gabarrell Durany and Teresa Vicent Huguet

Full paper available: Yes

Industrial ecosystems are theoretically an attractive idea, although not many practical cases have been developed. This communication considers the prerequisites to successfully transform a already existing industrial estate into an ecopark. Santa Perpètua de Mogoda is a city located near Barcelona that has several industrial estates. In December 1998 the Municipality considered the conversion of two of them (Can Roca and Urvassa) into an ecopark. During two years, an interdisciplinary scientific group from the UAB has been preparing the strategic steps to follow to achieve such change. The study had two different parts: diagnosis and planning phase. In the diagnosis, a forum in which the firms participated, and the educational target actions played an important role. At this moment, the elected politicians are evaluating the study to decide its total implementation.

Some of the characteristic of this industrial estates are: at the present moment more than 100 enterprises are installed there; most of them have less than 50 workers; the industrial sectors are diverse; there are no major firms; the cooperation and the knowledge among them are very poor. So, at the beginning, it seems that these are not the best one conditions to apply the industrial ecology.

The intention of this communication is to present the methodology followed, the obstacles found, the relationships between the different decision-makers, and to show that industrial ecological principles can also be used with medium and small enterprises.

Closing the Loop

System Modelling for Decision Support in Industrial Ecology

Roland Clift, Warren Mellor, Elizabeth Williams, Adisa Azapagic, and Gary Stevens

Full paper available: Yes

This paper will present a modelling approach developed to inform decisions over the routing of materials through a sequence of different economic applications, over logistic systems for distribution and collection, and hence over supply-chain relationships needed for the development of the Industrial Ecology. The modelling approach – CHAin Management of Products: CHAMP – combines Life Cycle Assessment and Process System Analysis. It has been developed in collaboration with a group of industrial companies representing all parts of the supply chain and potential industrial ecology for thermoplastic polymers, from polymer production through different products to end-of-first-life material management and recovery.

CHAMP has been formulated so that it applies to individual materials, components and complete products. The properties of a material at any point in the industrial ecology are characterised by a set of technical characteristics termed utilities. The elements of the utility vector include intrinsic and extrinsic material properties such as (for polymers) impact strength, density and hardness. They also include geographical location; this enables distribution and collection to be included within the same overall model framework as processing operations. Each activity within a system modelled using CHAMP is described by the changes it brings about in the utility set of materials passing through the operation and by its costs of operations and its environmental interventions or impacts. The environmental effects are treated on a life cycle basis by including the complete supply chains of energy and materials used by the activity.

Routing of materials through the network making up the industrial ecology is controlled by acceptance gates which check whether a ma-

terial is suitable for entry into any specific activity or for routing to a possible subsequent activity. Where the material properties are unacceptable, it can be routed to another activity either by the investigator or automatically by the model software. In this way a full model of the possible industrial ecology can be built up to investigate, for example, alternative scenarios, the effect of new processes or applications, and whether specific processes or additives shut off possible avenues for recovery and re-use.

The CHAMP methodology has been used by the industrial participants, and has led to redesign of some products – and, in one case, development of a new product – and of a major logistics system for recovery and re-use of containers. The combination of material processing and logistics within a common framework has proved to be particularly valuable.

The approach is now being extended to the most widely-used metals. Essentially the same framework is used, but with some differences due to the longer service lives of metals in applications other than packaging.

Evaluating Alternative Life-Cycle Strategies for Electrical Appliances by Waste Input-Output Model

Shinichiro Nakamura and Yasushi Kondo

Full paper available: Yes

Impacts of three alternative life-cycle strategies for electrical home appliances on economic activity, waste emission, and landfill consumption are analyzed by use of the Waste Input Output Model (WIO) [1]. The WIO table (the database for WIO model) is an accounting system that integrates the conventional Economic Input-Output (EIO) table with the inter-sectoral flow of waste via emission, treatment, recycling, and final disposal. The current research is based on a WIO table for Japan for 1995 that comprises of 80 industrial sectors, 30 waste types, and 3 waste treatment processes. While the WIO model is similar to the EIO model in many respects, the former is fundamentally different from the latter in its observation of material balance of waste, and in the integration of engineering system model of waste treatment. Using the WIO we can evaluate impacts of alternative product life-cycle strategies on the emission of waste including carbon dioxide, landfill consumption, and economic activity such as sectoral output and employment.

The first life-cycle strategy we consider is the open loop "material recycling" of the type represented by the home appliances recycling law that was put into effect in Japan this spring. The second refers to "reuse" strategy where parts of discarded appliance (plastics) are reused in the manufacturing of new appliances, subject to the implementation of design for disassembly (DFD). The major difference between the two strategies consists in the way recovered plastics are used, and in the efficiency of disassembling processes. Under the recycling strategy, the recovered plastics are mixed and of law quality which could be used as reduction agents in steel making, but not as materials for appliances. The third strategy is concerned with the extension of products life by increased maintenance and updating efforts. We find that both the reuse and maintenance & updating strategies outperform the recycling strategy in terms of environmental impacts (carbon dioxide and landfill consumption), whereas the latter could have significant negative impacts on the economy conditional on the relationship between the reduction in the demand for new products and the increase in the demand for maintenance service. Reuse turned out to be effective in reducing both landfill consumption and CO2 emission without significant reverse effects on the economy.

References:

1) Nakamura, Shinichiro: Input-Output Analysis of Waste Cycles, First International Symposium on Environmentally Conscious Design and Inverse Manufacturing, Proceedings, IEEE Computer Society, Los Alamitos, 1999, pp.475-480.

The Economics of Downcycling

Danilo Pelletiere

Full paper available: Yes

The downcycling of goods, materials and energy from their highest to lowest use after pro-

duction and prior to disposal is an important element of industrial ecology. There appear to be many instances where what no longer has value to one consumer or process has value to another. It is the belief that such transfers can be carried out economically as they occur in natural ecosystems that drives much of the research in industrial ecology and related fields. What can economics tell us about downcycling? How does economics explain why downcycling that might appear "economical" does not occur? This paper will provide a basic review of the economics of downcycling and how it might explain the apparent failure of economically efficient economies to be resource efficient. The first part of the paper provides a treetops overview progressing from a discussion of how downcycling does not occur under orthodox economic assumptions through the various types of market distortions in which it might emerge, including transportation costs, spatially heterogeneous factor distributions, imperfect information, the presence of distortionary policies, and fundamentally different perceptions of human behavior. The second part of the paper provides an illustration of how these factors come into play in the international trade in used automobiles. This paper is based on on-going dissertation research.

Technical Program III

Education

Practical Experience in Teaching Industrial Ecology to International Students at a European Technological University

Saul M. Lemkowitz, Geert H. Lameris, and Gijsbert Korevaar

Full paper available: Yes

Industrial Ecology has been taught annually at Delft University of Technology as a separate, introductory course since 1999. It is a small (2-3 credit points) elective course given in English to international under- and graduate students using, as basic text, Industrial Ecology: Policy Framework and Implementation, by B.R. Allenby (Prentice Hall, 1999). This is augmented as necessary by articles from journals, magazines, and newspapers.

While Industrial Ecology has only been given over the last three years, it is based on integration of academic areas with a much longer development at Delft University. These include: risk analysis; science, technology and society studies (STS); didactics; and sustainable technology. The first three have been developing for 25 years or more at Delft. Risk analysis is largely technical; STS-studies stress critical examination of societal basics, like institutions and worldviews. Didactic studies stress good teaching methods. The last area, sustainable technology, goes back only four years. While it also incorporates elements of the first three areas, it concentrates on sustainable design - what this is and how to achieve it.

The organisation and content of the course follows largely from Allenby's book. But, as noted above, this is augmented firstly with lectures and literature critical to the concept of Industrial Ecology, or certain applications (e.g. Earth-scale engineering) and, secondly, by more detailed literature when deemed necessary (e.g. external costs; risk; complexity). Important to note is that, with the exception of some introductory lectures, the students give the lectures themselves and direct the group activities per sitting. Students wind up the course with a short essay applying the principles of Industrial Ecology to a practical problem, like automotive transport. Student-teacher interaction is intense and occurs largely as between equals.

We have good experience in teaching Industrial Ecology this way. Our engineering students find the basic concepts of Industrial Ecology, as presented by Allenby, easy to understand, even though they find the book challenging to read (being non-native speakers reading a book written by an American lawyer). More importantly, they become enthusiastic about their own study by grasping that Industrial Ecology integrates their technical discipline (e.g. chemical or civil engineering) into a 'holistic' approach for achieving a more sustainable world - this without presenting a trivialised picture of technology as, in itself, the great techno-saviour of humanity.

But problems remain. Chief amongst these is

that while students find the principles easy to understand, applying them to a practical example is anything but simple. Good case studies would greatly facilitate teaching.

Based on our experience, we discuss effective and critical teaching of an introductory course on Industrial Ecology to university students from different engineering disciplines, including plans for improvement.

Industrial Ecology Curriculum at NTNU - An Interdisciplinary Approach

Martina Maria Keitsch

Full paper available: Yes

The Norwegian University of Science and Technology is the second largest university in Norway with 18.000 students. For the main profile is technological higher education and research, NTNU intends, however, to be a university of technological and societal correspondence. Thus, particular programmes are dedicated to interactions between technology and natural science on the one hand and humanities and social sciences on the other hand. The Industrial Ecology Programme is one of the main concepts to realise multi- and interdisciplinarity at NTNU. It started in 1993 supported by Norsk Hydro and in fellowship with MIT and was formally launched in August 1998, as a comprehensive and long-term interdisciplinary programme.

Characterising the industrial ecology curriculum and research at NTNU can be illustrated by sketching out two domains. The first called "ecological modernisation" concentrate on the micro and meso level - it seeks to order and optimise operations on specific sectors like for example product design, product use, cleaner production, sustainable energy use, waste minimisation and environmental management. However, ecological modernisation marks not an isolated strategy but acts in a wider frame. It is influenced by questions such as: "How to satisfy the needs of the present without depleting the achievement of the needs of future generations?" The answers point straight to social issues, as companies and consumers actions and clearly implicate prescriptive and normative dimensions instead of merely empirical, technological or economical responses. Ecologically desirable transformations might cause material and as well as social conflicts. To manage those difficulties "structural ecologisation" provides a corresponding plan to ecological modernisation. It acts upon a macro level within fields like economy, sciences, politics and education, bases on the idea to modify the perceptions and the interpretations of environmental values in general, and works broadly and enduringly problem preventing. The two domains represent the fields of industrial ecology as well as industrial ecology invite researchers to combine projects from natural sciences and technologies on one hand with projects from humanities and social sciences on the other.

Industrial Ecology is implemented on different education and research levels - from the beginners' phase up to Ph.D. studies and Post-doctoral inquiries. The PhD. Course: "Industrial Ecology - theoretical and methodological approach to multi-disciplinary research" considers that students, working with sustainability and industrial ecology, often come from different disciplines. In their PhD thesis the students are asked to integrate theories, ideas and methods from several areas in their work. The course shall make the students capable to understand, analyse and combine those unlike perspectives, while they focus on their particular case. The course should firstly give support to develop an individual research design for the students' concrete case. Secondly, it should advance the interaction between the "Two cultures" -a goal which is inherently tied to the concept of industrial ecology.

Environmental Issues in Manufacturing for Engineers: An Interdisciplinary Course at Northeastern University

Jacqueline Isaacs

Full paper available: No

Incorporation of interdisciplinary courses that address environmental and economic issues in materials processing into an engineering curriculum brings a necessary component for fostering broader perspectives for students. Students must be given opportunities to develop skill sets (e.g., effective communication, critical thinking, infor-

mation literacy and interpersonal skills) that stimulate life long learning, especially with regard to the new ABET 2000 accreditation criteria. These skill sets become enhanced for undergraduate and graduate students who participate in courses that involve active learning in teams and case studies.

Case methodology in research has long been lauded as an effective method for rigorously addressing research hypotheses. Application of these methods in teaching encourages students to ask how" and "why" questions on their own. By addressing these questions using a case-based method of instruction, students must apply and hone their critical thinking skills, e.g. defining issues, using sound reasoning, and making decisions. Interactive interdisciplinary courses offer an essential route to fostering and raising the environmental literacy of undergraduate and graduate engineering students.

Environmental issues are not usually "cut and dry" problems with simple answers; rather, these issues are interconnected with many other aspects, including technological and economic constraints. An opportunity to debate these issues, exchanging knowledge and points-of-view on the repercussions of various engineering technologies and design choices, is a valuable addition to the engineering curriculum.

The course, entitled "Economic and Environmental Issues in Product Manufacturing", is offered both as an upper-class technical elective and as a graduate course in the Department of Mechanical, Industrial and Manufacturing Engineering. In this course, students explore environmental and economic aspects of different materials used in a product throughout the life cycle and are introduced to concepts of industrial ecology, life cycle analysis and technical cost modeling. Students, working in teams, analyze case studies of specific products fabricated using metals, ceramics, polymers and paper. In these case studies, students compare cost, energy, resources used and emissions generated through the mining, refining, manufacture, use and disposal stages of the product life cycle. Students debate issues in legislation – manufacturer take-back, packaging, ecolabeling - and issues in disposal strategies - landfill, incineration, reuse and recycling. They also examine difficulties associated with environmental impact assessments, and the development of decision analysis tools to weigh the tradeoffs in technical, economic and environmental performance. To stimulate class discussion, visiting lecturers from industry give overviews of issues as seen from their perspective. During the course, students assess alternative materials used for beverage can manufacture, using technical cost models and LCA comparisons. Difficulties associated with environmental impact assessments, and the development of decision analysis tools to weigh the tradeoffs in technical, economic and environmental performance are discussed.

On overview of the course will be presented, along with an assessment of the past four offerings of the course. Students in mechanical, industrial, civil and chemical engineering have participated in the course, offering interesting perspectives to discussions. Group presentations, class participation, quizzes and written reports provide means for student assessment.

Education: Industrial Ecology through the Lens of Product Design

Ann Thorpe

Full paper available: Yes

We've often heard it said that a product designer shouldn't have to become an environmental scientist. Rather, the designer must be able to ask the right questions. This paper argues that in order to contribute to industrial ecology, a designer does in fact need to become an environmental scientist, in the same way that product designers must become ergonomic specialists, marketers/psychologists, manufacturing engineers and artists. These latter four are the traditional areas of knowledge for product design. We need to add a fifth area of knowledge: sustainability.

By "knowledge of sustainability" we mean an understanding of three inter-related systems—natural, cultural and economic. The paper argues that designers need this framework as a basis for understanding and then contributing to industrial ecology.

The paper profiles two case studies that illustrate how this framework can be integrated into design education. The first case documents how

sustainable design can be put into a "special event" class within a traditional industrial design curriculum in the US context. In this case the students were not asked to become environmental scientists. The second case documents the current and ongoing effort to integrate this new area of knowledge throughout the curriculum in a BA (Hons) product design course in the UK, where students are asked to learn principles of environmental science and use scientific concepts to develop and evaluate sustainable design proposals.

The paper explores the possible role for designers with respect to industrial ecology, suggesting that young designers who are currently being educated could have more leverage given the proper tools. In addition, the paper addresses issues of assessment, teaching tools, and the problem of finding the right expertise to build the class or curriculum.

Sustainable Cities/Tourism

Integrated Urban Planning and Estimation System for Recycle Oriented Sustainable City

Tsuyoshi Fujita and Tohru Morioka

Full paper available: Yes

The relationship between urban form and sustainability is one of the most urgent concerns both for urban planners and environmental policy makers. Decades of growing urbanization in the 20th century, which have enabled massive industrial accumulation as well as continual intra and inter migration of population from rural areas to urban and peripheral areas, brought various tangible and intangible environmental costs not only for the cities themselves but the surrounding regions as well as the nation and the global environments.

While several plans and concepts have been proposed such as growth management, sustainable planning, compact city, or industrial symbiosis, those concepts need to be defined from implementational planning and policy perspectives in order to identify the appropriate urban management strategies for a long run. In this paper, authors attempt to establish the planning and estimation systems which provide planning alternatives to cover wide range of urban management tools such as spatial management, energy supply management, transportation management, and material resource management, as well as provide objective estimation indicators for urban utility and environmental impacts.

After various planning concepts and implementations are surveyed such as compact city theory, sustainable development and its application for urban management, planning alternatives for a century- long urban environment management are firstly proposed. Alternative planning options for a long-run urban management are discussed organized. They constitute of those in spatial management business-as-usual type spatial control which allow sprawl development in peripheral areas, mono-centric compact city type control, and multi-central compact city type control schedules. Practicality and conditions to implement those options are also discussed. Other option categories include those for energy supply system, transportation system, and material resource management system, namely recycle centers for building wastes. Relationships among different management options are investigated and combination of management options are brought as the strategic management scenarios. Indicators to compare the different scenarios and options are discussed and eco-efficiency estimation process is proposed scoping on carbon dioxide and solid wastes as primary factors for environmental impacts.

Secondly, land use patterns for Osaka City are projects for one hundred years from 2000 based on the existing locational data of buildings and their duration period functions and environmental impacts for different scenarios and options are investigated. The following results are obtained: (1) The efficiencies of energy supplying and solid waste recycling are improved by strategic down zoning in suburb areas (2) This system can be applied to future urban environmental planning such as estimating environmental infrastructure's efficiency or comparing land developing alternatives.

Tourism and Environmental Impacts: A Look at Sustainability

Christine Ng, Katie Bergman, Caroline Graham-Brown, Rodolfo Farber, and Arpad Horvath

Full paper available: No

This paper looks at several of the environmental impacts that tourism has on the environment. As the definition of tourism is non-trivial, we examine the various ways that this definition has been addressed, enabling us to distinguish between several different types of tourism. After formulating our definition, we apply it to our analysis of tourism in the U.S. and the European Union. We then determine the dimensions of tourism's impacts, focusing mainly on the impacts on infrastructure. Data are obtained from various sources and applied to the hotel, restaurant, and transportation sectors. Conclusions are drawn based on an analysis of four categories: energy use, water consumption, emissions, and waste generation. However, the scope of this paper is to understand the implications and limits of sustainable tourism through the development of a detailed model using specific data from the four categories.

The aim is to arrive at a set of criteria that can reduce the impact of tourism on the environment, and hence improve the sustainability of the industry. We evaluate tourism's contribution to total energy use, water consumption, emissions, and waste generation in the U.S. and the E.U., and we compare this to its contribution to the economy, measured by the gross domestic product (GDP). Even having limited our analysis to primarily the lodging and transportation sectors, we find that both U.S. and European tourism are responsible for a greater share of domestic water consumption than their share of their respective country GDP. Our analysis serves as a lower-bound estimate of environmental impacts, and water consumption stands out as the most significant problem. While tourism's energy use, emissions, and waste generation do not demonstrate a disproportionately large share of the total, inclusion of more recreational and travel activities is required to make this analysis conclusive. This paper includes a discussion of the tourism industry's current approaches to environmental improvement, and the extent to which large-scale implementation of these strategies would affect the industry as a whole, both environmentally and financially.

Urban Energy Metabolism: Framework and Case Study

Marc Melaina and Gregory A. Keoleian

Full paper available: Yes

A comprehensive framework for measuring the energy metabolism of an urban community is developed using tools of industrial ecology. Energy flow analysis, material flow analysis and life cycle energy analysis are used to construct an integrated model for measuring energy metabolism. While previous models have captured the inputs of energy resources in the form of commercial fuels, they tend to disregard the embodied energy associated with goods and services crossing community boundaries. The embodied energy of goods and services imported by a community accounts for the material production and manufacturing energy requirements that often occur outside the boundaries of the community. Life cycle energy analysis can be used to measure this upstream energy consumption. The framework accounts for the embodied energy for materials as well as the total fuel cycle of energy resources imported by a community, including extraction, processing and distribution processes. Modeling challenges discussed include system boundary definitions and allocation rules. This framework is also compared with more general metabolism studies from systems ecology as well as other studies of urban metabolisms.

The case study characterizes major energy flows through Ann Arbor, Michigan, a city of 114,000 residents in the United States. Four major energy flows through the city are quantified for the year 2000: transportation fuels, electricity, natural gas and locally produced renewable fuels. These flows contribute, respectively, to approximately 29%, 35%, 36% and 0.2% of total primary energy use associated with the city of Ann Arbor. These flows sum to approximately 35.4 PJ (peta = 10^{15}) of primary energy per person. The flows support six major energy sectors: transportation, commercial, residential, indus-

trial, municipal government and the University of Michigan. These sectors contribute, respectively, to approximately 35%, 21%, 25%, 6%, 4% and 9% of energy use within the city.

This study also examines energy use associated with several major material flows, including automobiles, construction materials, food, and water. While data availability for embodied energy of goods and services is limited, an existing mass flow analysis for the city is used to estimate the significance of this component relative to fuel and electricity consumption. For example, a recent life cycle assessment for the U.S. food system by the Center for Sustainable Systems indicated that the average primary energy consumption is 42 GJ/capita/year. This value encompasses agricultural production, transportation of raw and processed products, food processing, packaging materials, food retail, commercial food service and household storage and preparation. It was assumed that the energy used for food retail, commercial food service and household storage and preparation occurs within the community. According to this energy allocation, the embodied energy of the food crossing the Ann Arbor city limits is 2.8 PJ, which is eight percent of total primary energy consumption associated with fuels.

Total energy use for the Ann Arbor metabolism is analyzed in terms of greenhouse gas production and energy use per capita income. The results of this urban metabolism study are compared with regional and national energy use patterns as well as other studies of urban energy metabolisms from around the world.

General Policy Issues

"Transition Management" in The Netherlands

Marko Hekkert, Ruud Smits, and Harro van Lente

Full paper available: No

To reach desired environmental goals, long-term environmental policy is needed. The problem with most environmental policy efforts is that they are strongly focused on the short term. This type of policy is often not effective to reach system changes as often advocated by the field of Industrial Ecology.

In the Netherlands a new concepts has recently come up in policy discussions. It is called 'Transition Management'. Transition management aims to support a transition from one dynamic equilibrium to another. The transition is the result of several coupled technologic, economic, ecologic en social processes. Examples of potential transitions are the shift to sustainable energy systems, the shift to sustainable production and consumption systems, and the shift to sustainable agriculture in The Netherlands.

The basic ideas behind transition management is that long term thinking will be used to influence short term decisions, it is focused on creating learning processes, the aim is to reach system changes (innovations, steering is done in terms of multi-level and multi-actor networks, it aims to keep the playing field open to prevent lock in of sub-optimal technologies.

At Utrecht University we have studied this abstract concept and translated it into specific, down to earth roles that governmental and intermediary organisations can play in order to be effective in transition management.

In our paper we will explain this concept further, state the roles that governmental and intermediary roles can play and we will explain how this concept may influence environmental policy making.

Transition Management

Derk Loorbach and Jan Rotmans

Full paper available: No

In our modern society we are confronted with complex and structural problems. Especially in the field of environmental and ecological issues, this complexity is manifest. Because traditional political and scientific approaches towards these complex issues fail to address all facets of this complexity, we have to find new and interdisciplinary ways to define and address these problems. Based on the concept of transitions as societal transformation processes with determinable characteristics, the concept of transition management provides a framework for policymakers as well as societal actors in which they

can work together towards possible solutions.

In the view of globalisation and increasing interdependencies amongst societal actors we have to address complex issues from a multidisciplinary point of view and be aware of the interrelations that exist between, for example, the fields of economy and ecology. On a smaller scale, this multidisciplinary approach also presupposes the interaction between economical, ecological, societal and political actors. Thus, policy-making in general has to consider these features of modern society. Our proposed concept of transition management as a policy-option to address structural and complex problems is primarily based upon the notion of multi-actor, multi-domain and multi-level interactions. We state that because of these interactions policy-makers have to develop policies in collaboration with the relevant societal actors.

The recent agricultural crises and the growing concern with the (over)use of energy resources in modern society are triggers for structural societal transformation processes and open up options for policy-makers that were until now unrecognised. We argue that by constructing interdisciplinary networks we can formulate long-term goals from which we derive short-term actions. In order to really manage such transition processes diverse tools have been developed such as network- and actor analysis, the facilitation of interactive and participative processes, the use of scenario's and models and so on. The paper will specifically address these policy-options of transition management and thus the relevancy of the concept for policy-making in the field of environmental issues.

The focus of the research presented in the paper is on the concept of transition management. The main objective of this research however is to make these ideas applicable to the practice of policy making. Based on the transition concept we have to change the way in which we define societal problems and the way in which we construct solutions for these problems. By combining different observations and options, linked to everyday policy-making (interactionism, multi-level governance) we can construct a theoretical framework which allows us to structure and organize policy-making processes. The thus structured, goal-oriented and multi-actor transition process overcomes criticism on the current practice of policy-making that it would be undemocratic and that there is no ground for legitimizing of the interactive policy-making practiced, for example, by the European Commission.

Long-term Energy Efficiency Agreements Between Dutch Industry and Government

Ton van Dril and Leon van der Palen

Full paper available: No

With the start of a new round of long term agreements with industry on energy efficiency, the Dutch government has introduced the option of improving energy efficiency in production chains. Companies can now be credited for innovations that save energy elsewhere, outside plant limits. These innovations include material efficiency and substitution, energy savings in the use phase of their product, extending the lifetime of components and improving recycling. This research on present experiences with this type of energy chain management focuses on implementation within the company organisation. Research has been done on the paper and metal chain. LTA-efforts up to now have a strong engineering focus on energy equipment within the company. A broader scope of energy efficiency in production chains requires specific efforts from sales, purchases and design departments, and a firm commitment from company management. The findings are that there are surprisingly few technological barriers for implementation, but a firm policy incentive and knowledge of energy accounting is still lacking.

Life Cycle Assessment Cases

The Ecological Footprint of a Mobile Phone

Sibylle Frey, David J. Harrison and Eric H. Billett

Full paper available: No

The Ecological Footprint (EF) is a conservative estimate of human pressure on global eco-

systems and has often been suggested as a sustainability indicator for the human impact on Earth [1]. The EF represents the total productive area of land and water ecosystems required to sustain the resources, wastes, and emissions of a population wherever that land may be located. The world's EF changes proportionally with global population size, per capita consumption, and intensity of the used resource technologies [2]. Traditionally, the EF has been applied to global or other geographic levels.

In this paper, we will discuss how the EF can be applied to electronic products. Based on life cycle energy assessment methodology, we used a bottom-up approach to estimate the bioproductive space needed to appropriate the resources and emissions of a mobile phone. For the direct land use, the methodology includes estimates from the density of materials, size of ore bodies, overburden, and biomass accumulation. As electronic products contain a wide range of materials including precious and rare earth metals, we have made statistical estimates regarding the energy and overburden arising from extraction and processing. For indirect land use, fuel specific carbon sequestration by forests and estimates for the oceans' carbon absorption capacity were included. We also use area as a single indicator to make our results comparable to the world-average bioproductive space of 1.92 hectares per person based on 1996 data or 1.89 hectares without sea space [3]. The results will give a snapshot of a mobile phone's demand for ecosystem services. Our previous estimates [4] suggested that the EF of a PC is about 9 per cent of the terrestrial area of a world-average citizen, which is probably underestimated. Although the results of this case study are a crude approximation, they indicate the magnitude of human appropriation of ecosystems by a single product.

References:

1 Wackernagel, M., Lewan, L. Borgstöm Hansson, C. (1999). Evaluating the use of natural capital with the ecological footprint. Royal Swedish Academy of Sciences. Ambio. 28 (7) 604-12.

2 WWF- World WildLife Fund For Nature (2000). Living Planet Report. http://panda.org/livingplanet/lpr00/download.cfm

3 Wackernagel, M., Callejas, A. Deumling, D. (2000). World of EF-1996-sumaries-WWF.xls. http://www.rprogress.org/ef/LPR2000/. Redefining Progress, USA; Centre for Sustainability Studies, Mexico.

4 Frey, S.D,. Harrison, D.J,. Billett, E. (2000). Environmental assessment of electronic products using LCA and ecological footprint. In: Joint International Congress and Exhibition. Electronics goes green 2000, Berlin, Germany, 11-13 September 2000. 253-258.

Greening of the Ivory Tower

Thomas Gloria and Greg Norris

Full paper available: Yes

Purchases by US colleges and universities exceed $60 billion annually. This research demonstrates the capability to identify which of the nearly 500 categories of college and university purchasing activities reported by the US Bureau of Economic Analysis (BEA) carry the greatest share of direct and upstream environmental lifecycle burdens related to climate change for the average US university, and for specific universities on a case-by-case basis.

The contribution of emissions from upstream production activities can be enormous. In a recent investigation of the nearly 500 sectors of the US economy the following surprising results were found:

- for a majority of sectors, upstream emissions exceed direct emissions;
- for many sectors upstream emission are 5-10 times direct emissions; and,
- the largest sector in terms of upstream emissions is the construction sector with upstream emissions 5 times its direct emissions.

This effort is an initial step to build collaboration among universities to collectively measure their environmental burdens. The approach will allow universities to determine a comprehensive benchmark to measure improvements over time, critical in the process to prioritize long-term strategies. Further, the results of this method would assist universities in establishing purchasing priorities to effectively reduce environmental harm.

There is an urgent need for universities to educate future generations of environmental lead-

ers that will affect policy decisions on climate change. The path to learning and civic engagement begins with keeping your own house in order. Professional and personal commitment in higher education will be motivated by first hand understanding of environmental issues in each institution's decision-making. By fostering stewardship and transparency, institutions of higher learning are better equipped to lead and inspire others.

Hydrogen Production and Fuel Cell Cars: A Life-Cycle Assessment

Edgar Hertwich and Anders Stromman

Full paper available: No

Fuel cells promise clean energy conversion for small scale power plants and mobile systems. They are more efficient than combustion engines or turbines and avoid generating combustion by-products such as PM2.5, hydrocarbons, and thermal NOx. Their fuel, hydrogen, does not contain sulfur or heavy metals. The hydrogen for fuel cells can be produced through a range of processes, including steam reforming of fossil fuels and electrolysis of water. Hydrogen can be produced on-board from gasoline, natural gas, or methanol, or in stationary plants. We have conducted a preliminary assessment of fuel-cell vehicles (FCV) and compared it to gasoline-powered internal combustion engine vehicles (ICEV). We included only direct hydrogen FCV because the literature shows that methanol or gasoline FCV have a lower energy efficiency. Because of this lower efficiency and the emissions of CO2 and other pollutants, methanol or gasoline FCV offer no clear environmental benefits over cutting edge ICEV.

Our assessment based on published data indicates that hydrogen-powered fuel cell cars are indeed environmentally advantageous, primarily because of the reduction of air pollution in highly populated areas. Cost projections, although uncertain and contingent on some technological breakthroughs, suggest that these pollution reductions increase the cost of driving somewhat, but they are affordable. We have found significant discrepancies in published data for both hydrogen production and fuel cell manufacturing, discrepancies that cannot be explained by the uncertainty connected to assessing an emerging technology alone. These discrepancies affect the affordability and eco-effectiveness of FCV. Our analysis suggests that a more careful assessment especially of the hydrogen production is required. Even using the most optimistic numbers in the literature, however, a fuel cell based transportation system will not bring the required reduction in CO2 emissions to compensate for increasing demand unless a CO2-free source of hydrogen is employed. CO2 capture in fossil fuel based systems and electrolysis powered by renewable electricity are two options investigated, but both are resource intensive. Significant increases in the material intensity and the energy intensity of the infrastructure, both of the vehicles and the fuel supply, suggest that a fuel cell/hydrogen transportation system is not the silver bullet promised by some. Local air pollution, primarily particulates, NOx and VOC, will continue to be the main drivers for the introduction of fuel cell cars as "zero emissions vehicles." Our analysis suggests that fuel cell cars are indeed worthwhile pursuing. Their environmental benefit, however, may not be as large as advertised. Other strategies, aimed at reducing mobility and shifting demand to collective transport, need to be pursued in parallel.

Indicators

Sustainability Spaces: A New Concept to Evaluate Development Using Indicator Systems

Claudia Binder, Arnim Wiek and Marcus Fenchel

Full paper available: Yes

This paper develops the concept of "sustainability space" based on indicator systems for evaluating development within defined sectors. Currently, to assess development, indicators are collected and evaluated individually and summarized in indicator lists, divided into ecological, economic and social aspects. Indicators often interfere with each other, leading possibly to contradictory results. That is, while one indi-

cator reflects a positive development, another might mirror a negative one at the same time. A simple example is increasing economic growth and decreasing environmental quality during certain periods of economic growth. Not considering the relationship among indicators could lead to a long-term degradation of the stability of the anthroposphere (defined here as the sphere of human-environment interactions, covering ecological, social and economic aspects). It is thus questionable whether the current practice of gathering data to monitor these indicators individually is sufficient and appropriate to support decision making to reach sustainable development.

To achieve sustainable development, it is necessary to consider the effects of one indicator on the others; i.e., applying a systemic perspective. Indicator systems, in contrast to indicator lists, pursue this goal. Based on the understanding of the dynamic interrelationships within groups of indicators, we identify the type of interference among indicators, classifying it into neutral, synergistic and antagonistic. Note that the type of interference is likely to change over time.

Based on these indicator systems we introduce the concept of "sustainability space". A "sustainability space" is developed by identifying "sustainability ranges" for each indicator in dependency of the other indicators within the system. The ranges are estimated with a variety of methods including inter-, and transdisciplinary methods, for example the concept of ecological threshold, expert interviews, system dynamics, etc. The "sustainability space" shows the effect of one indicator on the other indicators within the system. Thus, it permits to assess trade-offs of development strategies. Taking the simple example mentioned above, it might be appropriate to overuse the environment over a period of time to increase income, which, in turn, could be and often is used for improving environmental quality. First, income is traded against environmental quality and then vice versa. The "sustainability space" is a tool for early recognizing these trade-offs and therefore could support the designing of policies for sustainable development.

In this paper we will apply the concept of "sustainability space" to the case of agriculture.

Indicators for Eco-efficiency in Recycling Systems

Arne Eik, Helge Brattebo, Bernt Saugen, Havard Solem, and Solveig Steinmo

Full paper available: Yes

In order to obtain an industrial ecological flow of material and energy in societies recycling of used products and materials is an important strategy. However, to justify a further growth in the recycling rate for some materials and products there is a need for improved environmental- and economical performance in recycling chains.

The concept of eco-efficiency was introduced by the World Business Councils on Sustainable Development (WBCSD) in 1992. Since then it has been widely adopted among companies to measure and improve the value added per product or service while progressively reducing the environmental influence per product or service to the market. However, emphasise has until now mainly been put on the main production stage and to some extent the user stage of products or services, not on the end-of-life stage where recycling is one important option. In this paper, which is a result of the case-study "Eco-efficiency in recycling systems for plastic packaging" within the Norwegian research program Productivity 2005-Industrial ecology, we have developed three categories of indicators that should be applied by decision-makers to evaluate and improve the eco-efficiency of recycling systems. The general applicable indicators (GAIs), which we have developed to be total net costs, amount of material recycled, CO2-emissions and energy consumption in the defined system, can be used to measure the eco-efficiency of all kinds of recycling systems. In addition, if needed, the system specific indicators (SSIs) should be developed for the particularly system analysed. GAIs and SSIs are the overall system indicators for evaluating the eco-efficiency performance of the whole recycling system. The actor specified indicators (ASIs) should thereafter be developed for each of the most involved actor in the actual system to identify their contribution potential to the performance of the overall system indicators. We have developed indicators within the three categories and applied

them to measure the eco-efficiency of the recycling system for plastic packaging from households in the municipality of Trondheim, Norway. Due to steadily improved sorting in households and at the central sorting plant the eco-efficiency has increased from 1999 to 2001. However, to compete with the option of incineration with energy recovery we have shown that there is a need for further technological and organisational improvements in the recycling chain. We have developed three recycling scenarios with different technological and organizational options and thereafter evaluated the eco-efficiency of these scenarios. The evaluations show that recycling of the plastic packaging from households in cities is a future solution from both an economical- and environmental point of view.

Challenges in Making and Using Social Indicators for Sustainable Development

Øivind Hagen

Full paper available: Yes

It is common to divide the concept sustainable development into three different aspects; an *environmental*, an *economic* and a *social* dimension. While the environmental dimension is connected to the wellbeing of ecological systems and human impacts on these systems, the economic dimension is related to creation of wealth based on natural resources and how to state the values of this. The social dimension is about how wealth is distributed and what human wellbeing is about. Indicators for sustainable development are usually based on this tripartition of the concept and reported along these dimensions.

The use of indicators and measurement, and the belief in it as a catalyst for changes has its roots within a positivistic scientific tradition and statistics. The focus has most of all been on issues and phenomenon that can be quantified and counted, i.e. phenomenon that can be described and evaluated with quantitative scientific methodologies often being reported in numbers. Examples of quantifiable indicators for a company's environmental effort could be litres of spill from the production process or the amount of money invested in pollution preventing initiatives. However, indicators for sustainable development also need to be able to say something about less countable phenomenon, phenomenon of a more qualitative nature. Such phenomenon are often described and evaluated by text and therefor reported in less absolute terms than countable phenomenon. An example of a qualitative indicator for a company's environmental profile could be the employees' attitude toward environmental issues.

With the risk of being too categorical, we will argue that the quantitative-qualitative dichotomy is reflected in the tripartition of sustainable development. Environmental and economic issues are mostly reported in and measured along quantitative scales. Social issues could also be evaluated along quantitative scales (like e.g. systems for employees' participation, number of accidents and pension benefits), but qualitative aspects (like e.g. identity with corporate environmental policy, job-satisfaction and commitment) are more important for this dimension than the other two. In other words, a discussion on social indicators will also include qualitative issues, while a discussion on environmental and economic indicators is limited to quantitative issues.

Having in mind the recent popularity of concepts like industrial ecology, corporate social responsibility and extended producer responsibility, we ask what role social indicators can play to move societies, companies and individuals towards sustainability. Important questions to be discussed are: What is the state of the art on social indicators for sustainable development? What are the pitfalls and challenges for making and using social indicators? What is the relationship between economic, environmental and social indicators? And not the least, what are good social indicators for companies efforts towards sustainable business practices?

MFA in National Economies II

Methodological Experiences from Advising the Generation of National Material Flow Analysis' in Developing Countries

Christof Amann

Full paper available: Yes

Since the early 1990s, the instrument of economy-wide or national material flow analysis (NMFA) is widely accepted as one major tool to operationalize sustainable development. National MFAs were provided for a large number of industrial and developing countries, e.g. Austria, Brazil, China, Denmark, Finland, Germany, Japan, Sweden, The Netherlands, United Kingdom, United States, Venezuela. Due to a certain lack of international comparability large efforts towards harmonizing methodology were made by the European Commission (ConAccount project) and the Statistical Office of the European Union (EUROSTAT). Most recently, EUROSTAT published guidelines for "economy-wide MFA".

These guidelines are the result of a long discussion processes of a great number of scientific and statistical institutions dealing with NMFA.

We used the EUROSTAT guideline for the generation of NMFA of two developing countries, Brazil and Venezuela. This work was carried out in a project on "Sustainable Development of Amazonia", funded by the European Commission. Trying to use the guideline as strict as possible, we found that methodology is applicable in general, but that there are some difficulties in detail questions. These problems concern the following topics: It is still not clear where to set the border between direct input (into the socio-economic system) and hidden flows, especially for materials like natural gas, crude oil, and iron ore. We found that on the one hand the underlying system borders are different in some of these material categories, and that for some of the materials data are normally not available in the necessary form.

Another problematic task is biomass, especially grazing, where official statistics are rarely available, and where methods for estimations are necessary. In most cases, this material fraction is one of the largest and therefore a lot more effort should be put in finding international comparable estimation processes. Another important task is the clarification of dealing wirth subsistence economies, more or less negligible in highly industrialized countries, but very important in developing countries. Here, standardized methods for calculations are highly needed. We will discuss the usefulness of regional and local material flow analysis (RMFA, LMFA) for providing data on a national level.

Finally, we will discuss further research needed and suggestions for an internationally harmonized method of NMFA. This includes the development of new indicators and their relation to modes of subsistence.

Testing the Kuznets Environmental Curve in the Input of Materials in Economy

Paulo Ferrão, Pedro Conceição and Ângela Canas

Full paper available: Yes

Material flows sustain national economies: raw materials enter the economies to be used for production, materials leave the economies as pollution. Both extraction of raw materials and pollution affect the natural environment and both are linked with each other, given the Mass Conservation Principle. The input side of the materials flow into the economy has been gaining much attention, essentially because controlling the input of materials is seen as a solution to some problems, such as controlling pollution and waste. Most importantly, material flows are seen as key for sustainable development. In this context it has been advocated the need to limit the input of materials leading to calls for dematerialization.

Many studies have focused on the quantification of the input side of material flows into the economy using the technique of Material Flow Accounting. However the insights provided by those studies have generally been limited. In this paper, the validity of a popular hypothesis in the field of pollution studies - the Environmental Kuznets Curve (EKC) - is tested in the context in which the levels Direct Material Input (DMI) per capita (a common indicator of the input of materials in national economies) are mapped against Gross Domestic Product (GDP) per capita. The quadratic (evolution in inverted-U) and cubic (evolution in N) versions of the EKC are tested in a econometric study of DMI panel data ranging from 1960 to 1998 for 16 industrialised countries. Both the inverted-U and N shaped EKC are tested in models considering

GDP per capita as the only explanatory variable and DMI per capita as the dependent variable. Country and year fixed and random effects models are used, and corrections for non-spherical disturbances are made.

The results indicate a quite strong and robust support for an EKC evolution in the form of an N shaped curve in all the models tested. The inverted-U curve is supported only in the fixed and random effects models. Overall, the statistically stronger models are the quadratic and cubic with country random effects, on the one hand, and the cubic with country and year fixed effects, on the other. Within-country DMI per capita variation seem to be best accounted with a cubic (N-shaped) model on income per capita. Autocorrelation correction performed to a subset of observations for pooled and country effects models confirms these qualitative results. Between-country DMI per capita variation is not well described either by a quadratic or cubic function of GDP per capita. These results suggest that other factors not captured by GDP per capita, specific to each country, are relevant to explain the DMI per capita evolution. Also, time episodes seem to influence this indicator, suggesting that the EKC evolution is may not be an automatic evolution caused by GDP per capita stimulus.

Analyzing Material Flows—A Necessary Condition Towards Sustainable Development in Taiwan: The Case of Construction Aggregates

Teng Yuan Hsiao, Yue Hwa Yu and Iddo K.Wernick

Full paper available: Yes

Spurred by economic and industrial development, construction in Taiwan has grown rapidly over the last 20 years. Resulting shortages in the domestic supply of construction aggregates have forced the Taiwanese government to account for existing reserves and identify options to satisfy future requirements. To guide this activity, a method, which is based on the Industrial Ecology model, which advocates a systematic source view and industrial material sinks, as well as the web of economic enterprises that influence their flow through the economy, is proposed herein. This work will show the total construction aggregate requirements, materials intensity and efficiency in Taiwan. Furthermore, these experimental results are compared with developed countries including USA, Japan and Germany. This study also serves as a model for the material flow system on construction aggregates in Taiwan. An interdisciplinary study was conducted to understand the system and propose feasible solutions that allow for continued economic growth with minimal environmental impacts. As the flow of physical resources impacts both economic growth and environmental quality, this work is an essential component to ensuring sustainable development in the Republic of China.

Measuring Sustainability Through Materials Flow Analysis of Industrial Systems in Antarctica

R.J. Klee

Full paper available: Yes

Increasingly there is a general sense that our industrial society's use and disposal of materials affects our planet in ways that are detrimental to our long-term survival. However, we currently have limited means of quantifying this sinking feeling. This research approaches such quantification by studying one of the few industrial systems on the planet where systematic measurement is possible, namely the scientific research stations in Antarctica.

Most people equate the word "Antarctica" with an otherworldly land of ice and snow, full of penguins, seals, whales and the occasional scientist. However, there is another side of Antarctica that few care to notice. A collection of industrial centers has been built to support the scientific researchers who take the photographs of the penguins, measure the extent of the ozone hole, and observe the melting of the ice cap. There are currently 80 such industrial installations spread throughout the continent, operated by 29 different countries. In response to the potential hazards of placing an industrial center right next to a penguin colony, the countries that perform research in Antarctica signed the 1991

Protocol for Environmental Protection to the Antarctic Treaty (the Protocol). In doing so, the signatory nations

agreed to make the preservation of the natural laboratory of Antarctica a "fundamental consideration" in all their activities in Antarctica. As a result of the Protocol, each of the 29 countries that conduct scientific research in Antarctica must keep accurate records of the materials they bring onto and remove from the continent, and they must have plans in place for the handling and management of these materials.

Furthermore, this and any other information on a country's Antarctic activity must be made freely available to all interested parties, in the name of science and peaceful coexistence on the ice. Antarctica is arguably one of the few places on our planet that has systematic, non-proprietary data regarding the flows of materials into and out of its industrial centers. The continent of Antarctica thus serves as a unique "petri-dish" in which to study the movement and eventual fate of materials in industrial society.

I am collecting and analyzing industrial material flow data for the years 1995-2000 from fourteen countries that operate industrial centers (i.e. scientific research stations) in Antarctica. My research offers the unique opportunity to observe and quantify multi-national environmental philosophies, management tools, and implementation programs focused around a common problem of operating an industrial center in Antarctica. I will present industrial material flow data for the Antarctic stations of New Zealand, the United Kingdom, and perhaps other countries, and I will discuss the potential sustainability measurements that will be applied to this data and used to compare each country's industrial activity.

Technical Program IV

Industrial Ecology: The Metaphor

Industrial Ecology's Hidden Philosophy of Nature: Fundamental Underpinning to Use Nature as Model

Ralf Isenmann

Full paper available: Yes

Goal and Scope:

In this contribution a fundamental underpinning for industrial ecology's use of nature as model is presented. The underpinning provides an impressive battery of philosophical arguments bringing to bear against the sort of probably raised fallacies and facile proclaimed critics by sceptics who often overlook industrial ecology's stimulating role towards sustainability.

In industrial ecology nature is interpreted as model in order to gain fruitful insights for dealing with natural resources and services for a more efficient use of matter, energy, waste, by-products, time, space, etc., meeting ecological constraints. However, in contrast to its intuitive appeal, industrial ecology lacks of efforts to underpin and conceptualise this non-mainstream interpretation of nature. Hence there is urgent need for research on industrial ecology's underlying philosophical assumptions.

The tangible object is: firstly, as a larger goal, to make philosophical thinking quite accessible to industrial ecologists while its content is of interest to professional philosophers; secondly, more precisely, the contribution aims (i) to protect "nature as model" against inflationary use of biological analogies as merely rhetoric, (ii) to shield industrial ecology from sceptics, and (iii) to avoid it against obvious shortcomings.

Methods:

According to the above-mentioned goal and scope, basic epistemological and ethical aspects are situated in the centre. Four major philosophical methods are applied: (i) classification-framework to specify the interpretation of nature; (ii) dialectic principle of thesis, antithesis, and synthesis to settle the dispute between sceptics' and protagonists' viewpoints concerning nature as model; (iii) basics of anthropology to explain

how it is even possible to understand nature by science and to look to nature for a model by reflexive manner; (iv) epistemologically-based architecture of industrial ecology science to demonstrate that the reflexive interpretation of nature as model represents a paradigm serving as helpful heuristic and influencing industrial ecology's research and practice.

Results and Conclusions:

It is possible to elucidate industrial ecology's hidden philosophy of nature by reflexive manner. An impressive battery of philosophical arguments are presented to underpin industrial ecology's interpretation of nature as model. Consequently it seems plausible to learn from nature i.e. industrial ecologists may selectively apply nature's smart solutions, evolutionary strategies, and ecological principles for balancing ecosystems and industrial systems. The keynote is to be aware of nature's hypothetical status. Nature as model provides a minimum that can be considered but it does not represent an all-inclusive checklist that guarantees sustainability or ethical fairness itself.

Metaphorically, nature as model provides valuable insights as eye-catcher. From this rhetoric sense we can learn by gaining inspiration and encouraging creativity to derive ecological innovations. However, additionally to linguistic aspects, nature as model can also serve as paradigm from an epistemologically-based perspective. This paradigmatic sense includes rhetoric use as metaphor but broadens the interpretation as smart biological analogy and exceeds the connotation as picturesque note by far. Nature as model is seen as "regulative idea" that provides a helpful heuristic guiding industrial ecology's research programme. Such a regulative idea plays a dominating role that is i) to arrange our way of thinking, ii) to organise our imagination of phenomena, and iii) to govern our decision-making.

Industrial Ecology – A Paradigmatic and a Practical Source for Sustainability

Jouni Korhonen

Full paper available: No

The concept of industrial ecology (IE) has been interpreted with different perspectives in the literature on the theme. Others understand IE as a paradigm, as a metaphor and as a new way to construct our basic world view. Therefore, industrial ecology is understood as a normative source for sustainability. Others adopt IE in a more practical sense. In this shape of the concept, metrics, tools, policy and management instruments are developed. These are used to trace, monitor, and calculate the flows of matter and energy within the societal and industrial systems, and more importantly, between the societal system and the natural ecosystem. Suggestions for action are presented for reducing the environmental burden of products, processes or of systems of these.

In this paper, the metaphoric aspect of IE includes the four ecosystem principles of roundput (1), diversity (2), interdependency (3) and locality (4). It is argued that by using the ecosystem as a source for a sustainability metaphor, these characteristics of a sustainable system can be discussed in an unsustainable system. Such discussion can benefit the current societal and industrial systems that seem to be within an unsustainable paradigm. If the most commonly used IE principle of closed loops or roundput is understood as recycling of matter and cascading of energy, it can be argued that this has already been relatively familiar within the unsustainable paradigm of modernity. When integrated with the characteristics of diversity, interdependency and locality, the industrial ecology metaphor may move toward a more sustainable paradigm.

The material and energy flow model of an ecosystem is used in an industrial system for the practical aspect of industrial ecology. The flows of matter (biomass) (1), base cation nutrients (2), energy (3) and carbon (4) are considered by focusing on material cycles and energy cascades as they happen in an ecosystem and in comparison to an industrial system. It can be beneficial to adopt this kind of a practical focus on the roundput principle in a complementarity relation with the more metaphoric and paradigmatic aspect of industrial ecology, which can include also the principles of diversity, interdependency and locality.

Production Systems in Industry and Ecology: Some Comparisons Relevant to Industrial Ecology

Stephen Levine

Full paper available: Yes

Industrial ecology looks to ecosystems for both descriptive and prescriptive models. Descriptively, the ecosystem represents an archetypical complex system, containing many interactions between system components, interactions that are largely the result of the flows of energy and materials that characterize both ecological and industrial systems. These flows give rise to a hierarchical structure, referred to as trophic levels in ecological systems and production stages in industrial systems. Prescriptively, industrial ecology proposes ecosystems as a model of how industrial systems should ideally function. This proposal is based on the beliefs that (1) ecosystems display desirable characteristics regarding the recycling and reuse of materials, (2) it would be desirable if industrial systems had these characteristics as well, and (3) it is possible and practical to imbue industrial systems with these characteristics. It is this proposal and the supporting beliefs that are examined in this paper.

In particular, the evolutionary histories of ecological and industrial systems are very different, and, more specifically, the underlying forces that have shaped those histories are different. Ecological systems are input driven. The availability of energy in the form of sunlight makes the major part of the organic world possible, beginning with an autotrophic level and subsequently adding autotrophic levels. Each trophic level is itself input driven. Herbivores evolved due to the availability of energy in the form of plant biomass; the resulting availability of biomass in the form of herbivores drove the development of carnivores. Detritivores too arose due to the availability of energy in the form of organic material. By contrast, industrial systems are output driven. Final demand for products provides the overall impetus, and each industry exists because of a demand for its output, not because the raw materials it uses happen to be available. How does this evolutionary difference impact the prescriptive value of the ecosystem model? For starts it is clear that recycling and reuse are an integral part of ecological systems in a way they can never be for an output driven industrial system.

Industrial Ecology: The Biosphere - Technosphere Analogy

Ester van der Voet, Ruben Huele and Ruud Stevers

Ayres (1989) first introduced the biosphere-technosphere analogy as a useful image to develop in his description of Industrial Metabolism. In short, this amounts to the following:

- In the biosphere, evolution has resulted in efficient and problem-free use of materials and energy in processes to create biomass
- In the technosphere, where we create technomass, “evolution” is still in its earliest stages
- By learning from the biosphere, society may design its technical processes in a more sustainable manner.

Ayres has given us a powerful image with obvious usefulness. We can think in many ways about the 3rd evolutionary invention and its equivalents for society, in fact that is what Industrial Ecology in its present days is mostly about: closing cycles, use waste as resource, create industrial ecosystems etc.. This type of research and design is very important and will remain the core of IE for years to come. In the meantime it may be interesting to explore the biosphere-technosphere analogy a bit further.

In the first place, there are some obvious pitfalls in the analogy:

- Evolution has had 4 billion years, society must do it much faster, we can’t leave it to time.
- Evolution is at odds with any type of morality: there is no such thing as a “good” process design or way of living. Designs have to prove themselves in the real world: survival of the fittest.
- Nature represents a dynamic equilibrium: species appear and disappear, populations are decimated and multiply again. Major disasters lead to new chances on the evolutionary road. In society we don’t want dynamics, we want statics: disaster-free, risk-free, damage free lives

We should be aware of these differences as well when we look for lessons from nature.

In the second place, there may be some new lessons to learn from the analogy:

- New in this field, but already out there: the evolutionary design of processes. This type of design has only been possible since time can be compressed by using computers. It is based on random trial-and error and leads to remarkable products.
- Also new in this field is the use of natural processes instead of modelling processes after nature. Examples are agrification and biotechnology. Such processes have been used for a long time, but have not been a concern for Industrial Ecology until recently. This adds a new dimension: not only the use and dispersal of mass and energy, but also of genetic information may become problematical. New tools, including ways to assess information dispersal and its risks, are needed to deal with.
- Evolution discards species but keeps characteristics: all evolved basic characteristics are still there, sometimes only in remote corners of the world. Such a storage of options to be kept alive enables reaction to changing conditions. This storage occurs mainly in microorganisms, which can react quickly and efficiently. Can we think of an analogy for society?

Material Flow Analysis in National Economies III

Multi-stakeholder Decision Support in Long-term Construction Material Chain Management: A Dutch Case Study Using an MFA Model

Daniel Mueller

Full paper available: Yes

The construction material household is influenced and shaped by decisions of many different stakeholders in government, industry and NGOs, including forestry, forest industry, mining, construction industry, owners and managers of constructions and waste management. Most of these sectors have their own information systems, which support decision making for internal optimisation. There is a lack of information systems, which allow them to co-ordinate their strategies.

The TU Delft is investigating the Dutch construction material household with an MFA model. MFA models provide useful information about the physical context of the stakeholders field of action. The effects of different measures can be tested with scenarios. This allows different stakeholder groups to co-ordinate their strategies.

First results of the MFA model reveal the importance of the construction inventory. The dynamics of the construction inventory determine resource consumption and waste production. The construction inventory can be regarded as the motor of the construction material household. In contrary to the forest inventory, there is hardly any knowledge neither about the dynamics nor about the composition of the construction inventory.

The use of the model is being tested for intersectoral decision making.

Biological Metabolism and the Material Flow Balances of the Food Flux

Ilmo Mäenpää, Helmi Risku-Norja, Kauko Koikkalainen, Pasi Rikkonen, Pekka Vanhala

Full paper available: Yes

In this paper a materials flow model between nature and the food chain part of the economy is outlined, and the calculation method and preliminary material flow balances for the food chain are presented. The calculations are based on the data on the agricultural production in Finland in 1995.

The material flows of the food chain comprise four mutually linked loops: 1) the plant production 2) the livestock husbandry, 3) the food processing industry and 4) the human consumption. The plant production of agriculture amounts to 13 millions tons. About 70 % of the plant production is used for feeding the livestock to produce the animal products, meat, milk and eggs. A considerable residue from the livestock production is the manure used as fertiliser in plant production. Part of the products of plant cultiva-

tion and almost all of the products of livestock husbandry are further processed within the food industry to final foodstuffs. The residues of the food processing industry are mostly returned back to agriculture as livestock feeds. The humans consume the foodstuffs, and in preparing food part of the foodstuffs is lost as wastes. The metabolic wastes of the consumed foodstuffs end up largely into the sewer systems, from which the dry matter is recovered as sewage sludge to be used as fertiliser in landscaping and, to some extent, also in agriculture.

The system boundary between the economy and nature is defined in such a way that the photosynthetic activity responsible for the plant growth is considered as the phenomenon of nature, while the biological metabolism of the livestock and humans occurs within the economy. For exact balancing the metabolic material flows, it is necessary to integrate the flows of the nutritional materials, feed and food, with those of water and of respiration (oxygen in, carbon dioxide out). Based on the energy approach of the metabolism, preliminary calculation method for the different livestock species and for humans will be presented in the paper. The total metabolic material flow balances for the food chain with the four interlinking loops will be estimated for Finland in 1995.

The study is a part of the project "The Material Flows of Agriculture, Ecoefficiency and the Sustainable Compatibility of the Food Production" carried out in collaboration between the MTT - Agrifood Research Finland and the Thule Institute at the University of Oulu. The results will also be contribute to the overall development of the material flow accounting statistics, as they are used in compilation of the Finnish physical input-output tables.

Creating National Physical Material Flow Accounts

Donald Rogich

Full paper available: Yes

The potential to create a system of national physical accounts, an analog to national economic accounts, is a reality. Using the United States as representative model, this paper outlines how meaningful national accounts can be constructed using existing data, and supplementary estimation methodologies.

This paper builds on the work of the World Resources Institute, as represented in their report "The Weight of Nations," to show how physical accounts containing both macro (aggregated) material flow indicators and detailed sub-accounts can be developed. The aggregated accounts provide a strategic picture of the changing scale of physical flows, and the sub-accounts can be structured such that they create an interface with tactical substance flow analyses. A discussion of methods for aggregating material flow sub-accounts, based on mode of release, quality of the flow, and transit time in the economy is also provided.

Selecting the flows for inclusion in the accounts requires criteria which assure that the accounts are meaningful, but not overly detailed, and lacking in transparency. The accounts should provide information on all important commodity flows, and transformations of the landscape, occurring in the process of resource extraction, and in the creation of the built infrastructure, in addition to those flows classified as pollutants. Understanding, and managing the activities of a country, using economic accounts alone, obscures the physical reality of these activities. Developing, and incorporating, a system of national physical accounts is a major step towards overcoming this deficiency.

Material Inputs in the Portuguese Economy: The DMI approach

Paulo Ferrão, Pedro Conceição, and Ângela Canas

Full paper available: Yes

The Dematerialization debate, fuelled by concerns about sustainable development, and the subsequent setting of international goals for resource productivity increase, such as the Factor 2 and 4, have risen the importance of indicators of input of materials in the national economies provided by Material Flow Analysis. One of the most popular is Total Material Requirement (TMR) which accounts the material aggregate that enters national economies, measured in

tones, with or without economic value. This indicator has been selected as a key indicator in the European Union and in United Nations Organisation, but is of complex calculation due the general lack of information available on the quantities of not economically valued materials. A simpler and more easily calculated indicator accounting only the materials with economic value that enter national economies – the Direct Material Input (DMI) – can be used as a first approach to assess the evolution of the inputs of materials, providing at the same time base information for a posterior calculation of TMR.

Most of the DMI calculations relying on national official data have been performed for countries with similar economic development in terms of Gross Domestic Product (GDP) per capita, such as United States of America, Japan and Germany. In this paper the results of the DMI calculation for Portugal are presented, for the period from 1960 to 1998, following the methodology presented by Adriaanse et al. in the 1997 study *Resource Flows: The Material Basis of Industrial Economies*. These results help the broadening of the DMI data to lower levers of GDP per capita, which is important due to the frequent comparison between material input indicators and GDP. Additionally the variation of the DMI is submitted to a decomposition analysis to allocate the variation of the DMI to the variation of several factors such as GDP per capita, the material intensity of GDP (DMI/GDP) and employment.

The results indicates a level of DMI in 1998 of 174 million tones, nearly 18 tons in a per capita basis, a level of DMI similar with those for Japan and Germany. Nearly 70% of the DMI comes from the natural environment, being the most important categories of materials coming from the domestic environment the categories of Rock, Clay and Sand (74%) and Biomass (25%). When considering the evolution one finds that DMI has been increasing since 1960 (particularly after 1987) being this evolution found driven mainly by the Rock, Clay and Sand category, that has increased more than 2000% since 1960. From the decomposition analysis, some periods of decreasing material intensity of GDP before 1985 are detected, although these are not able to translate in overall reduction of DMI due to the increasing DMI effect because of the increase in GDP per capita. When considering employment it was found that DMI per employer has increased.

Policy Cases in Industrial Ecology

Free Riding in Voluntary Programs: The Case of the USEPA WasteWise Program

Magali Delmas and Arturo Keller

Full paper available: Yes

Since the 1990s, more and more Voluntary Agreements (VAs) involving regulatory agencies and firms have been formed to develop technological innovation or to reduce pollution. Our study focuses on understanding free-riding behaviors. Our research question is: What are the incentives that drive organizations to disclose information on environmental performance?

We use the case of the US EPA Wastewise program, which is a voluntary program established in 1994 as a non-regulatory means of promoting reduction of municipal solid waste and prevent pollution. The program is designed to provide its members with cost-effective solutions for waste reduction. In 1999 there were more than 900 organizations in the programs and only 20% of these were actually reporting their progress to the EPA. This paper is based on 106 responses to a questionnaire sent to Wastewise members.

Previous research in the economics literature has shown that information disclosure decreases with the cost of disclosure. We build on this literature to show that disclosure will increase when it provides potential benefits such as improved reputation. This will depend on how strategic is environmental performance for the firm and the overall reputation of the program. Our survey indicates that firms will report their environmental performance when enhancing their reputation is their primary incentive to enter the Wastewise program and when upper management is involved. We also show that later entrants report less than first entrants. The lax enforcement of the reporting requirements for first entrants may impact the behavior of later entrants. This may be reinforced by the difficulty to monitor a grow-

ing number of free riders by the EPA.

Our paper has important policy implications. Although firms are seeking help from the regulatory agency to promote their environmental efforts, certainty of the rules and their enforcement is a key component to avoid free riders. Furthermore, the involvement of the upper management in such voluntary programs decreases the amount of free riding.

Renewables as Chemical Feedstocks – An Assessment Prepared Under the European Climate Change Programme

M. Patel, C. Bastioli, K. Doutlik, J. Ehrenberg, D. Johansson, H. Käb, and J. Klumpers

Full paper available: No

Between spring 2000 and summer 2001, the European Commission organised its "European Climate Change Programme" (ECCP), aimed at developing a set of policies and measures (P&Ms) for the EU to achieve its commitments under the Kyoto Protocol. One of the objectives of the ECCP was to obtain a comprehensive overview of the reduction potentials for greenhouse gases in all sectors. Another was to evaluate, in a broad stakeholder dialogue, the feasibility and effectiveness of proposed policies and measures. A new feature in the climate policy field was the establishment of a subgroup under the Working Group Industry entirely devoted to the use of renewable raw materials (RRM) as a chemical feedstock. This is in contrast to renewable energy sources which have been on the policy agenda for several years already and for which policy targets have been established. No such targets have as yet been established for the use of biomass as a chemical feedstock in the European Union.

Four groups of products, which can be manufactured from RRM, were studied, namely polymers, lubricants, solvents and surfactants. This selection comprises mature products which already have considerable market volumes and at the same time have a potential for increased shares of RRM feedstocks (mainly for surfactants) and in some cases rapidly expanding product groups (e.g. plastics based on RRM).

In a first step, the quantities of polymers, lubricants, solvents and surfactants currently produced from RRM in the EU were established. Next, the expected production volumes by the year 2010 were estimated. Finally, the savings of GHG emission relative to comparable products based on petrochemical raw materials were estimated. A distinction was made between firstly, *direct* emission reduction due to a lower GHG impact mainly in the *production and waste management stage* and secondly, *indirect* emission reduction, enabled mainly by lower energy use in the *use phase* of the respective product containing RRM-based materials.

The main findings were:

- The *direct* GHG emission reduction potential amounts to approx. 2% to 4.7% of the total CO_2 emissions from the chemical industry (range: without resp. with P&Ms in place). This means that, in the short term, the increased use of RRM offers only a limited emission reduction potential.
- The *indirect* GHG emission reductions could be considerably larger (by an order of magnitude) than the *direct* GHG emission reductions. Examples are the use of starch as filler for car tyres and vegetable based motor oil (reduced friction).
- In the long term, by making use of biotechnology, large reductions of CO_2 emissions could be achieved by producing bulk chemicals from biomass feedstocks. Additionally, due to their bio-degradability, substances based on RRMs have the potential to contribute to the reduction of various health and environmental risks by reducing contamination of soil and water.

The RRM group prepared a list of possible P&Ms which would support an accelerated introduction of RRMs in each of the four product groups studied.

Techno-economic Life Cycle Modeling

Dolf Gielen and Yuichi Moriguchi

Full paper available: Yes

Industrial ecology poses a framework for many research topics. This presentation focuses on national and international environmental poli-

cies regarding bulk commodities.

Bulk commodities are part of economic policy, national security, agricultural policy or environmental policy. Contrary to environmental policies for substances, environmental commodity policies are much more complex because costs and benefits are uncertain. Transformation of bulk commodities constitutes a major part of the total economic activities (mining, agriculture and industry). As a consequence a change of bulk commodity flows can have major economic impacts.

Commodity policies in the past were largely driven by strategic concerns regarding the lack of adequate future supply of raw materials, amongst others driven by such messages from the scientific community. The European agricultural policy is still based on the principle of food self-sufficiency. Environmental concerns pose a relatively new policy incentive. For example the interest in energy policies can be explained by the oil price increase during the 70s and 80s, and the emergence of the global warming problem in the 90s

In fact prices of most commodities have fallen during the last century. Moreover economists have been arguing that natural resources can be substituted, and technological development balances resource exhaustion. This has lead to the widespread belief that the resource scarcity problems are in fact not severe, which has resulted in a declining policy interest in resource policies. This trend is in marked contrast with the emergence of industrial ecology as a policy field. This raises the question: are scientists mistaken or are policy makers misinformed? This question will be discussed on the basis of studies regarding the welfare effects of bulk materials policies.

The international trade of commodities is increasing rapidly. Moreover the scale of environmental problems is increasing. This poses new challenges for environmental research. The recent problems regarding the Kyoto protocol show the problems regarding international environmental policies with potentially significant economic consequences. As a consequence it is recommended to include more elements of the established economics and policy sciences into the industrial ecology field. In order to illustrate the relevance of such studies some examples will be discussed regarding our recent work on integrated techno-economic modeling on different spatial scale levels for petrochemicals, iron and steel and agriculture.

Ecodesign in the EU: Can We Hope for Factor X?

Arnold Tukker

Full paper available: Yes

As a support to the development of an Integrated Product Policy (IPP) in the EU, five leading institutes (TNO, Vito, econcept, CfSD, VDI) in the field of sustainable product development (SPD) have analysed the state of the art in Europe. For each EU member state, four elements reflecting the demand and supply side of SPD were analysed. It concerns *method development, dissemination, and education* (supply side oriented) and *practical application* (demand side oriented). A structured, qualitative indicator system (based on so called 'maturity profiles') was developed that were used to obtain a judgement of a set of (inter)national experts per country on each element. To get additional insight in practical application, additionally an inquiry to the Fortune 500 companies was performed.

The results showed that the EU countries can roughly de developed in three groups: 'front runners', who set the scene for about 10 years with regard to method development and dissemination; 'intermediates', who have been setting up their programmes for some 5 years now; and 'inactives', where SPD only in individual cases is practised. It was striking, though, that even in the front runner countries practical application was still quite limited. Even there ecodesign is mainly practised by several dozen of 'champion' firms, and mainly concentrating on incremental improvements rather than re-design or system innovations. The front runners are mainly advanced with regard to method development and to some extend dissemination and education. The conclusions are straightforward. Concerning method development, dissemination of knowledge should take place from front runners to other EU countries. New method development should mainly concentrate on issues still new for them (e.g. methods aimed at functional innovation). Dissemination should have more emphasis.

Above all, it should be analysed how the demand side of SPD can be strengthened.

Note: this lecture will be an adapted version of the talk held during the conference Towards Sustainable Product Design 5. Due to the time pressure I used an old summary for this abstract. I feel that even in its original form the message is still new and interesting for IE practitioners, and for SPD practitioners from the US, but in order to have a different story I'll put some more emphasis on the conditions that are needed to come to widespread dissemination and application of SPD/ecodesign.

Structural Change and Economics

Exergy and Work: Accounting for the Solow Residual

R.U. Ayres

It has long been obvious that a feedback process involving energy (exergy) consumption plays an important role in economic growth. Since the first industrial revolution, animal and human labor have been increasingly replaced by mechanical work, powered by fossil fuel combustion. Lower costs lead to lower prices, which encourage increased consumption, which contributes to learning-by-doing and economies of scale, resulting in lower costs, etc. Yet conventional economic growth theory does not explicitly recognize this mechanism, merely introducing a time dependent multiplier (the Solow residual) called 'technical progress'. We show that most technical progress in the US economy during the period 1900-1998 can be explained in terms of increasing thermodynamic efficiency in converting primary exergy to mechanical work or thermal quasi-work. Some implications for energy (exergy) conservation and the so-called 'rebound effect' are discussed.

An Approach to Dynamic Environmental Life-cycle Assessment by Evaluating Structural Economic Sequences

Thomas Gloria

Full paper available: Yes

This paper presents an approach to dynamic environmental life-cycle assessment based on the philosophy of Structural Economics and the constructs of temporal economic Input-Output interindustry modeling. Structural Economics provides a framework that integrates ecological economic and environmental engineering concerns in a system-wide perspective that is suitable for comparing the implications of alternative future courses of action. The Structural Economic philosophy is realized using a Sequential Interindustry Model (SIM) approach. SIM considers the time consuming nature of the production process and the corresponding timing of industry input. In essence, SIM unravels the "whirlpools" of interindustry relationships, providing an empirical approach to investigate transient behavior of finite economic activities. The methodology is demonstrated via a case study examining the environmental implications of introducing Fuel Cell Electric Vehicles into the U.S Economy over a period of twenty years. Scenarios developed in the case study embrace the constructs of experimental design, achieving rigorous results.

Assessing the Dynamics of Industrial Ecosystems

Matthias Ruth

Full paper available: Yes

Industrial ecology borrows concepts and tools from engineering and economics in efforts to identify optimal materials and energy use, and to reduce environmental impact of production and consumption activities. As a result of their choice of concepts and tools, analyses are often static or comparative static in nature, tend to inadequately represent the behavior of decision makers and thus fall short of their full potential impact in environmental investment and policy making.

This paper argues for the application of dynamic approaches in industrial ecology to assess materials and energy use, technology change, and emissions. Three case studies of industrial energy use in the USA are presented – one each for the iron and steel, pulp and paper, and ethylene industry. The dynamic models of these industries are used to investigate alternative carbon emissions and investment-led policies. The results clearly point towards the need for differentiated policy approaches which take industry-specific features into account, in order to effectively influence, over time, industrial fuel mix and carbon emissions.

Structural Decomposition of the Iron, Steel and Plastic Flows in the Dutch Economy, 1990-1997

Rutger Hoekstra and Jereon van den Bergh

Full paper available: Yes

Physical input-output tables of the iron, steel and plastic product flows for the Netherlands are presented for 1990 and 1997. The relationship between these flows and the economic structure is analyzed using structural decomposition. This method decomposes the sources of physical flows changes into different changes in the monetary and physical input-output tables. Technological, trade, consumption and sector shift effects can be distinguished using this method. For the technological change the substitution of metal and plastics will be highlighted. Conclusion about the main driving forces of the metal and plastic use change over this period will be drawn.

Eco-Design I

Models and Tools for End-of-Life Product Management

Manbir Sodhi and Winston Knight

Full paper available: No

At end-of-life products must be processed for disposal and/or recycling. This involves a network of operations including collection, transportation and storage, together with combinations of disassembly, bulk recycling and disposal of a portion of the product by landfill or incineration. The economics of the overall recycling network is often dominated by the costs of collection and storage because of the relatively low value of recovered materials. In addition decisions of the best combination of disassembly and bulk recycling may be necessary, along with other decisions concerning the batching of products for processing and so on. Determination of the most effective arrangement for a recycling network involves consideration of the various steps in the process. This paper outlines models for determination of best operating conditions for different stages in the overall process. Included are models for collection logistics, product analysis for disassembly, analysis of materials separation and overall recycling networks.

Models representing some of the lowest levels of the collection problem have been proposed and these allow an analysis of the operations of a truck collecting material from a variety of sources. The truck-sizing problem has been presented as a constrained news vendor problem, with the amount available for pickup being the waste material, and the constraints representing the bin (truck partition) sizes. In addition, a model integrating the material recovery, disassembly, disposal and collection has also been formulated.

Models for determining the best separation sequences for material mixtures produced by shredding during bulk recycling have been developed. These are used in combination with a previously developed analysis tool for disassembly and environmental assessment. Bulk recycling of the product rest fraction at any stage of disassembly has been analyzed using the material separation analysis procedures described above. This analysis confirms the general finding that small products do not release sufficient material value to overcome the labor costs of disassembly. However, bulk recycling of such products can possibly result in sufficient recovered value to outweigh the costs of processing. The software tool for determining appropriate separation sequences for material mixtures has been used to investigate general problems of the processing of batches of different products that result in different material mixtures. The

batching problem is one of selection of groups of products to be processed together, i.e. as batches, for separation by bulk recycling methods. Since different products result in different material mixtures the benefits or disadvantages from processing the mixtures together or separately can be determined.

Methodology for the Design of Sustainable Chemical Processes

Gijsbert Korevaar, G. Jan Harmsen, and Saul M. Lemkowitz

Full paper available: Yes

Sustainable Development deals with large time and spatial scales. This implies many uncertainties, for which robust chemical plants with rather long lives have to be designed. Moreover, design, including design of sustainable processes, occurs amidst competing societal, economic, and environmental constraints. The process designer can not influence most of these, although the concept of sustainable development presupposes that these constraints are integrated into every step of the innovation process.

It is therefore necessary to develop a methodology which, firstly, enables engineers to effectively incorporate the complex and often vague concept of sustainable development into design and, secondly, reduces complexity to a workable level without neglecting essential sustainability criteria. In our case we mean with design the conceptual process design phase, which results in the construction of a flowsheet together with mass and heat balances. Based on this, estimations can be made on the cost performance and the environmental benignity of the process.

Just like any other design, the conceptual process design of chemical process consists of four stages. First, setting the problem definition right considering the goal, constraints, and necessary domain knowledge. Then optimally combining the solutions in the synthesis part, guided by the creative and knowledge-based thinking of the designer. In the analysis of possible solutions, a procedure of reiteration occurs to determine whether the design is the best available solution to the given problem; this includes applying various criteria to test the robustness of the design. Finally the design is evaluated in the assessment phase, from which it can go on to the next level of detail. Of course, the steps are repeated frequently throughout this whole scheme.

From the perspective of sustainability, there are some specific demands to a design methodology. First, there must be a well-defined link between the problem definition phase and the analysis phase. Therefore we focus on methods for the definition of the design problem and the trade off in the analysis phase. Secondly, synthesis tools have to be developed, so that the generation of alternatives can be done constructively towards sustainability considerations. Further on, sustainability asks for a broader definition of the engineering practice; by this we mean that in a sustainable design the process engineer must have insight into the whole product and process life cycle and also must have the openness to work with societal issues during the design.

Based on this, our research approach consists of the following three parts.

1) Translating vague and broad societal considerations into concretely defined engineering criteria. These criteria concern important issues of the sustainable development debate that should be understood and applied by process designers.
2) Secondly, the design methodology is constructed using knowledge from both general design theories and existing chemical engineering practice. The framework conceptualises and structures the approach of the design problem and locates appropriate design methods. The design methods solve specific problems and generate alternative solutions.
3) Developing new tools and guides applicable to specific aspects of sustainable design, such as using insight into exergy for choosing optimal chemical synthesis route.

We present a short overview of our design methodology illustrating every step by examples. In the problem definition phase, stakeholder assessment and scenario building are mentioned. In the synthesis phase, route selection is important as well as the use of guidelines based on fundamental insights, like irreversible thermodynamics, and thinking in terms of task instead of unit operation. In the analysis phase, a forum

discussion is helpful to assay the final design concept against the stakeholders needs.

Industrial Ecology and Green Chemistry

Rebecca Lankey and Paul Anastas

Full paper available: Yes

Over the past decade industrial ecology has become a well-developed concept. The next stage in evolution of industrial ecology will require innovative technologies to further advance the goals and ideas set forth by the industrial ecology community. Green chemistry and engineering provides a fundamental approach towards designing products and processes to prevent or eliminate pollution and waste. Green chemistry research and technologies offer methods by which industry can make tangible environmental improvements while also maintaining or improving its economic viability. This talk will describe the relationship between industrial ecology and green chemistry and will provide specific examples of how green chemistry and engineering technologies are providing solutions to the challenges set forth by the industrial ecology and sustainable development concepts. The presentation will also describe how the environmental benefits of green chemistry technologies can be analyzed with qualitative and quantitative metrics and with the tool of life cycle assessment, and LCA case studies of selected technologies will be presented.

Lifecycle Assessment of Toner Particles

Anahita Ahmadi, Brendan Williamson, Thomas L. Theis and Susan E. Powers

Full paper available: No

The xerographic industry has seen remarkable advances in speed and quality of prints in the past few decades. This technology is still improving today with many companies competing for the future in copy and print technology. One of the main components in the xerographic process is the marking material, or toner. Toner is dry ink that creates the image on paper during the xerographic process used in most copiers and some large printers. The conventional method of toner production is a process by which particles are mechanically broken down to the desired size distribution. The manufacturing processes for toner production, however, are also progressing as the industry advances. This is good for researchers and scientists working on future technology, but what does this mean for the environment? Are the new technologies necessarily better? What are the costs (or the benefits) associated with the new technologies? To evaluate future technologies, the current technology must be evaluated as a baseline.

This presentation reports on a lifecycle assessment (LCA) that is being performed on a conventional toner manufacturing process. The goal of a life cycle assessment (LCA) is to examine the environmental effects related to a process or product from the initial point where raw materials are gathered to the point where all the residuals are recycled, reused, or returned to the earth. It is an evaluation tool that can be used to show areas of improvement within a process, or compare the environmental performance of similar processes. LCA's consist of four main phases: scoping, inventory, impact, and improvement. During scoping, the problem, objectives, and procedures are defined. The life cycle inventory (LCI) phase is critical and accounts for all the material and energy flows in the processes. The system boundaries are also defined during the LCI. The impact phase consists of analysis of the data obtained in the LCI to determine individual steps within each process that have the greatest environmental impact. Finally, improvements are suggested and implemented to optimize the process.

Initial findings suggest that the onsite manufacturing process is nearly optimized for mass flows (97% material yield) but does require large energy inputs, especially in the grinding process. The system boundaries have been extended both up- and down-stream beyond the onsite process. Final results, problems encountered, and suggestions for future LCA's, are the focus of the presentation.

Closing the Loop: Soft Barriers

Industrial Symbiosis: No Time to Waste

Maria Alexandra Aragão

Full paper available: Yes

The new ring-shaped economy aims at REDUCING, REUSING and RECYCLING the material flows between the social and the environmental spheres. Industrial ecology is one of the more feasible and effective ways to *close the circle*, accomplishing the third «R».

Ecological association between companies (called INDUSTRIAL ECOLOGY when carried out between industrial undertakings) depends on the matching of their *waste energy* outputs and *waste material* outputs on one hand, to their energy and material inputs on the other hand.

In the right background conditions (established by economic, fiscal and planning rules) these secondary energy and material flows emerge from spontaneous convergences between industrial undertakings. In this case we have SYMBIOTIC INDUSTRIES. However, public authorities can also unilaterally impose enterprise associations, for ecological reasons, when authorizing the project of a new industry. In that case we have PARASITICAL INDUSTRIES. This situation is beneficial at least for one of the industries involved but, above all, it's beneficial for the society as a whole.

Nevertheless, besides all the ecological benefits, one of the main reasons for the importance of ecological associations between industries is to refine the European concept of WASTE as stated in article 1 a) of the 75/442/EEC framework directive on waste management.

After analyzing the concept of waste in the legal doctrine and in the latest European Court decisions, we will conclude that in some conditions, recyclable materials reintroduced as SECONDARY RAW MATERIAL in a production process should be excluded from the concept of waste. This also will allow the distinction between *recycling facilities* and *waste treatment facilities.*

The core question is: when can we consider a secondary raw material not to be waste?

To answer the question we have to distinguish between:

a) internal recycling and external recycling,
b) external recycling before and after consumption, and, finally,
c) exogenous and ENDOGENOUS EXTERNAL RECYCLING BEFORE CONSUMPTION.

Only this last category can be exempt from the application of the waste legislation (namely rules on waste movements) without impairing the fundamental ecological purposes of European Waste Law.

Overcoming Opposition to Using Recycled Materials: Industrial Ecology in Manchester

Ian Douglas and Nigel Lawson

Full paper available: No

Many communities base their environmental concerns on the visible elements of pollution and contamination. In Greater Manchester fears of dioxins and other toxic materials from incinerator chimneys generally has inhibited the treatment of municipal solid waste (MSW) by incineration. The smoke emerging from chimneys that is easily seen concerns people more than any hidden leachates that may be escaping underground from landfills. Similar concerns over evident particles such as fragments of syringes and small batteries in soil forming materials manufactured from MSW causes regulatory authorities to deny permission for its use as a soil improver on brownfield sites which are being planted with trees or other vegetation.

As much as 220,000 tons per annum of Greater Manchester's MSW could potentially be recycled as such soil forming material and be used as part of the remediation of contaminated land and old landfill sites in lieu of requiring disposal in "new" sites. In Greater Manchester 900 closed landfill sites and 3217 ha of derelict land with potential for redevelopment, but which need additional soil material for successful plant growth, still await reclamation. Trials are currently being undertaken to enhance the acceptability of this soil forming material reclaimed from MSW as a means of improving the organic content of surfaces of reclaimed sites.

Concerns over the character and consistency of the appearance of reclaimed materials and a perception that all secondary products are inferior may also restrict the use of building products made from recycled aggregates derived from construction and demolition waste (C&D waste). A survey of businesses involved in the different stages of demolition, treatment and reuse of C&D waste is seeking to identify the contrasts between real barriers and perceived problems in this aspect of industrial ecology. This study of business strategies will complement a scientific evaluation and risk assessment of recycling contaminated C&D wastes. Initial results already demonstrate that total background levels of some potential pollutants exceed current guideline levels even in supposedly uncontaminated material. Issues of risks associated with end uses and of mobility of pollutants have to be addressed. These studies demonstrate the need to combine robust science with a better understanding of the concerns of the wider population in order to gain acceptance of recycling possibilities and enhance the human ecology of old industrial landscapes.

Policy Design For Material Recovery Systems: A Case Study of Policy and Technology Based Obstacles for Eco-efficiency in the Recycling System of Plastic Packaging from Households in Trondheim, Norway

Hilde Nøsen Opoku and Arne Eik

Full paper available: Yes

Previous studies undertaken separately by the two authors have identified obstacles in the plastic recovery system in Trondheim – the third largest city in Norway -, at the political and administrative levels and in terms of technology based solutions. The intention of this paper is to combine and elaborate on these findings.

Last year 22% of the national consumed plastic packaging was recycled in Norway. From the total annual consumption of 100.000 tons plastic packaging, 55.000 tons comes from the households. Ultimately then, 55.000 tons plastic packaging should be collected and redistributed, along national guidelines, for further treatment at the municipality level.

Norwegian municipalities have a great deal of autonomy concerning their waste collection strategies. Today more than half (250) of some four hundred municipalities have introduced source separation and recycling systems for plastic packaging. One of them is Trondheim, situated by one of the fjords 500km north of the capital Oslo.

In 1997 Trondheim municipality introduced a source sorting system based on four separate waste bins at the curbside. The intention was to reduce the amount of waste going to the incinerator and landfill, and to increase the potential for recycling. The local source sorting system contains three normal-sized bins: The one for 'Paper and hard paper ' together with the one for 'Environmental Waste' are both designed for materials recycling, while the purpose of the last one, 'Residuals', is energy recovery. In addition a small container for hazardous waste is kept at the household. The concern of our study is the bin labeled 'Environmental waste'.

Instructions regarding the interior of this particular bin have varied over time, a source of frustration in the populace. Throughout the period, however, 'Environmental waste' has included a various set of sources. Today plastics, metal and drinking beverages (*drikkekartong*) are collected here, often resulting in unclean fractions unsuitable for material recovery.

Now, four years after the introduction of the source separation system, only 9% of the total amount of the plastic packaging waste from the households are recycled into new plastic products. Our hypothesis is that these rather disappointing results lies in poor policy design due to insufficient will and understanding of the problem at both political and administrative levels, resulting in inadequate technical solutions.

Traditionally, as far as Industrial Ecology is manifested in a tradition, advocates of Industrial Ecology from the technical and natural sciences tend to focus on economic and technical barriers when analyzing the efficiency of recycling systems. The importance of sufficient policy design and implementation is often overlooked. On the contrary, Social scientists have a hard time assessing the technology being used, ending up with conclusions that might prevent a more holistic problem description. This study combines the two approaches hoping to overcome these

shortcomings in our analysis of the plastic packaging recovery system in Trondheim.

Our data is based on an extensive analysis of the policy designed for the source sorting system and its implementation in a particular city area. Secondly, statistics of the recycling rate for that particular area in 1999, 2000 and 2001 will be analysed in comparison with the development at the policy level. Finally an LCA analysis identifying where in the life cycle loss of material occurs will be carried out, to support suggestions for improvements in the system. The goal is to bridge empirical knowledge from traditionally two separated scientific cultures and give a more profound problem description of a recycling system.

Unique Non-profit Assists Auto Recycler with Environmental Compliance

Jack W. Scannell

Full paper available: Yes

Historically, in a similar way as municipal landfills, automobile recycling businesses were often established in less favorable, sparsely populated geographical areas of little interest to the average person unless a used car part was needed. Given such isolation and low visibility to the general public and regulatory agencies, these operations were left alone for many years to do business and manage their part of the environment at their discretion. Due to the nature of their business and a general hands-off policy, most developed into a visual eyesore and serious potential source of pollution.

As land use needs and environmental regulations changed over the years, some automobile recycling companies suddenly found themselves scrutinized by different federal, state and local regulatory agencies. On-site investigations by agency inspectors frequently confirmed the seriousness of the problems. The issues are varied, ranging from clearly identified land, air and water pollution to complex environmental justice concerns for nearby multicultural residential neighborhoods. Consequently, these types of companies have often been given an ultimatum: clean up and comply, or shut down.

For some businesses, the task of cleaning up and doing what it takes to comply represents an insurmountable problem due to the size of operations and lack of knowledge for overhauling a large business operation for compliance with government regulations.

While some companies may have chosen to shut down under these circumstances, one automobile recycling company in Seattle, WA chose to seek technical assistance from a qualified nonprofit environmental technical assistance organization chartered for providing free services to industry. The Environmental Coalition of South Seattle (ECOSS) is a local organization with a unique position within the community, and a reputation for providing such qualified services to businesses in all industrial sectors. This paper describes some of the work by ECOSS staff to assist Affordable Auto Wrecking in correcting and/or improving their facility for required compliance with environmental regulations in the media of air and stormwater. These activities also included the development and implementation of comprehensive plans for both source and structural controls for pollution prevention in various areas of the facility. As a result, Affordable Auto Wrecking was able to continue full business operations as an improved environmental steward and partner in the community.

Technical Program V

Social Framework III

Solving New Environmental Problems by Going Beyond Regulation and Response

Clinton Andrews

Full paper available: Yes

This paper describes the popular conception of an environmental problem-solving system that relies on government regulation and industry response, and then shows how it fails to address important new environmental threats. It identifies alternative pathways for solving environmental problems that focus much more on individual

choices in a variety of social contexts, drawing on the experience of the recently completed New Jersey Comparative Risk Project.

The paper begins by arguing that environmental policymaking in post-industrial countries must change to reflect the rise of "second generation" environmental problems. "First generation" environmental problems included belching smokestacks, mountainous garbage dumps, and other obvious insults. For these problems, a scientific consensus existed regarding root causes and potential solutions. In recent years, first generation problems have been supplanted by second generation issues such as tailpipe emissions and suburban lawn runoff that are subtler and more dispersed. Accompanying these newer problems are diffused responsibility and rampant scientific uncertainty, which conspire to paralyze existing policymaking processes.

The paper then maps the current governmental regulatory system, which is supposed to work as follows: adverse environmental conditions should affect public perceptions, which should influence government policies, which should modify the behavior of firms and other offenders, which should improve environmental conditions. This "problem-solving" conception is embedded in the civic dialogue about the environment, and it represents an optimistic, rationalist vision of the processes by which environmental information affects environmental outcomes.

Next the paper dissects the problem-solving model of environmental policymaking, showing that other factors often drown out the weak signals being transmitted from scientists, to citizens, to government, to polluters. While acknowledging that the model has some descriptive and prescriptive value, the paper argues that it needs drastic re-thinking. The paper offers a better approach based on three central tenets. First, policymakers must concentrate on measuring what matters, as the indicators movement advocates. Second, it must reflect the decentralized nature of real environmental decision-making and support both bottom-up and top-down initiatives, as the devolution and green consumer movements do. Third, environmental policy making must concentrate on reconciling competing civic objectives, as the sustainable development paradigm attempts to do.

By examining environmental regulation as if it were a coherent social problem solving activity, we gain a better understanding of why it sometimes is not. We know that much social, political, and economic activity in fact ignores environmental problems rather than addressing them in a timely manner. By integrating and extending previous work on risk perception, public opinion, regulatory policy, and impact analysis, this paper presents a unified view of the whole process of environmental improvement, and it shows how the process itself might be improved.

New data are available to illustrate the themes outlined above. The author is one of the principals of the New Jersey Comparative Risk Project, a multi-year effort to characterize and then rank the state's environmental problems. Funded by the US Environmental Protection Agency and the New Jersey Department of Environmental Protection, this project blends scientific knowledge and stakeholder values in an elaborate process involving dozens of experts, repeated interactions with stakeholders and public officials, and outreach to the general public. For 75 environmental problems spanning 11 major categories, scientists have prepared peer-reviewed analyses of their impacts on human health, ecological quality, and socioeconomic concerns. This paper will use illustrative results of this project as a springboard for investigating broader questions about the social framework of industrial ecology.

Stakeholder Involvement in Life-Cycle Assessment

Robert Anex

Full paper available: Yes

Recognition of the contingent and social nature of human interpretation of the environmental impacts and environmental risks created by both public and private decisions has led to an increased appreciation of the importance of involving stakeholders in the assessment of these risks and impacts. Human responses to environmental change represent risk management strategies reflecting complex judgments about environmental and economic risks which are in-turn derived from more subtle social-cultural-psycho-

logical judgments anchored in ethical and historic beliefs about nature and humans' relationship with it. In order for analysis to capture the full complexity of human responses to environmental change, stakeholders should be involved in the process.

In risk assessment the need to involve stakeholders in evaluating and prioritizing risks for policy attention is becoming accepted generally. Arguments for stakeholder involvement in environmental assessments can be situated comfortably in the National Research Council's (NRC) 1996 prescription that reconceptualizes risk assessment as a recursive analytic-deliberative process, instead of the strictly top-down science-driven process. The 1996 NRC report identified two challenges in implementing the analytic-deliberative process. The first of these concerned the substance of risk-based decision-making: how to get the science right and how to get the right science. The second concerned the process of risk-based decision-making: how to get stakeholder participation right and how to get the right stakeholder participation. In this paper, a risk-based LCA framework is proposed that recommends stakeholder participation strategies designed to meet these challenges and enhance the effectiveness of policy-driven analyses such as LCA, based on the level of trust that stakeholders have of various policy participants.

Individuals, Social Groups, and Institutions: An Examination of the Locus of Decision Making with Major Impact on the Environment

Faye Duchin

Full paper available: Yes

Industrial Ecology focuses on 2 categories of decision makers, corporate managers and government policy makers, and their control over material and energy flows. Society of course includes a wider set of decision makers, but they are physically more dispersed, they are assumed to be more passive, and their impact is considered more incremental and indirect. The key example of such "weak" decision makers is consumers. However, the social landscape is complex because of the extensive overlap of roles (e.g., some consumers are also managers, all managers are also consumers, and no one is only a manager and a consumer). In addition, the prospects for institutional changes that can strengthen weak decision makers, like the emergence of an environmental movement that influences group behavior or the creation of non-governmental, not-for-profit organizations in the public interest like Public Citizen, the U.S. organization that litigates on behalf of all consumers, are as significant as those for technological change. This paper explores the set of actors and the possibilities and constraints they face. I go on to suggest directions for broadening the social landscape of Industrial Ecology in a way that is based in social theory that relates categories of decision makers to the flows of energy and materials associated with the activities that follow upon the kinds of decisions they make on both a routine and an exceptional basis.

Implementing Industrial Ecology – A Policy Science Exercise?

Arnold Tukker

Full paper available: No

Industrial Ecology (IE) typically focuses on greening of major parts of our societal systems, usually asking for rather radical changes compared with the current situation on longer term. Metaphors used are 'Factor X', 'transitions', and 'system innovations'. IE seems to have its roots predominantly in natural science oriented research: a typical issue of the Journal of Industrial Ecology mainly contains papers on mass flow analyses, LCAs, input-output analyses, etc.

There is of course nothing wrong with that. Analytical tools can certainly help to give guidance into which direction the required systems changes have to take place. However, when it comes down to implementing the ideas of such natural science based IE research, a number of typical problems is encountered. These problems are mainly based in the fact that IE deals with large societal subsystems and hence a lot of actors, and environmental problems that are inherently complex:

1. Often, there is no such thing as one single view on what is the problem, and the solution. There

might be different paradigms or frames that different actors related to the IE system at stake adhere to.
2. Often, there is no clear dominant problem owner or decision taker either. It is the network of actors, working together (or not), that lets things happen.

Two examples will be given of such problems. One is the problem of diffuse emissions leading to polluted sediments in the Netherlands, asking for an integrated, EU wide IE approach to the related compounds – but where in fact EU regulation of free trade blocks all initiatives, supported by those who do not like such a source oriented IE approach. The second example is the debate on the use of a number of toxic substances in products, where the balance of power in the production-consumption chain actually determines if a risk-based management approach (using the substances and keeping their production infrastructure intact) or a precautionary management approach (phasing large production systems of chemicals out) is applied. The conclusion is straightforward. Implementing Industrial Ecology implies:

1. Dealing with an analysing the views of the stakeholders that have key position in the IE system at stake;
2. Designing processes, based on the notion of network management, that can overcome opposing views or other institutional barriers, and create arrangements that lead to action.

Which means asking policy science to come to rescue.

Eco-Design II

The GQFD as a Methodology of Environmentally-Conscious Manufacturing

Andrea Raggi, Luigia Petti, and Lorella Mercuri

Full paper available: No

In today's globally competitive market, design and manufacturing of products that meet customer requirements and environmental constraints has become the goal for most manufacturing organizations. The concept of environmental quality is becoming increasingly important and the "green" behaviour of many companies is also a result of consumer demand for environmentally-friendly products. These issues must be considered at the product design stage.

Green Quality Function Deployment (GQFD) is a recently proposed tool, providing an efficient methodology to face such problems.

Quality Function Deployment (QFD) is a system for translating customer requirements into appropriate company requirements at each stage from research and product development to engineering and manufacturing to market and distribution. Life Cycle Assessment (LCA) assesses the environmental impacts for all activities taking place over a product's full life cycle, "from cradle to grave".

Environmental conscious manufacturing can be implemented by integrating LCA (and LCC) into QFD matrixes.

This paper presents a critical review of this methodology and an attempt to point out new advancements.

Advances in Design for Environment at Motorola: 5 Years of Lessons Learned

Katrin Mueller, Michael Riess, Markus Stutz, Doreen Schnecke, Siegfried Pongratz, W.F. Hoffman III, Ion Nicolaescu, Steve Scheifers, and Bob Pfahl

Full paper available: No

We first described the processes and methods Motorola was using to implement Design for Environment in the Winter 1997 JIE. Many of those methods survive today but many aspects of DfE have also changed. The intervening five years have also seen considerable change in the competitiveness of environmental issues. It is no longer just regulation and environmental activists setting the pace of environmental innovation, companies are beginning to compete based on the environmental attributes of their products. New initiatives have also been implemented to meet the needs of management of portfolios of products and the engineering design process. Yet many issues remain. External regulations still

loom, banning specific materials and demanding the design of recyclable products. This paper will describe how time and experience have modified our initial Design for Environment initiatives and what new directions are being taken to implement DfE within Motorola.

Regional Material Flow Analysis

On MFA and Policy-Making, or What if Data Uncertainties Were Considered?

Fredrik Burström and Lena Danius

Full paper available: Yes

Regional material flow analysis/accounting (MFA) has been proposed as an analytical tool to be used in various environmental management decision-making situations, for example as a tool for early recognition of major problem flows or stocks, priority setting, effective policy and goal making, follow-up/analysing trends, and screening (Burström, 1999, Hendriks *et. al*., 2000, Udo de Haes *et al*., 1998). However, data uncertainties in MFA, as in other environmental system analysis tools such as LCA, are very often of varying standard. This leads to questions like: How reliable are the results? How big recorded difference between flows is necessary to guarantee that one is larger than the other? Has an improvement really occurred from one year to another? For LCA there exist a number of methods to deal with data uncertainties (Björklund, 2000). Data uncertainties connected with MFA studies are however mostly not dealt with. The usual way of handling these questions is to conclude that, in spite of the unknown uncertainties, the result is good enough and that the correct order of magnitude of the different flows are accounted for.

Aiming to raise the awareness on the generally neglected but very important issue of data uncertainties in MFA, the paper analyses how data uncertainties affect the results in an MFA study and the possibilities to give policy recommendations for related to environmental policy and management. A newly developed model to determine, present and calculate data uncertainties in MFA studies (Hedbrandt & Sörme, 2001) is modified and applied on data from an earlier case study of nitrogen metabolism in the Swedish municipality of Västerås. Two situations where regional MFA is proposed to be useful will be investigated: priority setting and follow-up respectively. Priority setting is investigated by analysing data uncertainties for different flows and their mutual relation within one year, 1995 or 1998. Following up is looked upon by analysing the change of particular flows between the two years 1995 and 1998.

When the nitrogen flows are analysed without consideration of data uncertainties, it appears that certain conclusions can be drawn concerning relative importance for the total load on the environment. But when data uncertainty is considered, the conclusions are not so given. In the situation when MFA is used as a tool for priority setting the following can happen: Two flows that earlier seemed to be of the same importance, can in extreme situations vary so that any one of the two flows are twice as large as the compared flow. Flows that initially seemed to be of different size may turn out to be of equal size. In the situation when MFA is used as a tool for following up the following can happen: For flows recorded from data with high uncertainty, the change is no longer certain. Only when the data have very low uncertainty a change remains even when data uncertainty is considered.

In all, our study indicates in both cases that the consideration of data uncertainties makes the results less certain and the policy recommendations more ambiguous. Based on the analysis of data uncertainty in relation to the case study presented in this paper, it is concluded that to use MFA as a tool for priority setting and follow-up is associated with considerable difficulties. However, MFA is still a useful tool for screening in order to identify areas for further and more detailed investigation.

References

Björklund, A.E. (2000) Survey of approaches to improve reliability in LCA. Manuscript submitted to *International Journal of Life Cycle Assessment*.

Burström, F. (1999) Materials accounting and environmental management in municipalities. *Journal of Environmental Assessment Policy and Management*, 1(3): 297-327.

Danius, L. & Burström, F. (2001) *Kvävemetabolism i Västerås kommun 1995 och*

1998 (The nitrogen metabolism of Västerås 1995 and 1998). Technical Report 2001:1. Royal Institute of Technology, Division of Industrial Ecology. Stockholm.

Hedbrant, J. & Sörme, L. (2001) Data vagueness and uncertainties in urban heavy-metal data collection. *Water, Air and Soil Pollution* (in print)

Hendriks, C. *et al* (2000) Material flow analysis: a tool to support environmental policy decision-making. Case studies on the city of Vienna and the Swiss lowlands. *Local Environment*, 5(3): 311-328.

Udo de Haes, H., Huppes G. & de Snoo, G. (1998) Analytical Tools for Chain Management, Chapter 5 in: *Managing a Material World: Perspectives in Industrial Ecology*, Vellinga, P., Berkhout, F. & Gupta, J., eds., Kluwer Academic Publications. Dordrecht.

Linking Energy, Material and Economic Flows on the Local and Regional Level: First Steps Towards a Material-flow Economy

Uwe R. Fritsche

Full paper available: Yes

The sustainability of local and regional developments on the level of two new inner-city neighborhoods (city quarters) in the German cities of Neuruppin (Eastern Germany), and Freiburg (South-West Germany), is quantitatively analyzed with respect to ecological and economic impacts, while social indicators are included qualitatively.

Based on this analysis, the linkages between the ecological and economic impacts of various local and regional activities and strategies to achieve a more sustainable neighborhood are determined, and "win-win" options identified.

The analysis of the real-world examples of local activities considers their full life-cycle impacts, and differentiates between local, regional and national/global impacts.

The linking of micro-economic impacts with meso-scale (regional) effects uses a process-chain ("bottom-up") approach, while the national and global economic impacts are determined by macro-economic input-output ("top-down") modeling.

The material flows are linked to the economic activities on the local/regional scale to determine the effects of the local activities.

The project results are used in the considerations of local/regional actors and stakeholders to determine their future implementation strategies for "sustainable development".

The quantitative linkage of ecological and economic effects using a bottom-up allows first steps in the direction of a material-flow economy on the local and regional scale.

This work is sponsored by the German Federal Ministry for Education and Research (BMBF) under the program "Regional sustainability".

Detailed results can be found on the project website http://www.oeko.de/service/cities/

A System to Optimize Regional Material and Energy Flow for Designing Recycling Society

Naohiro Goto, Koichi Fujie and Tomotaka Usui

Full paper available: Yes

To maintain sustainable development, it is required to establish new society with low environmental load and low resource/energy consumption, i.e. recycling society. A method to design the recycling society is to raise effectiveness of resource/energy utilization and recycle of waste.

Material balance of manufacturing process is composed of raw material input, product output and waste generation. Ratio of the input to the output could be interpreted as effectiveness of resource/energy utilization. Rise of this ratio is to increase the effectiveness. Recycle of waste also plays an important role. The recycle makes waste disposal and virgin resource/energy consumption reduce. This makes ratio of virgin input to output raise and brings the effectiveness increase. In order to establish the recycle society, it is required to optimize theses material flows.

The objective of this research is to develop methodology to optimize regional material flow, i.e. to maximize effectiveness of resource/energy

and recycle of waste for recycling society. Procedure is described as follow. First is to analyze regional material and energy flow. Second is to design waste utilization among industries, "industrial network". Last is to minimize environmental load and energy/resource consumption. We have developed a computer system for this procedure. It is composed of four compartments, analysis of regional material flow, design of industrial network, optimization of the material flow and some databases for the system.

1) Analysis of regional material flow

There are two approaches for regional material flow analysis. One method uses input output table and estimates material flow among industrial sectors. The input output table shows relationship among industrial sectors in cash flow. Then the cash flow should be converted to material flow by setting conversion factor. Though this is the best to comprehend profile of regional material flow easily, it cannot investigate detail material flow. Another method uses questionnaire and investigates material flow among individual factories. Though this method is most accuracy to analyze, it cannot investigate all regional material flows. These two approaches complement each other. By using same method water and energy balance could be estimated.

2) Design of industrial network

When regional material flow is analyzed, regional elemental flow could be also analyzed by setting elemental composition of products. If elemental composition of waste from one industry is similar to that of products from other industry, industrial network between the two industries can be connected.

3) Optimization of regional material flow

In designing industrial network a lot of industrial network candidates could be found. The network to minimize final disposal of waste should be selected. This kind of optimization is applied to all industrial sectors, and industrial networks with maximum waste disposal reduction show optimized regional material flow.

4) Database

There are some databases for this system. One is on material balance in factory. It includes waste generation or waste recycle per each product. Another is on recycle technology. When one industrial network is selected, it should be recognized whether the network is feasible or not. In the reorganization, the database on recycle technology is referred.

Improved Environmental Performance by Means of System Innovation and Networking: Case of a Regional Energy Supply System

Kirsi Hämäläinen and Hanne Siikavirta

Full paper available: Yes

A case study about a regional energy supply system of Jyväskylä, Finland is presented. The energy supply system is based on a network of companies and organizations operating in the energy generation and transmission fields in Jyväskylä. The case of the energy generation system in the City of Jyväskylä shows how co-operating partners can enhance their environmental performance and eco-efficiency by networking.

In order to illustrate the suitability of the network co-operation for enhancing environmental performance and eco-efficiency, a comparison is provided by generating a model of an alternative energy supply system. The comparison system is assumed to be based on companies and sites producing energy separately instead of co-operation. In the comparison system wood residues from the neighboring industrial plants and processed chips from forest harvesting would not be used as a fuel as in the current system. In addition, the district heat distributed to the rural areas surrounding the city of Jyväskylä and the process steam consumed by a local paper mill and by a local paper machine producer would be generated in separate boilers instead of the power plants belonging currently to the system. Moreover, the ash produced by the power plants in the system and the heat extracted currently from the condensing water of the paper mill and from the district heating waters returning from the city would not be utilized in the comparison system.

The fuel consumption and the environmental loads related to the current system and to the comparison system as well as the investments used for building up the systems are compared. Consequently, the eco-efficiency of the systems is compared. The data used for modeling the systems is acquired directly from the companies

operating in the energy generation and transmission fields in Jyväskylä. In addition to this site-specific data, secondary data gathered from statistics and publications is used.

If the energy generation system of Jyväskylä were not based on the network co-operation like in the current system, the primary fuel consumption and the environmental loads of the system would increase. The carbon dioxide (CO_2) emissions generated by the system would be about 30% higher than in the current system. Moreover, the particle emissions would be nearly 20% higher than the emissions generated by the current system. In addition to the environmental loads related to the current system, the investments needed for building up the system would be higher without co-operation. Thus, in the current system the energy produced in the Jyväskylä area is generated with lower primary energy consumption and lower emission and investment rates than in the comparison system, which does not rely on network co-operation.

The environmental performance and eco-efficiency of the energy generation system of Jyväskylä has increased alongside with the network co-operation. In the Rauhalahti Power Plant, which causes most of the environmental loads related to the system, the specific emission rates have decreased by 25% to 80% in last ten years. At the same time, the primary energy consumption of the power plant has increased by more than 30%. This illustrates that the growth in energy generation and thus, in the primary energy consumption has not been harmful for the environment. On the contrary, the growth has enabled the energy companies belonging to the energy supply system of Jyväskylä to invest in advanced environmental protection technologies and to environmentally more benign local fuels.

Corporate Integration – ICT

Economic and Environmental Implications of Online Retailing in the United States

H. Scott Matthews and Chris T. Hendrickson

Full paper available: Yes

E-commerce is revolutionizing product distribution and other business functions. Implementing E-commerce is heavily dependent on both constructed and digital infrastructure. However, the implications of E-commerce for environmental quality, infrastructure requirements, economic impact and sustainability have not been systematically assessed. Our research is focused on a life cycle approach to estimating the economic and environmental implications as well as sustainability of the Internet, specifically of E-commerce, compared with traditional logistics and manufacturing systems. For example, a case study of book publishing compares the traditional retail system to electronic ordering (e.g. using Amazon.com, a major American online retailer), and to a new system that would produce the book at the time and place where the customer orders it. We will generalize from our case studies to examine impacts for transport congestion and infrastructure needs from product delivery, including energy and transport infrastructures. At one level, E-commerce may substitute for more costly catalog or retail outlet marketing channels. We will use our Internet based life-cycle assessment model (EIO-LCA) which is based on an input-output framework of the U.S. economy augmented with the most current environmental and resource use data.

The traditional logistics system starts with product manufacture and then distributes the product through regional warehouses, a retail store, and finally delivery to the consumer. This system is expensive and resource intensive. First, for almost every product, too much or too little is produced since the product demand is uncertain. Second, the product moves much further than from the manufacturer to the consumer. Third, the transport and storage require the product to stay in the system for a long time, which expends resources and provides many opportu-

nities for damage or theft. While this system takes advantage of economies of scale in production and freight shipping, resources are used and pollution generated by the additional shipping and excess production. E-commerce systems substitute "warehouses in the sky" with Federal Express and UPS providing rapid delivery from the manufacturer's warehouse or for products made to order. However, packaging, airfreight and home delivery also use resources and pollute. It is not obvious which of the two systems results in less overall resource use and pollution. A further step is producing to order, to eliminate inventories. A possible future step would be "manufacture to order" at the customer's location when the order is placed. Visionaries focus on what is or might be technically possible. Total costs, resource use, and environmental discharges are rarely considered but are critical issues.

An initial discussion of these general points was made by Matthews (2000), suggesting that online retail systems depend on traditional logistics carriers in the U.S. (UPS and FedEx) for fulfillment. A primary concern of this paper was that the additional packaging and overnight air shipping present significant environmental challenges. For example, shipments of books to traditional retail stores typically are in bulk boxes containing 10-30 books, while online shipments to customers typically contain only 1-3 books per box. A subsequent paper by the authors (Hendrickson 2001) compared traditional versus online retail shopping models and found scenarios by which e-commerce systems could actually cause 5-30% less environmental effects compared to traditional systems.

As with any model, the comparisons between different retail and logistics models are sensitive to the inputs used. For example, the distance from a consumer's home to a traditional bookstore is significant. The distance from the online retailer warehouse to the consumer is also significant.

However, the most important input variable is the amount of unsold product. In the book publishing industry, unsold product is called 'remainders' and averages 35% for best seller hardback books. This implies that 35% more product was manufactured than was sold. In the publishing industry, wasted production leads to many tons of pollutant releases that could have been avoided if manufacturing systems were optimized to demand (as is done for other products).

We are also considering the implications of advanced technologies such as on-demand manufacturing, where a product is only manufactured when it is demanded. For book publishing, this is 'print on demand', which allows low-volume books to be printed at a local bookstore. This is accomplished by digitally providing the electronic contents of the book to a printer. One of the primary benefits of such a system is reducing 'unsold inventory'.

We are also analyzing the environmental and sustainability implications of the Internet infrastructure in the United States. Our research involves large system descriptions of the Internet in terms of computers, hubs, and telecommunciations links needed to direct Internet traffic throughout the country. Our work will lead to estimates of the 'overhead' of Internet use, e.g. the energy and environmental impacts of sending e-mail or web surfing. Once found, these effects can be added to the logistics impacts cited above for an overall assessment of the sustainability implications of e-commerce systems.

In summary, we will present results summarizing our work to date on the comparative effects of online retailing in the United States. This research uses life cycle assessment as a tool to organize impacts during the manufacture and delivery of products. The effects compared include costs, energy use, releases of conventional pollutants and greenhouse gases, and hazardous waste. Finally, we will extend our research on book publishing to other products, and note the different results generated by sensitivity analysis of the inputs of our model.

References

[Hendrickson 2001] Chris T. Hendrickson, H. Scott Matthews, and Denise L. Soh, "Economic and Environmental Implications of E-commerce: Case Study on Book Publishing," Proceedings of the 80th Annual Transportation Research Board Conference, January 7-11, 2001, Washington, DC.

[Matthews 2000] H. Scott Matthews, Chris T. Hendrickson, and Lester Lave, "Harry Potter and the Health of the Environment", IEEE Spectrum, November 2000.

The Environmental Benefits and Costs of Telework

Erasmia Kitou, Arpad Horvath and Eric Masanet

Full paper available: No

A substantial portion of the U.S. labor force, estimated at 30 percent, now works from home at least part of the time. An estimated two million are full-time employees who otherwise would commute daily to an office or other workplace. With traffic congestion bordering on unbearable, and the reduction of air pollution continuing to be one of the most important public policy goals in many metropolitan areas, working at home, commuting only to neighborhood telework centers, or cutting weekly commute entirely or by at least a day or two may bring environmental benefits. Telecommuting is becoming popular, and due to its scale and potential, telework's environmental impacts have come to the forefront of interest of decision-makers.

We present a comprehensive systems framework that includes the multitude of direct and induced effects of telecommuting in order that the environmental analysis accurately captures all factors relative to the status quo, non-telecommuting. Both environmental and economic factors are included as economic information complements environmental assessment, while environmental emissions (through their full social costs) have economic implications. This research quantifies the systemwide operating effects of telecommuting by assessing the energy consumption and the resulting air emissions related to transportation, office and home space, and electronic equipment use. Telework's effects on these components include estimation of the emissions associated with rebound effects such as latent demand, or increased demand for other activities such as increased number of shopping trips, pleasure travel, etc. The external costs of air pollution are converted into dollar terms using full cost accounting methods.

We have developed a comprehensive, web-based decision support tool that is available in the public domain. The tool is designed to help individuals, company managers, regulators, as well as other stakeholders (such as the general public, environmental health and safety professionals, etc.) interested in the environmental implications of telecommuting to make more environmentally sound decisions while understanding the complexity of the system.

Are air emissions indeed reduced as a result of telecommuting, or have the emissions and exposures simply shifted to other providers, products or services in the supply chain? Using the tool, a decision-maker should be able to decide when telecommuting is a more environmentally benign option.

Will Industrial Ecology Give Way to Service Ecology? : A Critical Review of Ideas and Research on "Sustainable (product) Service Systems"

Oksana Mont and Chris Ryan

Full paper available: Yes

As the long-term focus for change in production and product systems has moved from (easily) achievable technical changes able to deliver "factor 4" reductions in environmental impact, to larger systems realignment for "factor 10" changes, the idea of a shift from "product ecologies" to "service ecologies" has gown in policy and industry research. Although these ideas take a number of forms, they all propose that significant gains in environmental improvement can be achieved from an approach, which would see economic and business activity move from product sales to selling services (including the services of the utilisation of a product). Such thinking has been boosted by the recognition of various consumption effects, which severely limit the overall societal gains from realised improvement in technology, materials and product design. This can be illustrated by the situation where energy savings by improved car engines are frequently "eaten up" by bigger and an increased numbers of cars, faster cars or longer distances driven.

Although the sustainable services approach continues to be an active focus for research in the EU and a new dimension for policy formulation (for instance in Integrated Product Policy) there is reason to be concerned that knowledge, concepts, terminology and practical development is not developing in a critical and coherent way. Yet already some core issues seem to be clear

and the simplistic assumptions that have been characteristic of much of the writing and projects to date can now be refute.

Software Renting – A Platform for Sustainable IT Sector?

Andrius Plepys

Full paper available: Yes

The Information and Communication Technology (ICT) sector does not only create hazardous waste problem, but it is also surprisingly highly resource-intensive. The data about the environmental impacts for electronics is gradually being collected and analysed in a few life cycle analysis (LCA) studies. Some life cycle stages such as material extraction and component manufacturing are highly material and energy intensive and hazardous waste is being generated along most of their life cycle stages.

Rapid technology development has tremendously increased functionality of electronic products. Unfortunately, the development has caused faster product rotation and growing consumption due to increased affordability. Therefore, the environmental gains are often reduced or negated by the rebound effect of consumption.

In this light improving resource efficiency of ICT sector is a vital goal, which could be reached through product dematerialisation. The sector has enormous potential for substituting a physical product by its functionality or servicizing. Successful combination of ICT products and services into new competitive systems reduces resource consumption, offers a larger variety of better quality services for consumers and generate more added-value for less resources. Unfortunately, today such potential of the ICT sector is either under-utilised or has led to rebound effects in consumption.

The article analyzes a business model of Application Service Provider (ASP) as an example of ICT product dematerialisation - a less material intensive alternative to traditional computing. The paper describes the benefits of ASP vs. traditional computing looking from environmental, economic and consumer perspectives and drivers and barriers for ASP business are analysed here. The conclusions show that there are several groups of barriers that hinder a broader use of ASPs: technical, cultural, knowledge, economic and legal barriers that can be addressed by different actors. Companies can overcome some of those barriers, but the issues of property and privacy right protection, anti-trust legislation, standardisation and infrastructure development have to be addressed by government.

Industrial Symbiosis II

Fulfilling Taiwan's Aspiration of Becoming a "Green Silicon Island" through Industrial Ecology

Allen H. Hu and K. Y. Chong

Full paper available: Yes

Several scholars had pessimistically predicted that humanity had just fifty years left. While those predictions may be exaggerated and unrealistic, given that one-quarter of the world's population remains in severe poverty and more than 100 million people survive on less than US$ 1 per day, as well as the irreversible environmental damage being caused by human activities, including global warming, ozone layer depletion, the proliferation of toxic and hazardous wastes, desertification, deforestation and the loss of biodiversity, the above scenario seems at least plausible. To overcome the devastating problems mentioned above, the international community has developed some solutions, and proposed the so-called "Agenda 21" during the 1992 Earth Summit. Although there appears to have been little progress since the Earth Summit, people are gradually realizing that we need to examine our way of life and seek a solution from Mother Nature, that is to close the loop, maximize the use of materials and energy, and utilize natural materials. These actions are the essence of industrial ecology (IE).

Although enjoying unprecedented wealth and prosperity in recent decades, Taiwan has also suffered unprecedented costs from environmental damage. The government was quick to realize this problem, and initiated various environmental protection programs from the late 80', including pollution control, waste minimization,

environmental management, pollution prevention, cleaner production, and more recently, promoting eco-industrial parks. These measures have significantly improved Taiwan's environmental situation. Last spring, the opposition DPP party finally broke the KMT's long hold on power and pledged to establish Taiwan as a Green Silicon Island (GSI), emphasizing that environmental protection policies had joined the pursuit of economic growth in the political mainstream.

This study aims to discuss how to apply IE to Taiwan and thus realize the above vision. Using existing infrastructure and the theory of industrial ecology as a foundation, a system has been developed. This system has a hierarchical and interrelated framework, comprising the lowest waste exchange information system to resource recovery system, corporate waste minimization synergy system, eco-industrial parks (EIPs), and virtual EIPs. Five IE scenarios, namely the baseline of waste exchange, waste minimization and pollution prevention, pollution prevention plus industrial symbiosis, physical EIPs and the virtual EIPs, were analyzed regarding their potential economic and environmental benefits. Furthermore, the economic, environmental, regulatory and technological infrastructures were also reviewed.

Results in this study demonstrate that the case study of the National Waste Exchange Information Center can be used to expand into a physical EIP or even a virtual EIP by providing regulatory incentives. The Corporate Synergy Systems positively contributes to small and medium enterprises in efforts to enhance their competitiveness by developing waste minimization programs. Changes to current regulatory and incentive mechanisms that are necessary for Taiwan to become a Green Silicon Island are also suggested herein.

Construction of Cycle-oriented Industrial Complex Systems: Strategies for Planning and Estimation

Tohru Morioka, Noboru Yoshida, and Hiroyuki Fujimura

Full paper available: Yes

The author describes the concept and practices of recycle-oriented industrial complex which utilizes by-products or wastes from different industrial sectors as inputs to production activities. First three types of societal demonstration sites of recycle-oriented complex are investigated and their management plans from a standpoints of material and product chain management as well as spatial metabolism management. Three demonstration sites include industrial collaboration complex, recycle conscious food supply and retail chain, and sustainable urban renewal projects. Secondly, integrated planning and estimation models are presented based on implementational analysis on three demonstration sites. Estimation indicators for eco-efficiency and environmental soundness are proposed. Thirdly, network type eco-industrial park projects are planned and their environmental impacts and effects are estimated as a case study in Osaka Metropolitan Region, Japan.

Industrial Symbiosis as Economic Development

Marian R. Chertow

Traditionally, economic development has been done on the basis of exploiting key geographic, economic, or institutional conditions of a region as a means of attracting and sustaining development. Industrial ecologists have theorized about a different type of locational advantage, known in the literature as "industrial symbiosis." This part of industrial ecology considers material and energy flows among groups of businesses and industrial operations. This paper argues both theoretically and through a case study that industrial symbiosis should be considered a novel, environmentally conscious tool for economic development.

Industrial symbiosis has been previously defined as engaging "traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and by-products" (Chertow, 2001). The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity. The industrial district at Kalundborg, Denmark has become an archetype of industrial ecology illustrating high levels of environmental and economic efficiency.

The primary partners in Kalundborg, an oil refinery, power station, gypsum board facility, pharmaceutical plant, and the City of Kalundborg, share water, steam, and electricity, and also exchange a variety of wastes that become feedstocks in other processes.

In a project conducted in the winter and spring of 2001, Yale researchers were invited to offer environmental and technical advice for the development of New Haven Harbor based on the lessons of industrial ecology and experience in researching industrial symbiosis. The resulting studies, examined here, revealed industrial symbiosis to be a powerful analytic tool both for suggested revitalization of existing businesses as well as for identifying new development that could be brought in to exploit synergistic opportunities

Evaluation and Monitoring of Ecoefficiency in Ecoparks: A Case Study from the Ora Ecopark in Norway

Johan Thoresen

Full paper available: No

The monitoring and evaluation of aggregate and individual environmental performance of companies in Ecoparks will become extremely important in the next few years. One reason is the requirements which have been put forward by national and cross-national governments, e.g. to decrease the rate climate gas emissions (the Kyoto Protocol) and future focus on the improvement of energy efficiency in industry. Another reason is the need for an "eye-opener" to show the considerable environmental improvement potential from systematic Ecopark co-operation to authorities, to the public and to industry itself.

Ecoefficiency indicators may be used in a set of different planning and decision situations within companies, within ecoparks or between external stakeholders and industrial companies. The required format of the relevant ecoefficiency information will differ strongly between the different external stakeholders and company internal decision makers at various organisation levels. However, irrespective of the different formats for any one type of impact, such indicators must all provide the relevant decision makers with ecoefficiency information as decision support adjusted to each person's decision needs. This information may represent the aggregate performance of all companies within an Ecopark or the performance of an individual company within the park. Based on empiric information gathered from the Ora Ecopark in Norway, it has been established that a time series of the usual ecoefficiency indicators (expressed as value added in some form : relevant environmental impact) may not be valid indicators to represent company performance. The reason being that changes to a product mix with different environmental impact lifecycle characteristics may have been introduced or the rate of process capacity utilisation may have been radically changed. In addition, if the ecoefficiency indicator is expressed in monetary terms, radical and periodic changes in market prices may upset the representativeness of such an indicator. A series of case-examples from the Ora Ecopark will be given in the paper to show and explain this situation. Furthermore, different principles and concepts for establishing functional ecoefficiency indicators have been developed and will be addressed in the paper. Adjusted time series representing aggregate and individual climate gas emissions rates and development of energy efficiency of the Ora companies will also be shown.

Substance Flow Analysis Cases

Toxic Accumulation in Efficient Recycling – Societal Cadmium Dynamics and Recycling of Phosphorus

Fredrik Fredrikson, Sten Karlsson, and John Holmberg

Full paper available: Yes

Phosphorus is an essential nutrient for all life and it is one of the major nutrient inputs to food production. Since the reserves of phosphorus are limited there is a need to use these resources carefully. A more resource efficient management of phosphorus is therefore a key question in order to secure the increasing and long-term demand for food, bio-energy and other materials based on biomass.

Transfer of phosphorus from agriculture to society will be an increasingly important loss of phosphorus and it is therefore important to recycle the phosphorus back to agriculture. One problem with this is that the flows of phosphorus in society are contaminated due to societal use of different toxic substances. Contamination of sewage sludge with cadmium is one such example that is getting a lot of attention.

Cadmium is also transferred to agricultural soils as a contaminant in phosphorus fertilizer. Since a growing part of the population lives in cities it is important to evaluate in what way the use of cadmium could be consistent with re-circulation of phosphorus. Is the societal use of cadmium restricting a long term resource efficient recycling of phosphorus or not?

In this study we have evaluated different possible long-term scenarios for cadmium transfer to agricultural soils in Sweden. One important feature of the study is that we focus on the dynamics in the societal metabolism of cadmium and its possible constraints on an efficient recycling of phosphorus. One important dynamics is the limited resources of cadmium. Together with the scenarios we also look on different indicators for the system. We also makes a historical scenario about what would the situation look like if we had used sewage sludge in the agriculture since the introduction of sewage plants.

The study shows that the dynamics in the societal use of cadmium (intentionally and unintentionally use) is very important and that it must be taken into account for policy makers in order to avoid future large-scale lock-ins that may restrict a resource efficient use of phosphorus.

Grand Technological Nutrient Cycles: A Survey and Status Report

T.E. Graedel and R.J. Klee

Full paper available: Yes

The modern technological society uses a very large number of materials. These substances are derived from rocks, sediments, and other natural repositories, and most undergo transformation prior to use. A large fraction of the materials is eventually returned to the environment. The natural world also mobilizes and uses materials in its processes. The derived quantitative cycles of four crucial natural materials, carbon, nitrogen, sulfur, and phosphorus, are termed the "grand nutrient cycles", and have been well characterized.

Historically, there has been minimal overlap between the cycles dominated by natural processes (sulfur, for example) and those dominated by technological processes (tin, for example). In the case of elements widely used by our technological society, we might term their cycles the "grand technological nutrient cycles". The technological cycles are poorly quantified, however, and it is not very clear how important technology may be to many of the global cycles. Where extensive studies have been made (for nitrogen, for example), it is apparent that strong anthropogenic influences exist for at least some of the elements whose cycles were once wholly controlled by natural processes.

For purposes of industrial development and potential environmental impact, it is important to know, at least approximately, what quantified cycle information is available and to what extent natural, technological, or mixed dominance occurs. In this connection, we have reviewed the available information on the cycles of the entire periodic table of the elements. Many elements have not yet been studied from this perspective, and a number of cycles remain to be derived. Where information is extant, however, it appears that human activities dominate the cycles of most of the Group IIIa-VIII and Ib-Vb elements and that natural activities dominate the cycles of most of the Groups Ia, IIa, VIb, VIIb, and 0 elements, dominance being measured by the ratio between anthropogenic and natural flows. In several instances, neither anthropogenic nor natural processes dominate. We will present several examples, and discuss explanations for the patterns that emerge.

The Contemporary European Copper Cycle: One Year Stocks and Flows

Sabrina Spatari, Thomas E. Graedel, Marlen Bertram and Helmut Rechberger

Full paper available: Yes

Substance flow budgets can provide a picture of resource uses and losses through a geographic region. By tracking specific substances, such as copper, through its various life cycle transformations, we can assess our approach to regional resource management and estimate gross environmental impacts associated with the copper cycle. This paper traces the flow of copper as it enters and leaves the European economy over one year. We examine the major flows of copper from ore, as it is extracted from the earth, transformed through intermediate forms – to product, as it is manufactured and used – to possible resource, as copper products are retired then recovered from waste management. A regional material flow model was developed to estimate patterns of copper use in the early 1990s in select western European countries. Successive mass balance calculations were used to determine copper flows, including the amount of metal that enters stocks in waste reservoirs and products, within the system boundary. A database, which emphasizes temporal and spatial boundary issues and data quality, was developed for continental substance flow analysis. All data were collected from statistical reports, periodicals, and public databases made available by government agencies, industry trade associations, and industry contacts.

The one-year European copper budget is characterized by a high import of processed and refined resources. A significant amount of copper is mined, smelted, and refined outside of Europe. A total of 1900 Gg/yr of copper is imported into Europe. About 40% of cathode copper produced within the system is recovered from secondary resources. Within fabrication and manufacturing processes, approximately 950 Gg/yr of new and old scrap are recycled and, together with primary production plus import, roughly 3500 Gg/yr of copper is made into finished products. The majority of copper in finished products is contained in pure form (77%), the remainder in alloy form. Post-consumer waste contains about 920 Gg/yr of copper. Waste management processes recover about 30 % of this copper from waste streams. Copper from post-consumer waste is roughly five times higher than waste from copper production. This ratio would decrease if we consider production wastes generated outside of the European system boundary. The fastest growing stock in the system (2600 Gg/yr) is represented by the storage of goods in the use phase— in infrastructure, buildings, industry, private households, and other uses.

The presence of pure copper in product applications suggests a strong potential for recycling of the metal. Alloys too, have a high recovery potential. Unlike other metals like zinc and cadmium, the pattern of copper use is less dissipative. The different use categories identified in this model show that most of the copper processed during the last decade is still in society

Sustainable Metals Flow Management – First Steps in the Region of Hamburg

Arnim von Gleich

Full paper available: Yes

Metals are not regenerative resources but their chemo-physical properties would in principle allow long lasting circulation of these materials in the technosphere. In reality however, we are far from this goal. In every product life cycle we loose about 1/3 of the metals by corrosion, waste and dissipation. Additionally we lower the quality of recycled metals (e.g. iron & steel and aluminium) by accumulating impurities like copper. Actually this problem is ‘solved’ by diluting the impurities in pure fresh material.

According to the first law of thermodynamics (energy and matter conservation within closed systems) there is no sustainability problem. The problem appears in the form of materials and energy availability and use (second law). We can (and we do) decrease and even ruin the usefulness of energy and materials within the, at least energetically, open system earth. This seems to be a central problem of sustainability. Regarding this aspect we can learn a lot from ecosystems. They show us how to build sustainable structures and systems (far from thermodynamic equilibrium) with an even growing level of ‘order’ fed only by the exergy stream from the sun.

Using the method of entropy balancing (see abstract Stefan Goessling), it is possible to measure the thermodynamic expenditures of manufacturing a certain amount of metal - for instance aluminium - or a certain product made out of

this metal. Of course, this can be done more or less efficient. But the next step is still more interesting: How are we going to use this high purity, light-weight metal? We can imagine a 'tendencial (thermodynamic or sustainable) amortization' of the definitely high construction phase inputs of aluminium products during the use phase and the following recycling cycles. If ever we would be able to handle the product and the material in a sustainable way!

This is the general approach we follow at the University of Applied Sciences Hamburg, Dep. of Mechanical Engineering and Production in a research project. The project is funded since 1999 by the German Ministry of Research and is cooperating with the University of Hamburg, Dep. of Informatics, the Ökopol Institute of Hamburg, the consulting engineers from SumBi, the local Environmental Authority of Hamburg, the enterprises Norddeutsche Affinerie (Europes biggest copper smelter), Hamburger Stahlwerke (electric steel), Jungheinrich AG (fork lifters) and several smaller machinery producers.

We work on three levels with different time scales: On the first level, with short time range, we are realising efficiency gains in high level recycling of grinding sludges and metal beads from surface blasting (transformation into metal foams) and by introduction of the use of minimum cooling lubricants in metal processing with several partners (efficiency gains by more than factor 1000!). On the second level, with medium time range, we are trying to optimise metal flows along the different phases of the product life cycle. We are modelling and managing material flows with focus on the avoidance of the accumulation of copper in the iron&steel flows and with focus on the collection and treatment of electric and electronic wastes by organizing communication between different actors. Another important issue on this level is product design and product use with focus on modularisation and platform strategy, leasing and rebuild of used parts and machinery.
On the third level, with long time range, we are developing strategies and scenarios using the approach of backcasting from the year 2050, assuming the metal flows of the economy then consist of 90% recycling materials, that means only 10% of additional fresh material per circle.

Issues in Academics – Plenary

Formal Education in Industrial Ecology

Helge Brattebo

Abstract unavailable

Utrecht University's New Education Program on Natural Sciences and Innovation Management

Marko Hekkert

At Utrecht University a new educational program is started on Natural Sciences and Innovation Management. In this program the students are offered courses in both natural and social sciences. Special attention is paid to the subject of innovation. Students learn on understand why new technologies often have difficulties to get implemented succesfully and they learn strategies to effectively manage a successful innovation process.

In their second year, the students may choose a study trajectory. One of the three themes that is offered is the trajectory on Energy and Materials. Here the students are trained in a wide variety of subjects in the energy and materials field. Subjects included are: energy analysis, environmental technology, materials efficiency, sustainable energy, life cycle analysis, several other research methods, risk analysis, grand cycles and applied thermodynamics / energy conversion. The total period that the students focus on energy and material issues is two complete years.

The strong side of this study trajectory is that the students learn much specific insights in the problem field of energy and material production and use, combined with specific knowledge on how to speed up (sustainable) innovation. We think that this gives them a very strong position in the job market and will hopefully lead to more sustainable innovations in industry.

In this paper we will give more insight in the experiences with this educational program. We would like to use this paper to exchange information on our program to other universities and companies to increase (international) cooperation in this area, for example by means of student exchange programs.

Professional Identity and Interdisciplinarity at The Industrial Ecology Programme at NTNU: A Fight Between Disciplines and Perspectives

Margit Hermundsgård, Stig Larssæther, and Elin Mathiassen

The Industrial Ecology Programme (IndEcol) at the Norwegian University of Science and Technology (NTNU) has since the start in 1998, developed into a rather extensive institution. With more than 15 PhD students, 8 graduate students and approximately 40 undergraduates following a multidisciplinary study programme, there is a rather urgent need for developing and maintaining a common denominator and to some extent, a common professional identity.

The interdisciplinary character of the IndEcol Programme is reflecting an adaptation to the complex, systematic nature of environmental challenges confronting industry today, while simultaneously being one of the first arenas where the multidisciplinary ambitions of NTNU is put into practice. This mandate gives us opportunities to have a wider perspective than within the traditional discipline borders, but also creates challenges connected to a larger diversity of professional backgrounds and ambitions on behalf of the IndEcol Programme. The development of a certain degree of a common identity has thus become important because of the interdisciplinarity. We need to set some borders. But how wide should the borders be? Who should decide which disciplines are allowed to make contributions to the field? How common must the common identity be?

In this paper we want to focus on how PhD and undergraduate students experience the interdisciplinarity at IndEcol and how it relates to the forming of their own professional identity. Based on interviews with both groups we want to focus on the balance between the industrial ecology perspective and the different disciplines that constitute their formal backgrounds when they enter the IndEcol programme at different stages in their professional careers. Is there a fight or a symbiotic relationship between them? Which level of discipline specialisation compared to industrial ecology perspectives is perceived to be appropriate, and how is this expressed in student projects at different levels?

Sustain This?: Environmental Management Program at the Stuart School of Business

George P. Nassos and John Paul Kusz

The Environmental Management Program contains traditional courses that reflect a model of compliance with a “command and control” regulatory framework. These courses include Environmental Law and Compliance, Air and Water Pollution Control, and Hazardous Waste Management. The authors have engaged in an effort to shift the curricula from one that solely presents these traditional courses to a curricula that includes the creative and proactive integration of environmental consciousness into the business model. The initial focus of this effort has been the development and refinement of two courses, “Industrial Ecology” and “The Sustainable Enterprise”.

Projects and exercises in both courses center on the often overlooked question, “Why sustain this?” By exploring both the systems and the networks that support a product, students develop an understanding of the elements that influence product choices from the perspective of multiple stakeholders. They are asked to employ the learning and philosophy from the course work in “product-centered” exercises and projects. The student experience includes examination of the product as the as a means to meeting a “need”; understanding what needs, and whose needs, are being met; exploring the many forces that shape the product, including systems and networks; and finally, proposing viable alternatives that are designed to reduce or eliminate negative environmental consequences.

“Product-centered” exercises and projects will be presented with discussion of the results. Examples of student team projects will be included in the paper and presentation.

The paper will discuss how these two courses were developed and how they work together to help the students develop an appreciation of the economic, environmental and societal consequences related to the development and deployment of a product.

Poster Abstracts

Process Integration in Industry for Cost-effective Greenhouse Gas Reduction

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Combustion of fuel for heat and/or power production is often the largest contributor of greenhouse gas (GHG) emissions from a process industry. To reduce these emissions, improvements in the plant's energy system and fuel switching are the only economically feasible options today. With process integration methods and tools, attractive measures for energy cost savings in process industries can be identified. Possible options for accomplishing such savings in an existing plant include the following:

- Reduction of hot and cold utility usage by increased heat recovery;
- Integration of combined heat and power (CHP) systems;
- Heat pumping;
- Process modifications.

The complex interplay between above-mentioned options calls for an systematic method for evaluating combinations of measures. Previous and ongoing work at the author's department has resulted in a methodology for identifying the most cost-effective mixtures of these measures for achieving a targeted reduction of GHG emissions from a process plant. Combinations of measures are mostly more attractive than single measures. In our studies we consider LCA GHG-emission values for fuels used.

The predominant factor which influences the choice of measures is the existing plant layout, which determines the feasibility and cost of increasing heat recovery. If heat pumping and/or CHP are possible options, the measures to be considered are particularly sensitive to the electricity-to-fuel price ratio and the CO_2 emissions from the electricity grid (since Net CO_2 emissions are considered). An important issue is the choice of system boundary, and how the choice affects the results.

Dynamic Life-Cycle Assessment for Product Comparison

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This paper develops a method for comparing the life-cycle environmental impacts of systems that have time-dependent emission profiles. LCA studies are beset by several sources of uncertainty and variability, such as parameter uncertainty, model uncertainty, spatial variability and temporal variability. A different situation occurs when the system under study is known to vary over time. Although practically all systems have dynamic components, not all dynamics have significance from an environmental life-cycle perspective. Important dynamic behavior can arise due to changes in the product itself, the way a product is used, or natural processes that modify emissions over time.

Examples of dynamic behavior that may be significant include the increase in emissions from internal combustion engines over time and chemical chain reactions that remain active in the environment for long periods producing a sequence of chemicals with varying environmental impacts. Such dynamics become important when one desires to conduct an LCA study comparing different products. This paper applies dynamic programming techniques to address the issues in one type of dynamic LCA problem, that of optimal product replacement. Dynamic programming is applied in a life-cycle comparison of walk-behind lawn mower designs. The results are used to show the policy-relevant life-cycle environmental trade-offs associated with volun-

tary accelerated retirement programs that have been implemented in regions with severe air quality problems.

Application of Input-Output Network Analysis to Assess Material Cycling in Industrial and Natural Systems

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A cornerstone of industrial ecology is the analogy between natural and industrial systems. From a quantitative perspective, however, the precise meaning of the analogy remains ambiguous. Hence, it is difficult to identify the goals of the field. For example, the final goal of industrial ecology may be to enable industry to cycle materials as well as natural systems or it may be to enable industry to cycle at 100%. Although it is generally accepted that a goal of industrial ecology is to increase material cycling, the concept remains unclear given that natural systems are often portrayed as the ideal.

This paper describes a tool capable of exploring the analogy between industrial and natural systems based on the fact that both are defined by conservative flows of material and energy. That is, both natural ecosystems and industrial systems are part of a more general type of system – systems of conservative flows of materials and energy. Given this similarity, ecosystems and industries can be directly compared on a quantitative basis. A method for such comparisons is presented in this paper to better describe the relative behavior of industries and natural systems.

To assess the method presented in this paper, the U.S. lead industry and five different ecosystems were chosen. Each system has a defined boundary and the applicable material flows within this boundary are identified. Next, a model of each system of flows is constructed using a common model structure. A common *structure* for the models is used to increase the validity of comparisons across the different systems. Once the systems were modeled and the data collected from public sources, input/output network analysis tools from ecology were utilized to characterize the direct *and* indirect relationships in the systems. Of particular interest is a metric titled “cycling index,” which represents the proportion of material or energy in a system due to cycled flows. We assert that this cycling index is an effective measure of material and energy cycling which incorporates both the direct and indirect interactions in a system.

This methodology may be applied to identify industry goals, track progress, strengthen the analogy between industries and ecology, conduct a gap analysis between industry and ecosystems, potentially learn design and manufacturing techniques from nature and use all of the information to improve decision making processes in order to reduce human environmental impact. In the lead case, it is demonstrated that the lead industry outperformed some ecosystems, such as a stream, and was surpassed in efficiency by more tightly looped natural systems, such as a tropical forest. More importantly, these results qualitatively indicate that it may not be appropriate to consider the goal of industrial ecology to be matching the material cycling of natural systems. Ecosystems are shown to be diverse in their degree of material cycling. However, the results do indicate that this methodology may be used to effectively model material cycling in complex industrial material flow systems. The results did not reveal any design or manufacturing techniques utilized by nature.

Assessment of Non-Virgin Copper Stocks in the Cape Metropolitan Area – South Africa

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Historically, the material use by our technological society has been largely based on virgin stocks (ore bodies, mineral deposits, and the like). These stocks may in future become inadequate or unavailable at various times and locations in the future. However, other reservoirs do exist, such as material contained in products in use, stored, or discarded over the years by corporations and individuals. These reservoirs may become significantly important over the next few decades as a result of rapid population growth and resource use. As a case study material, we focus on copper. Copper is of particular interest because it has long-term uses and is efficiently recycled. Additionally, copper has a depletion time of less than a century.

The increasing occurrence of large urban areas has lead to higher concentrations of in-use resources in constrained geographical areas. As a result, it may prove desirable within the next few decades to recycle resources within those areas. The Cape Metropolitan Area (CMA), within which the City of Cape Town falls, has been selected as a geographical area for a detailed assessment of non-virgin stocks and flows in Africa. The CMA is one of the three largest industrialised areas in South Africa, and has characteristics consistent with both the developed and developing world. The Cape Town case-study may thus provide a valuable framework for proxy data for other parts of Africa.

The analytical approach is as follows:

1. Determination of the major uses of copper within the Cape Metropolitan Area
2. Application of proxy indicators for material use (buildings, automobiles, etc.), in order to determine the quantities in-use of copper products on a spatial basis.
3. Estimation of lifetimes of the major copper uses and of available resource flows from landfilling, recycling, and dissipation within the CMA.

Comparison of anticipated rates of use for copper products with estimated copper supply thus provides evaluations of the magnitudes and spatial distributions of a common industrial metal. The proxy data that are derived for the various use categories of copper products are potentially useful as well for similar studies in other parts of Africa.

Recycling and Land-Filling of Copper Waste in Europe

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Waste represents the loss of both material and energy resources. Producing copper from secondary resources contributes to saving energy and prolonging existing reserves. Waste generation in Europe in the 90's is characterized both by the high quantity of goods produced and consumed and the efficient use of copper resources in production. For a complete assessment of secondary copper resources it is necessary not only to analyze the use of secondary copper at the

production stage, but also to investigate the waste sources and the consequential recycling possibility. The authors trace the flows of copper induced by post consumer and production wastes in Europe as a sub-project of the STAF-project (a NSF project, carried out at the Yale Center of Industrial Ecology). First generation rates on a country level and the copper concentrations of all relevant waste groups are defined, followed by a waste treatment balance and an assessment of technical properties of landfills and incineration plants.

The total post-consumer waste generation of 770 Mio.t/y can be divided into seven groups: municipal solid waste (21%), construction and demolition waste (24%), waste from electrical and electronic equipment (1%), end-of-life vehicles (3%), sewage sludge (1%), hazardous waste (4%), and industrial waste (46%). Waste from electrical and electronic equipment (WEEE) is the fastest growing waste group; it is expected to grow 5 to 10% annually in the next 10 years. Little or no information exists on the reliability of published data on waste generation. Uncertainties are expected to be rather high and may be +100% for construction and demolition waste and $^{+}$/- 20% for municipal solid waste. Data on the copper content in some waste groups are scarce and incomplete. The assessment of copper flows reveals that eighty percent of the total turnover (ca. 1.1 Mio.t/y) results from WEEE (49%), end of life vehicles (22%) and construction and demolition waste (12%), while sewage sludge and hazardous waste are negligible small. These findings emphasize the growing need for comprehensive recycling activities, particularly for WEEE.

Today almost 100% of the valuable copper production waste in Europe are recycled. Only galvanic sludge, chemical and electrolysis residues, whose recycling is not yet economical, are disposed of as part of hazardous waste. The recycling rate of post consumer copper waste varies between ten and sixty percent in Europe. As a result, the high secondary production rate (54%) in European is mainly based on the large manufacturing base from which new scrap is generated, as well as on high scrap imports. Domestic old scrap, on the other hand, contributes only 26% to the total scrap used in the European copper production. If all countries were to achieve an 80% recycling rate, the contribution of old scrap would rise to 47%.

This analysis represents the first comprehensive examination of copper in waste management. When embedded within the complete European copper budget this analysis shows the relative importance of waste management in the copper life cycle.

Pollution Prevention, Industrial Ecology and the New York/New Jersey Harbor

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This is a dynamic time for the entire Hudson Valley watershed, and the New York/New Jersey Harbor in particular. Currently, decisions are being made regarding a number of key environmental topics, including the impact of land-use practices on the quality and quantity of drinking water, and the implications of dredging the shipping channels in order to increase capacity of port facilities. These and other decisions will have far-reaching consequences for the economic future of this region.

Industrial pollution of the NY/NJ Harbor looms as one of this region's most pressing environmental problems. If pollution concerns are not resolved in an acceptable way for the broad base of stakeholders, they will compromise human and environmental health, and impede the region's economic expansion. The New York Academy of Sciences has initiated a five-year project to define and promote pollution prevention strategies for a number of toxicants in the Harbor using an industrial ecology approach. Traditional methods of pollution assessment are burdened with having to sample intensively over space and time which can be prohibitively ex-

pensive, time consuming and inapplicable to entire watersheds. Industrial ecology uses already available economic statistics to quantify key points in the toxicant cycle, thus making it quicker and more cost-effective than traditional methods.

The Academy's approach to developing pollution prevention (P2) is two pronged: a thorough uncovering of the scientific research and data, and an outreach and communication component to assure that the public is able to speak their mind. At the center of the project is a Consortium of stakeholder institutions (broad-based and includes big and small business, local, state and federal government, university, labor and conservation sectors) from the entire Hudson River watershed. The NY Academy of Sciences is in the final stages of gathering the pertinent scientific, legislative, economic and regulatory information on Mercury and Methylmercury, the first toxicant to be addressed. With this information, and taking into consideration the concerns from communities within the watershed, the Consortium will produce, publish, and promote specific P2 plans for mercury using analytical products derived from industrial ecology.

The mandate of the Consortium is to implement the following four project goals:

1) to identify the locations in five selected toxicant cycles where pollution prevention would most efficiently contribute to long-term reductions in loadings of toxicants;
2) to develop the most practical strategies to reduce toxicant emissions by working with all Consortium members and the community at large;
3) to encourage implementation of the recommended actions by working with environmental groups, industries, trade associations, labor, and governments; and
4) to evaluate quantitatively the success of these strategies in achieving environmental outcomes.

This presentation will focus on the successes and progress of this approach to address Mercury pollution in the New York/New Jersey Harbor Watershed.

Industrial Ecology of Sulfur within Australia

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Full paper available: No

The main source of sulfur in Australia is from naturally occurring deposits of mineral sulfides. These deposits are substantial and include those of lead, zinc, copper and nickel, giving rise to large scale extraction and export of metals. While hydro-metallurgical extraction routes for mineral sulfides producing sulfur and sulfates are available and adopted worldwide, the predominant technology adopted thus far in Australia is pyro-metallurgy. No signs are currently apparent of any shift from pyro-metallurgy to hydro-metallurgy in Australia for either existing or future extraction processes for mineral sulfides.

Sulfur dioxide produced from the pyro-metallurgical route is potentially an environmental hazard and must be treated. Regulatory pressures on sulfur dioxide emissions are becoming increasingly stringent. The most widely accepted treatment approach is sulfuric acid manufacture. This option has been shown in earlier work by the author to be the most satisfactory, both from environmental and cost viewpoints. However proceeding beyond the boundary of the SO_2 treatment, questions arise regarding markets for sulfuric acid – the applications, tonnages, and points of use. Transport of acid is expensive in relation to its value, and involves a degree of hazard. Sulfur is more easily transportable and can be stockpiled, but current technology for sulfur production from sulfur dioxide has limitations.

The main bulk markets for sulfuric acid are for phosphate fertilisers and for leaching mineral ores in hydro-metallurgical processes. There are smaller volume markets in diverse industries, for example lead acid batteries, gas drying, refinery alkylation, and alkali neutralisation. Some of these applications will come under increasing pressure to recycle spent acid, as environmental standards tighten, impinging on the total market demand for acid.

A key challenge for smelter acid producers is to ensure access to markets which are located close to the point of acid production. This challenge impacts on decisions for locating both new smelters and industries which consume acid. There are issues of supply-demand balance, since acid production is a by-product of the much more valuable metal production.

A quantitative picture of the sulfur-sulfuric acid supply-demand situation in Australia and its dynamics is presented. Examples are given of cooperative and stand-alone industrial approaches in Australia, with their relative advantages and disadvantages.

There are implications for improved industrial ecology with regard to:

• Location

Factors governing smelter location at mine site, coastal town, or point of use are complex depending on transport costs, access to markets, and environmental impacts. The proximity of particular acid markets to acid recycling facilities is also an important consideration.

• Technology

There is potential for a hybrid approach to metal extraction, using both hydro and pyro metallurgical approaches. Improvements in existing technology for sulfur production from smelter gases are needed. Acid recycling technology presents particular challenges; closer consideration of acid concentration at points of disposal and re-use could be fruitful.

• Industry Cooperation

More highly integrated operations offer both potential benefits and risks. Increased industry and government co-operation are essential to achieving better planning and investment decisions.

Dynamic Systems Analysis and Life Cycle Assessment Applied to Implementation of Extended Producer Responsibility in Australia

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The concept of extended producer responsibility has taken hold in Australia and was used as a basis for the introduction of the National Packaging Covenant and accompanying National Environmental Protection Measure (legislation). Consistent with international concerns surrounding environmental protection, the disposal of packaging waste (a potential resource) was identified to be a significant part of the municipal waste stream. The benefits of packaging, lies in the pre-consumption stage by ensuring an efficient and effective delivery of goods to the consumer, but its disposal is a problem as it is associated with throwing away a valuable resource. The Australian model of extended producer responsibility is based on sharing responsibility for the product (packaging material) across the product supply chain, from the raw material suppliers to its ultimate disposal. The model calls for a voluntary agreement between industries and governments (signatories), where a regulatory safety net would apply to non-signatories, ensuring that the signatories are not disadvantaged by “free riders”. The Covenant requires industries to commit towards the improvement of packaging waste recovery, reprocessing and reuse; and to support the collection and recovery system. The governments would contribute through the facilitation of supporting legislation, market development, community education and kerbside collection services. The signatories are also required to produce action plans to state their commitments to specific measures and activities. This paper aims to demonstrate how system dynamics combined with life cycle assessment

(LCA) could be used as a tool to analyse the sustainability and environmental impact of commitments given by a signatory as stated in the action plan.

System dynamics has been shown to be a beneficial tool for policy formulation and analysis. Numerous "yardsticks", for example, monetary benefit / cost, and unemployment figures, are used to measure the expected economic and social impact that may arise during the implementation of a policy. However, when it comes to environmental impact the "yardsticks" used are often too specific in nature, reflecting a particular aim of the policy framework. This may lead to the formulation of policies and commitments that have an overall adverse effect on the environment, whist addressing a particular environmental issue of concern.

Combining LCA with system dynamics can overcome this problem. The synergies arising from integrating LCA and system dynamics are that LCA provides quantitative environmental indicators and system dynamics brings to LCA the dynamic characteristics missing in its framework. In addition, the holistic nature of LCA broadens the scope of system dynamics modelling to examine all "cradle to grave" processes. Consequently, the integration of LCA with system dynamics provides an analytical tool, that considers the economic, social and environmental impact, which could be used by covenant signatories to analyse and formulate sustainable action and commitment.

Towards a Sustainable Development of Production

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Full paper available: No

Industrial ecology is an emerging concept to decline sustainable development aims in the production sector. This article explores the capacity of environmental design tools (evaluation methodologies and policy strategies) to transform material and energy flow system. To this purpose the different strategies used to influence environmental quality, ranging from regulations and economic instruments to evaluation methodologies (i.e. Environmental Impact Assessment and Life Cycle Assessment) are analyzed and compared. The argumentation reaches the conclusion that there isn't a specific tool to apply in order to achieve sustainable development of industry, but a set of different instruments that can help on that way if they are correctly used. This statement determinates two consequences. The first consequence is the urgency to develop existing tools in order to integrate their lacks of accuracy. The attempt carried out to integrate site dependent evaluation in LCA shows an effort in this direction. The second, more radical, consequence is that it is necessary to train new professional figures managing all the environmental design tools system and able to evaluate in each situation which set of tools should be applied.

The issue of sustainable changing of products can be placed between different disciplines (i.e. industrial design and environmental design). So also the instruments that can help in this direction are emerging from different disciplinary contexts like planning as the Environmental Impact Assessment (EIA), management as Ecoaudit. These tools operate in different ways and are applied in different moments of the decision making and design process and in different ways: as a support to drive the design process of new products towards sustainability, as a support to choose between existing products.

The necessity of this set of tools is also due to the complexity of environmental problems and to the fact that often it is not sufficient to face them from a unique point of view.

Having to deal with a topic crossing the established disciplines, an effort should be done to reorganize knowledge around actual problems. In other words, what is maybe missing and constitutes the typical feature of this text, is the comparison and integration of the most important assessment and certification tools (Life Cycle Assessment, Ecolabel, Ecoaudit, ISO 14000, Environmental Impact Assessment) applicable to improve environmental quality of products and production processes.

Having to deal with a topic crossing the established disciplines, an effort should be done to

reorganize knowledge around actual problems. In other words, what is maybe missing and constitutes the typical feature of this text, is coordination between knowledge and disciplines aiming at solving the real environmental problems.

Beyond RCRA: Prospects for Waste and Materials Management in the Year 2020

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This paper outlines a new public policy "vision" of a more sustainable system for managing wastes and materials in the United States two decades from now. The current system for management of industrial and post-consumer wastes in the US has been directed since 1976 by the federal Resource Conservation and Recovery Act (RCRA)—while the past few decades have seen great improvements generally in waste management practices in the US, the current system is not without its flaws. In any case, the US Environmental Protection Agency, along with partner state environmental agencies, have commissioned a working group to begin exploring how the country's current waste management system could and should evolve to meet the challenges and opportunities of the new century. This paper is the initial product of that effort, and is thus intended to creatively engage and stimulate a dialogue on the future of the nation's waste management system, unconstrained by the current legal and institutional structure of the RCRA program.

The paper first makes certain general projections and assumptions as to the economic, technological and societal "landscape" that would shape a future waste and materials management system in the US. Much of the conceptual groundwork for this discussion was generated from the 1999 EPA-sponsored "Future of Waste" roundtable meeting in Washington, DC, which included a number of experts in the field of industrial ecology and related disciplines. This discussion in the paper is organized around six general themes: Resources, Health and Risk, Industry, Information, Globalization, and Society and Governance.

Several major conclusions are reached, including:

- The need to broaden the scope of the current system from its current "waste only" focus, to place much greater emphasis on more sustainable, more efficient, and less wasteful use of resources (i.e., a materials management system)
- The need for a future materials management system to more effectively control potential risks from hazardous chemicals throughout their life-cycles under a more integrated system, rather than the patchwork of regulations, incentives and other measures that serve this function today.
- The need in future for a simpler, more performance-based system to control the proper disposal of hazardous industrial wastes (whose volumes would presumably be greatly reduced under a more effective materials management system).

The paper further discusses a number of tools and strategies that would likely be needed for such a broader materials management system to be achieved. These would likely involve combining traditional regulatory controls with a number of non-traditional (at least for the United States) approaches, including certain types of economic incentives, voluntary programs, public education initiatives, and other measures.

Sustainability Performance of Neighbourhoods: Decision Support Instrument for Municipal Policy Makers

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To determine the sustainability performance

of a neighbourhood a prototype tool is developed and tested in three case studies by IVAM Environmental Research, TNO Building and Construction and TNO Environment, Energy and Process Innovation.

Based on 'people' and 'planet' from the triple bottom line, indicators are developed for 25 aspects leading to theme scores for global environment (based on LCA), local environment, health, nuisance, safety and facilities. Aggregated they lead to –at this time ten– quantitative scores for Environment and Quality of life: the Sustainability Performance Indicator of a Neighbourhood (SPIN).

The power of the instrument is that insight is given into sustainability of alternatives for a neighbourhood in the planning phase.

The instrument consists of the following components:

- SPIN scheme (divert from Sustainability to Environment and Quality of life themes and convert to indicators and finally SPIN) to put aspects of sustainability in order;
- SPIN questionnaire to gather input data from a neighbourhood;
- SPIN matrix to calculate sustainability scores for the different indicators, based on the input data; and
- SPIN profile that indicates the sustainability of a neighbourhood, now consisting of ten figures.

The preliminary conclusions of the project are:

- The instrument enables calculating a SPIN profile of a neighbourhood. Municipalities are able to supply about 75% of the requested information.
- Comparison of three case studies shows that the instrument is able to distinguish levels of sustainability.
- Determination of the perception of the environment is most difficult. Further research is necessary to forecast perception out of the physic properties of a plan.

Digital vs. Traditional Libraries: A Comparative LCA of Their Relative Performance

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Internet technology is enabling profound changes. It is important to understand the unintended consequences associated with a variety of networked systems. One such system is the digital library, a managed collection of digitally-stored information accessible over a network. An interdisciplinary team with expertise in Industrial Ecology and Information Science conducted a life cycle assessment of a digital library at the University of Michigan, a major center for digital library research. Particular attention was paid to the Shapiro Science Library's journal collection, nearly half of which is already available in digital format.

Objectives:

Conduct a systems-based, first-order analysis of the environmental aspects of digital libraries.

Identify any unintended consequences that may exist with regard to the environment.

Disseminate research results to a wide audience of decision-makers, including digital librarians and public policy-makers.

Suggest appropriate areas for further research into the environmental performance of computer networks and related information systems.

Methods:

A comparative life cycle approach was adopted for this study. Two different systems were considered: a digital library and a traditional, print-based library. The digital system boundary included all major activities and infrastructure required to produce, maintain, access, and archive information contained in electronic journal articles. Similarly, the traditional system

boundary included processes and facilities required to produce, deliver, manage, and store paper-based journal articles. Both systems were modeled to determine relative environmental performance. Individual modules were developed for the following components:

Digital Library System - data storage and server computer; routers, switches, and hubs; client computer; library facility; collection maintenance; personal transportation; laser printing

Traditional Library System - journal paper production; journal printing, binding, and delivery; library facility; collection maintenance; personal transportation; photocopying

Modules were then used to construct various life cycle scenarios for both systems. As part of the analysis, sensitivity of results to selected variables was tested.

Preliminary Results:

This study focused mainly on energy consumption as a key indicator of environmental burden. While findings are still preliminary, they suggest several key points:

Energy embodied in a paper journal article is substantially greater than energy used to access online articles using a computer workstation. However, a paper article's *per use* burden falls dramatically as the number of readings per article increases.

Energy used for indirect activities such as laser printing and photocopying can be more significant than the direct effects associated with journal production and online viewing.

Energy consumed in transportation to and from the library has the potential to dwarf effects of all other model elements.

Networking technology continues to evolve. This LCA does not attempt to provide more than a first-order analysis of such a dynamic phenomenon. It does, however, yield valuable insights for planning the developmental pathway of digital library systems. Environmental aspects can now be considered along with other design factors such as performance, cost, and social impact. This study also highlights modeling challenges, and contributes to the ongoing development of LCA methodology for digital networks in general. Final results of this study will be presented during the ISIE Conference poster session, and will be available in an upcoming master's thesis publication.

Personal vs. Socio-Technological Change: Experimenting with Enhanced Household Energy Accounting Software for Swiss End-users

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A household energy accounting software application was enhanced and tested in a pilot study with Swiss subjects in order to examine ways of improving conventional energy/environmental information approaches for laypeople. Conventional consumer and household energy analysis focuses on direct, discretionary choices of individuals that influence energy demand. But institutional, socio-technological, and historical constraints are at least as important as personal ones in explaining individuals' patterns and levels of energy consumption. This research seeks to test the practicability and utility of illuminating the role of some of these less-discretionary factors —especially technological levels and social and demographic forces influencing activity utilization rates — for lay end-users, alongside the usual analysis of the impact of personal behavioral choices. Their appreciation of the wider factors may be crucial to their role in shaping societal and environmental outcomes as well as in making their own personal, discretionary consumption choices.

Developed on the theoretical basis of ecological modernization thought and consumption research — involving the notion of a range in end-users' "discretion" and applying a "social-revealing" approach to energy analysis — the program builds on a pre-existing, individual-oriented energy accounting module. This generates an individual's profile of primary direct and embodied energy use for daily activities like heating, housing, transport, and diet. The newer module allows the user to manipulate larger- and longer-scale variables and see their effects on his individual energy profile and Switzerland's aggregate energy balance. These 'less discretionary' factors include technological variables (e.g. in-

dustrial efficiencies and power- generating fuel mixes) as well as demographic (e.g. percentage of single-person households) and sociological variables (average car and plane travel, dwelling size). Other important factors like institutional and economic rules and incentives are not modeled but suggest themselves in interaction with the program and discussions in interviews. There are separate displays for individual/average and Swiss national energy consumption, currently, under future trend, or tailor-made scenarios; and - as an explicit link between the micro and macro levels - any of the personal profiles can be scaled up to national levels for hypothetical simulations.

Preliminary results suggest this type of modeling and indicator presentation is a potentially promising way to show the interaction and relative importance of individual, industrial, and societal interventions for energy consumption, at least for subjects already interested in energy conservation. The combination of positive (what can I change?) and normative (what am I willing to change?) elements in the guided use of the personal module makes for highly individual outcomes as to what makes more difference in energy reduction for one's profile: personal efforts in one's daily life or advances in technological development (e.g. higher efficiencies or improvements in fuel mix). Interactions and connections between the social and the technical are made apparent in the Swiss average and aggregate displays. This sort of information tool may point the way towards both direct individual behavioral change and enhanced consumer-citizen involvement.

Eco-Parks for Eco-Development

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"Industrial ecosystems have the potential of changing today's industrial development paradigm" [Côté, R. 1997. Industrial Ecosystems Evolving and Maturing. *The Journal of Industrial Ecology (JIE)* 1(3): 9-11.] Since these prescient words appeared, we've been able to chart these changes in following issues of JIE, other scientific publications and the Cornell University Eco-Industrial Development Program Clearinghouse.

The first man-made ecosystems appeared in complex resource-sharing production sites as diverse as Kalundborg, Denmark and the Texas Gulf Coast, USA. Based on by-product exchanges and cascading energy and water systems, they were early examples of industries' ability to identify and implement unique cost-saving solutions for limited natural and energy resources. Now we find new parks across the US and Canada based on a shared infrastructure including a commitment to sustainable development. These parks "balance ecological integrity, economic efficiency, and social equity" leading to "an opportunity for employment and a reasonable quality of life for all in the community" [Côté, R. 1998. Thinking Like an Ecosystem. *JIE* 2(2): 9-11.]

As economic development agencies and community action groups investigate both inner city and rural employment, this new definition for eco-efficiency looks attractive. But where is the model for this new eco-industrial concept? I suggest the Burnside Industrial Park in Nova Scotia, Canada where 12% of the more than 1300 businesses provide services to "reuse, refinish, refurbish, repair, rent, remanufacture and recycle" the region's discards and byproducts [Côté, R. 1999. Exploring the Analog Further. *JIE* 3(2-3) 11-12.] This is the model to support a region's recycling needs, whether based on landfill regulations or business expediency.

Presently, several cities and towns in the Commonwealth of Massachusetts, USA are examining these concepts as they plan for new economic development. Faced with a new statewide Solid Waste Management Plan (SWMP) calling for a 70% reduction in waste generation by 2010, these communities are searching for new solutions. The recycling related manufacturing sector presently employs more than 12,000 people in the Commonwealth and it is estimated that the SWMP will make close to nine million tons of materials available for new products. With the assistance of the Chelsea Center for Recycling and Economic Development (University of Massachu-

setts), grants for analyzing by-product and waste flows are available to communities and non-profit groups.

The recipients generally complete these material flow analyses in a virtual eco-industrial park framework where they evaluate qualities and quantities by source and location. They establish potential processing and manufacturing facilities to meet anticipated markets for a variety of new products. I will report on several of the current Massachusetts Recycling-Based Community Economic Development Projects including those in Boston, the north-central area, and the old industrialized coastal southeastern area. This last project with the regional Chamber of Commerce as the lead agency will include two communities and a common landfill with significant fish and rubber processing byproducts. Reuse opportunities include both high value fertilizer and mixed compost from fish processing and food wastes, and new manufactured products from rubber processing wastes and used tires.

Efficient Material Use and CO2 Emission Reduction

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The life cycle of materials and products requires large amounts of energy. Therefore, the production and use of materials and products leads to large greenhouse gas emissions. In this research project we have studied which possibilities exist to produce and use materials and products more efficiently and we calculated the impacts on greenhouse gas emission reductions. By means of several case studies we show that more efficient material management can be a strong tool in reducing greenhouse gas emissions: the potential is large and the costs are very low.

Will ICT enhance IE?

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Kalundborg(D)is a shining example of an industrial ecology (IE) for over four decades. It started as a greenfield operation quite comparable to mainframe computers. It´s architecture has a unique time and space frame which offer it excellent stand alone operation capabilities. In todays world of network computers (client/servers) many time and space impediments of main frame computers have been overcome. Can we apply this metaphore to IE? In this paper, based upon an information exchange model among IE partners, the following topics will be dealt with Kalundborg: stand alone for ever or client/server in the future? Co-operation and information exchange among IE partners; What we can learn from Supply Chain Management (SCM); From SCM to Reverse Logistics; Window of opportunities.

Material Flow Quality Management – the Example of Aluminium Recycling

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Recycling of materials is one important way to potentially decrease processing costs including environmental and resource costs. One important cost factor that should be considered is that recycled and remelted materials can be of lower materials quality, lower value, than primary materials. In this study we discuss and analyse concepts and mechanisms for the quality of secondary materials. For metals, such a

lowered material quality can be caused by a mixing of various alloying elements into the metals, a deliberate mixing of different alloys in the production of the secondary materials, or be due to different impurities coming into the scrap streams. When these mechanisms lead to a decreased flexibility of the metal there is a possible loss in the value of the secondary materials. The flexibility is often uni-directional and can be seen as a down-cycling. Accordingly, to efficiently utilise the potential benefits of recycling, it is important to consider not only the possible quantities recoverable for recycling, but also qualitative aspects. The prerequisites to get useful secondary materials are influenced along the whole materials chain from materials production, over use to recovery and recycling. To handle these qualitative aspects of recycling, the material flow-quality, there is need for what we can call a proper Material Flow Quality Management. The down-cycling will lead to adoption in flow and values along the materials chain. In a model we analyse these changes. Ultimately some of the recovered scrap can be dumped. The study also suggest some direct physical measures of flexibility, or rather the lack of flexibility of aluminium alloys, in the form of necessary dilution with primary aluminium. These measures are quantified and analysed for aluminium alloys used in Sweden. Finally, different strategies for materials flow quality management for the aluminium system are identified and analysed regarding their ability to give flexibility to the recycled aluminium

CO2 Reduction Potential for Laundry Detergents Using Life Cycle Assessment

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A Life Cycle Inventory (LCI) and Analysis (LCA) database for P&G laundry detergents was constructed using SimaPro software. The input data needed to conduct a product LCI came from different supporting databases to cover supplier (extraction and manufacturing of raw materials), detergent product manufacturing, transportation, packaging, use and disposal phases. Manufacturing, packaging and transportation phases are usually representative of European conditions while the use and disposal phases are country specific and represent how consumers are using a specific product and how wastes are disposed of. The database was constructed to analyse detergent products from a system-wide, functional unit point of view in a consistent, transparent and reproducible manner. LCA can clearly be used to identify improvement areas. Firstly, the LCI of a laundry detergent is presented. Secondly, LCI information is combined with actual market data to calculate P&G's contribution to key emissions from laundering. The presentation will demonstrate changes in CO_2 emission resulting from 1) a change in wash habit practices, 2) from different market composition (e.g. powders vs. liquids) and 3) from reformulating laundry detergents (renewable vs. fossil based surfactants). This information is used to guide R&D department in priority setting for further product improvements.

Sustainable Development and Noosphere Function of Economics: Trajectory of Possibilities and Restrictions.

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Natural changes that have enveloped the modern world continue to remain one of the global problems of the humankind.

Under such circumstances, there is a need to talk about the modern system definitions of the natural changes as endogenous factor for the related economical changes.

Sustainable development can be presented as an optimal trajectory of the humankind movement with its possibilities and restrictions. In this context, the attention has to be paid to the theoretical and practical matters of this development.

Firstly, the functioning of economy within the boundaries of the global ecological system characterized by the limited possibilities of pure water production and production of the surface photosynthesis requires the review of the structure of the macroeconomic models that should be based upon the spatial laws of the natural process. For that purpose the ecological supply of the natural capital should be defined on the basis of the modeling its biophysical function.

Secondly, the theory of the macroeconomic balance does not provide the self-organization of the ecologically sustainable economics. For that reason the market mechanisms in the use of nature have to be supplemented by the mechanisms of provision the sustainable functioning position for the ecological-economical systems that are the non-equilibrium systems as a open to environment. The major criterion should be the preservation of the of the biological productivity of the natural capital based on the law of the biological mass preservation.

Thirdly, the theoretical economics cannot be just limited to the modeling of merely productive function. The necessity to model the sustainable natural used function arises, which can be named as the noosphere function. We propose the model of the noosphere function as a qualitatively new one of the sustainable development, and it consists of the following three functions: negentropy function; biophysical function of the ecological-economical systems; the function of the natural capital consumption. This enables us to have a different approach to a definition of the sustainable development indicators. The realization of the sustainable development conception of the world has to be adequate to its diversity.

A very negative phenomenon that does not favor the realization of the sustainable development of the world is the practice of the poor countries in rent seeking in the sphere of the use of nature. This has been accompanied by the further transformation of the price formation mechanism that does not reflect the level of the limit scarcity of the natural capital resources, but also leads to the ever more ineffective use of nature with the purpose of increase in shadow export transactions, this practice worsens the global ecological situation.

Hence, the modern stage of the sustainable development has to draw the world economy to the needs of the harmonious coexistence of the nature and society as close as possible through the formation of the new geological cover of the planet, that is noosphere. This, in its turn, requires the application of the new methodological and practical technologies.

Application of Information Management to Improve Environmental Material Accounting Techniques

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There are a number tools or techniques that have been developed to assess and provide information to manage material flows in the last two decades, including; life cycle assessment, material flux analysis, material input per service

unit, sustainable process index, ecological footprint, and total material requirements of nations. These techniques are based on the same principle – tracing materials and energy flows through the human economy, but at different scales. Currently each technique is undertaken separately, requiring significant amounts of data and hundreds of processes to be balanced in separate methodologies.

There has been little cross-linking of the existing databases between techniques. With little uniformity in database structure, it makes the sharing of data difficult. To overcome this problem, a database model is starting to be developed by utilizing a Relational Database Management System (RDMS) to integrate the wide variety of data collected in the established databases within different material accounting techniques. This model may provide better information to the different techniques. It may enable some integration among the techniques.

This paper outlines the proposed study method and presents the current, still developing, structure of the relational database model for some of the material accounting techniques.

Streamlined Life Cycle Analysis for the U.S. Powder Metallurgy Industry

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Streamlined Life Cycle Analysis (SLCA) is used to track the environmental performance of the U.S. Powder Metallurgy (P/M) industry, where scope and goals, inventory analysis, impact analysis and improvement assessment are defined for a gate-to gate approach of P/M manufacturing operations. The P/M industry consists of two sectors, powder producers and part producers, which primarily supply components to the automotive industry. Data from the U.S. Environmental Protection Agency Toxics Release Inventory (USEPA-TRI) are used for the inventory analysis of 72 production facilities to track trends in toxic emissions over a recent five-year period for both sectors. Air emissions and solid wastes were the most significant waste streams for both sectors. To address impact analysis, toxicity and production intensity indicators are computed. Energy usage and related carbon emissions trends are also examined for fabrication of P/M components. Selected results are compared with similar indicators for related metal industries in the U.S., e.g. primary and fabricated metal products, and automotive parts and accessories.

Results from the inventory and impact analyses and consultation with P/M parts industry managers led to identification of opportunities for pollution prevention in fabrication. Source reductions of air emissions and toxic solid wastes are explored as a first option. One of the case studies focuses on cleaning operations for P/M parts, where technology substitution is imposed; an aqueous solution coupled with ultrasonic cleaning is compared with current cleaning technologies that use organic halogenated solvents in vapor degreasing units with solvent recycling. Explicit regulatory costs (tier 1), such as hauling and landfill disposal costs, are included. Process modeling tools were developed and were used with financial tools to estimate fixed and variable costs, as well as energy consumption and associated wastes for each scenario. Financial management indicators such as rate of return, net present value and payback period are computed, using a depreciation method, with taxes and inflation rates that are representative of investment conditions for U.S. decision makers in industry.

Results from this case study show lower variable costs, quick payback period and competitive rate of return for the technology substitution investment in an aqueous based cleaning operation. Other benefits include: reduced risk for workers, lower liabilities, increased efficiency in resource use, and minimized environmental impact through the reduction of air emissions and waste streams. Financial and process modeling tools proved valuable for enhancing the results of the P/M SLCA. This modeling approach weighs economic and financial aspects with technical factors, and identified relevant cost drivers to offer a more comprehensive decision process.

Environmental awareness, business strategies and competitiveness for the P/M industry are also explored in the context of Environmental Management Systems and the adoption of ISO 14000 standards. As tier one suppliers to the auto manufacturing industry in the U.S., P/M companies face the challenges of developing corporate strategies for ISO 14000 certification to demonstrate commitments to excellence in manufacturing, sustainability and environmental quality. Low ISO 14000 adoption for P/M companies highlights their need for increased integration of corporate policies that include progressive environmental management practices.

Using Recycled Highly Alloyed Aluminium in Crude Steel Production as a Way of Maintaining Aluminium Scrap Quality – the Example of Sweden

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Aluminium could be an important metal in a more sustainable society but due to the energy intensive primary production it ought to be recycled to a high extent. A way to facilitate the recycling would be if the problematic aluminium scrap, owing to a high content of different alloying elements, could be used for valuable fields of application where the aluminium ends up in a form not suitable for recycling anyway. The use of aluminium in crude steel production is such a field of application and in this study it is analysed whether aluminium with a high content of different alloying elements could be used in crude steel production to an extent of importance for the aluminium recycling system. The study is carried out mostly through interviews with people at steelworks in Sweden, covering almost 97% of the crude steel production in Sweden today. It shows that about 9 thousand tonnes of aluminium were used in crude steel production in Sweden in 1999, which corresponds to about 10% of the estimated potentially available amount of old aluminium scrap in Sweden in 1995. It also shows that aluminium with a high content of iron or manganese is usually accepted to be used in crude steel production today, but aluminium with a high content of copper, magnesium, silicon or zinc is usually not. However, there are some possibilities for changing this acceptance today already, especially for silicon, if the economic incentive is large enough.

An Analysis of the Long-run Socio-cultural Changes in the Energy Sector of the Wealthiest Industrialised Countries: Comparison and Analysis of G7-Countries Energy and CO2 Efficiency Dynamics in the Years 1960-1997

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In the research field of industrial ecology the long-run socio-cultural changes in the energy production and consumption have been an important research topic. In the study, authors continue this tradition. They analyse long-run changes and trends in energy production of world wealthiest nations, so called G-7-countries. This study is a comparative analysis of energy consumption and CO2 emission flows in the G7-countries in the years 1960-1997. The comparative analyses are based on the complete decomposition methodology. Authors provide the analysis of dynamic changes of energy consumption and CO2 emission flows in the G7-economies.

The comparative analyses reveal that
1) Activity effects of the different G-7 countries were quite similar. Biggest increase in the activity effect has been in the US economy due to the large size of economy.
2) Structural effects varied considerably indicating differences in economic activities in the analysed countries.
3) Intensity effects on energy use and CO2 emissions revealed large differences between the G-7 countries. The energy intensity effects have decreased after 1970 in all the G-7 countries except France. All the G-7 countries have showed a decreasing CO2 emission intensities after the year 1970.

The Rebound Effect for Various Dematerialisation Strategies

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With the rebound effect is meant the effect that an increase in the efficiency of a factor of production or consumption, for instance, energy, will be partly or wholly counteracted by different economic mechanisms. These will, based on the lowering of the factor price introduced by the increased efficiency, increase the utilisation of the factor in question. The rebound effect has empirically and theoretically been extensively investigated within the energy field, even though the concept and its potential effects also have been extensively debated, partly due to different bases for the theoretical and empirical analyses.

For materials there is considerable and growing interest in achieving a dematerialisation of the societal turnover and the application of various strategies to this end. However, the potential rebound effect in connection to the utilisation of materials has not been investigated to any large extent. In this paper we will discuss the application of the rebound effect to the materials field. We make a short review of the theoretical basis of the rebound effect within the energy field and discuss various mechanisms contributing to the rebound effect at different levels in the economy. We then translate these theoretical considerations to materials. The turnover in society as well as the principles and potential mechanisms for increased efficiency differs considerably between the usage of energy and materials. We analyse these difference and their implications for the rebound effect when applied to various strategies for dematerialisation. We conclude that in some important cases the rebound effect for efficiency increases in the utilisation of materials can be considerable.

Research and Education of Industrial Ecology in the Study Programmes for Process and Environmental

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Process Metallurgy and Industrial Environmental Engineering at the University of Oulu are both new educational orientations. Thus, between these two young orientations it was considered important to have a good co-operation both in research and education. Industrial Ecology and Recycling, which is a study course given in the Industrial Environmental Engineering orientation and an important research area in the Laboratory of Process Metallurgy, is one of the fields where the two units have quite a lot mutual benefits and goals.

Industrial ecology (IE) is a new approach to the industrial design of products and processes and the implementation of sustainable manufac-

turing strategies. It is a concept in which an industrial system is viewed in concert with the surrounding systems. IE seeks to optimise the total materials cycle from the virgin materials to finished materials, to components, to products, to waste products, and to the ultimate disposal.

IE is a combination of several fields, like industrial metabolism, design for the environment, life-cycle analysis, green chemistry, pollution prevention, environmentally conscious manufacturing, and sustainable development. Decision-making is needed to understand the effects of product-design, process-design, and materials choices on the material outputs of the manufacturing system, including the fates of the products when finally discarded by its owners.

Because of the great importance and volume of the metallurgical industry, it is a very interesting application area for the industrial ecology approach. The total load of the nature has led to a more strict use of raw materials through recycling the main and by-products. Besides the problems involved in the energy production, a big problem both in pyrometallurgical and especially in hydrometallurgical production is the solid waste and the complex utilisation and elimination of harmful impurities. Further processing of the waste material demands great efforts, the costs of which are at least partly directed to the primary process forming an essential boundary condition for the process selection.

None of the goals related to environmental issues will be accomplished without extensive and creative application of innovative technologies. The combined dimensions of the technological basis of modern civilization and the remaining unmet human needs for current and future generations dictate the use of the sustainable, more efficient, and less resource-intensive technologies to replace or modify existing practices across a wide spectrum of activity. The main target is in long run the sustainable development without any harmful side effects of the industrial activity.

During the course for Industrial Ecology and Recycling, the relationship of humanity and environment is explicated, and the need for sustainable development highlighted. The concept of IE is explained, the systems and the life-cycle approaches as well as the economic and legal backgrounds are outlined. IE considers environmentally appropriate technology as a critical component of transition to sustainability. Design for Environment is introduced as a tool of internalising environmental considerations into economic activities. Considerable attention is also paid to waste management, particularly to waste minimisation in industry.

An Object-based Tradeoff Modeling Framework for Household Waste Processing

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With the approval of the container recycling law in April 2000 and the food recycling law in April 2001, Japan has shown firm conviction to the promotion of recycling. Waste can be recycled, i.e. resource value of waste material can be recovered, in many ways. These include various material recycling and energy recycling options. Alternatively, waste can be reduced or just disposed. Each technology has a different set of required inputs such as equipment costs, electricity requirements, heating, water, and so on. They also have different sets of outputs both as valued products such as recycled bottles or electricity, and as pollution emissions. Furthermore, each option has different requirements for the purity of the material to be processed. For example, plastic material recycling often requires that the input plastic be of a single type such as polystyrene. If the consumer separates the garbage, then multiple vehicles may be necessary to collect the different types of garbage, increasing collection cost. In fact, this cost reflects a fundamental reason why using household waste as a valuable resource is difficult: it is thinly distributed spatially and temporally and highly heterogeneous in composition.

Object-based model integration using the Internet combines aspects of traditional centralized and network technology approaches to ad-

dress large-scale, complex, multi-disciplinary system problems. As a prototype application of this approach to holistic system analysis decision support tool for environmental sustainability issues, an object-based modeling framework is developed for examining the various tradeoffs between costs, pollution emissions, resource consumption, and land fill use for the different recycling and disposal options. The framework is applied to household plastic waste processing. The overall process is divided into three stages: generation of plastic waste from households, collection using different kinds of garbage collection vehicles, and plant processing for recycling or disposal.

Six types of plastic waste processing technologies were examined: production of plastic pellets, production of RDF (refuse derived fuel), production of oil, waste incineration to produce electricity, use of waste plastic as a coke substitute steel making, and simple incineration. The default scenario assumes all waste plastic is land filled. Models based on data from actual plants, laboratory experiments, and theoretical considerations of scale effects and mass balances are developed to calculate the cost, energy consumption, CO2 emission, and land fill occupancy for each technology. The models also calculate the resource produced by each technology, i.e. plastic pellets, electricity (from incineration and from use of RDF in thermal power plants), oil, and coke. Each resource production rate is converted into cost, energy, CO2, and landfill use using LCI data. These values are subtracted from the outputs of the waste processing models to obtain overall performances for each technology. The models are used to compare the advantages and disadvantages of each of the technologies for processing the waste plastic generated in Tokyo, Japan. The overall tradeoff system model is then applied to several scenarios for combinations of the plastic recycling and disposal technologies in Tokyo based on currently considered waste disposal strategies.

Application of Industrial Ecology to Human Settlements for Sustainable Development

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In the process of evolving economically and socially, human settlements have inputs of energy and resources and outputs of waste similar to ecosystems. However, a major difference is that whilst the natural ecosystem is 'closed' with waste being internalised, in many cases human settlements operate with linear resource flows. The well recognized environmental consequences of linear systems is that human settlements will not be able to manage sustainably the growth in demand for inputs and their subsequent outputs.

Despite Australia being an industrialised society with a strong commitment to promoting sustainable communities, industrial ecology (IE) as a model for helping promote sustainable development has made little or no inroads into systematic planning of industrial activity, let alone human settlements (Christesen *et al*., 1999). A major obstacle being the lack of case studies in Australia to convince government and community that the political, social, economic and natural environments are all suitable for adopting and adapting the IE model (in particular, taking into account large land tracts and relatively low population densities). This research attempts to fill the need for a demonstration IE case study by investigating with a regional local government authority, whether IE, mainly previously applied to only industrial systems, could be applied to human settlements in Australia. The stated aim is to reduce consumption of resources and production of wastes by planing for, and developing, long-term 'synergies' within a settlement. The research is, therefore, investigating whether IE could be used as effective policy tool embed-

ded into localised urban management and planning.

Reference: Christesen Ian, J.Ashley Scott, Kanduri Krrishnamohan, Albert Gabric and Sunil Heart. (1999). What Is Needed To Encourage Adoption Of Industrial Ecology? In Global Competitiveness through Cleaner Production. Edited by J.A. Scott and R.J. Pagan. Australian Cleaner Production Association Inc. Brisbane, Australia. pp681.

Use of Information from Material Flux Analysis for Human Health Risk Assessment at Regional Scales

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This paper presents the study method that will be used to attempt an integration of Materials Flux Analysis and human health risk assessment at a variety of appropriate regional scales. The problem definition stage and plan for the work has been completed, and this will be presented in the paper.

A heavy metal, cadmium has been selected, and will be used as a case study in a system boundary of Australia.

The Material Flux Analysis (MFA) technique provides information on fluxes of cadmium into, through and out of the anthroposphere into the regional environment. Another tool, environmental and human health risk assessment, is gaining increasing attention as an important component of Environmental Impact Assessment (EIA), and as a means for providing information for environmental decision-making in Australia. As awareness of the impact of human activities on the environment has greatly increased, the outputs/emissions determined by MFA methodology could be a quantified link between economic process outputs, and environmental concentrations and subsequent human and ecosystem health risks. This linking will require knowledge of the pathways of material flows from the anthropogenic processes to environmental media, where adverse effects to humans and ecosystems can occur. Investigation of the environmental fate, transformation processes, and potential transport of substances within the regional environment is also required here. These material pathways are also crucial to effective risk assessment, because both bioaccessibility and bioavailability are controlled by these processes. The chemistry and distribution of the materials of interest need to be thoroughly understood for the overall environmental analysis.

If this integrative approach proves to be successful, holistic information for decision-makers at all levels, from local to regional and possibly national scales will be provided on selected materials.

Structure Efficiency: A New Tool in Achieving More Efficient Ways of Organic Matter Recycling

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Organic matter has several virtues that together indicate its value. In our society, which is dominated by human beings, the main virtues of organic matter are: food (for people and/or animals), energy and “structure”.

The units in which the quantity of these virtues can be expressed are, respectively: “feeding value”, “energy value” and “structure value”.

Of these, only the second one is relatively easy to quantify by means of the “energy content” of the material, which is equal, under standard (oxidative) circumstances, to the heat of combustion of the material involved.

Quantification of both the feeding value and the structure value of organic matter requires some kind of arbitrary valuation, since no methods are available to measure these virtues on a non-biased manner at present.

For food, a scale is imaginable in which sev-

eral classes of compounds are distinguished:
Essential compounds
Vitamins, hormones, etc.
Structure compounds
Proteins/amino acids; minerals (Ca, etc.)
Energy compounds
Carbohydrates, fats, etc.
Toxins
Organic toxins; heavy metals, etc.

The total "value" of some amount of food could be expressed by some expression in which several weight factors are applied to the distinguished classes of compounds, though it remains comparing apples with oranges, of course.

Likewise, the total "value" of some amount of organic matter could be expressed by some equation in which both the structure content and the energy content are expressed. Of course, structure and energy are two virtues that are hardly comparable, so it will always involve some arbitrary decisions.

The energy content of an organic compound can be viewed in several ways:

1. the total chemical (bond) energy;
2. the total heat of combustion *(in theory, i.e. without taking actual circumstances into account)*;
3. the total heat of combustion *(with taking actual circumstances into account)*;
4. the total heat of combustion, minus the energy that was needed to produce the compound in the most economic way.

For theoretical studies on organic matter the second method seems the most appropriate one. For efficiency studies on complex chemical reactions, however, the third or fourth method seem more appropriate.

The structure content of an organic compound is not that easy to measure. That is why a new method was developed, based on a methodology that is widely used in disciplines like mathematical chemistry and drug design. The backbone of the method is the calculation of *Paramosts* for all organic compounds involved. The Paramost, which is an acronym for PARAmeter of MOlecular STructure, is a versatile, dimension-less parameter that can be used in molecular based environmental studies.

The Paramost, which is based on topological indices, is a measure for the structure of an organic compound. The only factors involved are the atoms and the bonds inside the molecule. The user has a "toolbox" which he can use to find the appropriate Paramost needed for a special application.

The Paramost P consists of a summation of all bonds (paths) inside the molecule, to all of which Weight factors (W) are attributed; the value of W (and therefore of P) is steered by the Elemental factors E and the Power factor f, which can be chosen by the user.

There are Paramosts of different order.

$P(0)$ takes only atoms into account and no bonds (in graph theory: only vertices, no edges).

$P(1)$ takes only bonds (edges) into account.

$P(2)$ takes only paths of length 2 into account.

Etc.

Combinations are also possible: $P(01) = P(0) + P(1)$, etc.

Because of the way Paramosts of various order are defined one might associate certain properties or "virtues" with them.

$P(0)$ deals just with atoms, not with bonds; atoms are associated with mass, so P(0) might be associated likewise with mass or with matter in general.

$P(1)$ deals just with bonds, which are associated with bond energy; so P(1) might be associated likewise with the (internal chemical bond) energy of the compound.

$P(n)$ (where $n > 1$) deal with paths of length n and might be associated with the structure of the compound rather than with its mass or with its energy.

After calculating Paramosts of all the compounds involved structure analysis of compounds or reactions is possible. By analysing the change in structure content of the compounds involved in a reaction or a series of reactions one can evaluate the structure efficiency of the whole process; by comparing this structure efficiency with other kinds of efficiency (as energy efficiency, atom efficiency, monetary efficiency) one can design processes which are optimised on different levels.

As far as industrial processes are concerned, care should be taken that they are designed as sustainable and environmentally friendly as reasonably possible. Optimising processes on structure efficiency will result in processes that are also relatively sustainable.

A Dynamic Systems Formulation for an Extended Life-cycle Assessment

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Environ analysis, developed by Patten and colleagues, applied Koestler's system theoretic concept of the holon to ecosystems. Environ analysis is in an extension of traditional static input-output theory of Leontief, as introduced into ecology by Hannon. It includes not only the direct and indirect inputs required by an ecosystem component (or "object"), referred to as its input environment, but also the direct and indirect outputs generated by the organism, its output environment. Unlike the static input-output model, capable only of examining steady-state conditions, environ theory is intended (in theory) to provide a dynamic description. That is, the inputs and outputs can vary over time and the production or utilization at any time is determined by the history of final output.

Environ analysis provides a potentially useful framework with which to develop an extended LCA, one capable of considering the indirect as well as direct environmental impacts of both the production and utilization of a product. Thus the air pollution generated in producing a unit of electricity is associated with the product utilizing that unit of electricity in its production. Or when a control system is incorporated into a boat that in turn generates water pollution, some appropriate share of that water pollution is attributed to the control system.

Provided we supply a dynamic extension of the static Leontief input-output model, our analysis can be done in an explicitly dynamic manner. The Sequential Interindustry Model (SIM) is a dynamic counterpart to the traditional static input-output model. It describes the time of occurrence as well as the magnitude of economic activities directly or indirectly required in producing a product. SIM was developed to investigate temporal aspects of the economic impact of transient economic events, such as major construction projects or introduction of a major new production technology. Because it includes the timing of production activities it incorporates engineering as well as accounting descriptions of the production process. This paper describes an enhanced version of SIM that generates the output as well as the input environment of products and it thus can provide a suitable basis for both dynamic and extended LCA.

A Decision Making Tool for Sustainable Forestry: Harvest Patterns and Biodiversity Risk

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Wood constitutes nearly one-third of all raw material humans use to make consumer goods. In the next 40 years, worldwide demand for pulpwood is expected to increase by 50%, even taking into account increased efficiency in recycling. North American forests, some of the most productive in the world, will contribute in a major way to meeting this demand. Increasingly, however, extractive uses of forests are in conflict with public environmental values such as biodiversity protection and recreation. In many forested sections of the world the public is struggling with how to balance economic and environmental goals for forests.

Much of the debate regarding sustainable resource use derives from our poor understanding of how modern commercial forestry affects the persistence of native plants and animals. We lack reliable, cost-effective, accurate tools for identifying species at risk of extinction due to harvesting practices. In addition, a variety of harvest practices could be used to achieve a particular economic goal. For example, in temperate and northern forests, harvest can remove all trees, or selectively remove trees from a larger area to create the same yield. Harvest methods also vary in input, from allowing natural regeneration to planting fast-growing exotic hybrids and treating with herbicides. Market demand for high-quality paper has resulted in converting hardwood forests to softwood. Each of these methods can have complex and largely unknown impacts on native biodiversity. Here we focus on evaluating the impacts of harvest patterns on species with different survival, reproductive, and dispersal capacities.

It is impossible to do detailed research on the thousands of species present in every forest to determine the specific reactions of each species to various harvest practices. Therefore, we developed a spatially explicit simulation model (as a cellular automaton) for use in identifying combinations of life-history traits that are vulnerable to different harvest patterns. With this tool, one can propose and evaluate alternative harvest practices to protect at-risk species on industrial forest landscapes, and provide the information to evaluate the economic costs of the alternatives to timber companies. In addition, we can evaluate the efficacy of non-harvest alternatives, such as creating reserves, in ameliorating risk of local extinction.

The specific forestry scenario we model is that of a commercial forest in northern Maine (U.S.A.). The model is generalizable to any ecosystem undergoing systematic alterations.

Balancing Uncertain Substance Flow Data

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All estimates of substance flows are more or less uncertain, implying that the collected data can violate mass balance constraints that theoretically should be valid. In this article, we introduce a general principle of automatic balancing of substance flow data. Moreover, we present a software prototype. In particular, we describe a class of multi-stage balancing algorithms that can accommodate prior information about the uncertainty of the data under consideration. First, we specify a set of cells and all permissible connections between these cells by defining a so-called connectivity matrix. Then, we introduce mass balance constraints by specifying a subset of cells for which the total output equals the total input. Finally, the balancing problem is formulated as an optimization problem. Since any set of observed data can be balanced in an infinite number of ways we define objective functions and algorithms identifying the solutions that are optimal, given the objective function under consideration. If it is desirable to achieve balanced flows only by increasing observed flows, we can use an ordinary simplex method to identify the solution minimizing the total increase of all flows. Other numerical algorithms can be constructed to handle non-linear objective functions. For example, we can minimize the sum of squares of all adjustments and identify the minimum number of flows that must be adjusted to satisfy a given list of mass balance constraints. Prior information about the uncertainty of different substance flows can be taken into account by weighting different terms of the objective function. In particular, we illustrate how we can utilize simple classifications of the uncertainty of different substance flows. To facilitate the computations involved in the balancing we have

developed a software prototype in which balancing is integrated with a variety of tools for quality assurance of collected data. A previously published study of nitrogen flows in Sweden is used to illustrate the different steps involved in the proposed balancing algorithms.

The 10 (or 20) Million Dollar Question: Can Airlines Recycle Their Aluminum Beverage Cans?

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Life cycle assessments show that aluminum recycling is economically profitable and environmentally beneficial. Domestic airplane flights in the US generate approximately 1.2 billion used aluminum beverage cans (UBCs) each year. This represents 18,000 tons of aluminum, which is worth $20 million at the current market price of $0.55 per pound. The potential profit from recycling UBCs represents approximately 1% of annual profits for the airline industry. Airlines could easily capture these lost profits, and reduce the environmental impacts of their businesses by implementing recycling programs.

Implications of Industrial Ecology for Environmental Policymaking at the Sub-National Level: A Conceptual Framework

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There have been relatively few attempts to systematically apply IE to actual problems faced by environmental policy-makers, especially those working at sub-national levels. Such applications are hindered by the lack of a conceptual framework to integrate IE's characteristic model's and tools into a coherent whole. Some have argued that core IE concepts like sustainability are only meaningful at a *global* level.

This paper outlines a conceptual framework for systematically considering the implications of IE for problems of environmental regulation faced by a sub-national environmental agency, the New Jersey Department of Environmental Protection (NJDEP). As a densely populated and heavily industrialized state in the Eastern US, New Jersey faces a wide range of environmental problems. New Jersey also has a reputation as one of the most environmentally innovative states in the US, with its own Greenhouse Gas Action Plan and a cooperative agreement with the Netherlands Ministry of the Environment to address global climate change.

To be effective at the sub-national level, the paper argues that IE must give increased attention to regional geography and land-use planning. Even an area as small as New Jersey is too large for some purposes, and watersheds shows prom-

ise as a suitable scale for applying IE. IE should broaden its focus on "firms and farms" to include households and communities. Improved methods for comparative risk analysis and more causally- and economically-oriented environmental indicators are needed. Inter-agency cooperation is important for government to be an effective "player".

The paper also points out that as a young field, IE presents many difficult and unanswered questions. What is government's proper role in "closing loops"? In fostering life cycle assessment or design for environment? How can materials accounting information best be used? Is IE's "systems" approach always better than "command and control" regulation? How can IE take account of the growing demand for "environmental justice"? How should the inherent tensions between descriptive and normative approaches to IE be managed? IE offers great potential for addressing environmental problems at the subnational level, but the field must begin to tackle some of these major unanswered questions for that potential to be realized.

Note

While NJDEP provided the author with substantial assistance in the preparation of this paper, the conclusions reached and views expressed are solely the author's and do not necessarily represent official policy positions of NJDEP or the State of New Jersey.

Can Economic Growth and Improving Environmental Conditions be Compatible? Environmental Kuznets Curve in Long Term Finnish Perspective

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Economic growth and improving environmental conditions are not necessarily incompatible, if appropriate actions are taken. It is proposed that some pollution would follow an inverted U-curve related to GNP, increasing at low-income levels and decreasing at high-income levels. Such a relation is called environmental Kuznets-curve.

We have estimated the historical developments of Finland's emissions of carbon dioxide, sulphur dioxide and nitrogen. These calculations are based on Finland's historical energy balance from 1800 to 1998 worked out by a research project headed by Timo Myllyntaus. In order to test the relevance of the theory in explaining the development of Finland's air pollution emissions, we have related the emissions to the growth of the gross domestic product from the time before industrialisation to present. The use of this long time series gives a clear insight on the consequences of the industrialisation and provides useful instruments for policy recommendations.

Our research hypothesis is that the environmental Kuznets-curve primarily explains local environmental effects or regional environmental effects, which are connected to cost effective solutions. In the case of those regional environmental effects resulted from emissions for which there have not been cost effective solutions (for example nitrogen oxides) or that of global environmental effects (global warming), the explanatory power of the environmental Kuznets-curve is much weaker.

In Finland industrialisation started with renewable energy, and wood and water energy remained the foremost sources to the mid-20th century. Only in a mature phase of industrialisation became fossil fuels the major energy sources, and the 1960s and 1970s formed a turning point of Finnish industrial ecology. Owing to the energy-intensive structure of the manufacturing, industry has been the main source of air pollution. In Finland, moving to non-renewable and more polluting energy sources, and the improving the cleaning processes of emissions and energy efficiency have been two concurrent but conflicting trends.

Since 1914 to 1994 the energy use in industry has grown 11-fold despite the growing efficiency in the use of energy. However, labour productivity has grown much faster than the energy efficiency. Correspondingly, wages has risen more steeply than energy prices, which has led to the replacement of work by energy whenever

it has been cost effective. This fact has recently been used as an argument for an ecological tax reform, i.e., a shift from the taxation of labour to the taxation of natural resource use. In order to stay within the carrying capacity of the environment, there might be necessarily to sacrifice the targets for economical growth or to find new growth strategies (eco-efficiency, dematerialization and decarbonisation). If these new growth strategies could be linked with the needs to tackle with the current unemployment it could be politically easier to justify.

A better understanding of the relations between economic development and environmental pressure in the developed countries might help us to deal with environmental problems in countries in the beginning of their industrialisation process. For emissions, which development path follows an inverted U-curve related to income, it could be possible by technological transfer and economic help to move straight to the declining part of the environmental Kuznets-curve.

Economic Considerations of Sustainable Forest Management in the Ukraine

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Since the middle of the 19th century scientists have been dealing with the concept of sustainability in forestry, and at that time it was based precisely on the idea of maximum sustained yield. However the idea has several weak points, and the most important are that prices and costs are not incorporated in the concept, and that discounting is not considered. Faustman (1849) gave first correct formulation of the harvesting problem. Later the model was extended, for instance by incorporating of a flow of non-timber benefits (Hartman, 1976) or forest's ability to accumulate carbon (Van Kooten, 1995). General conclusion is that to ensure sustainable forestry, it is wise to postpone harvesting as long as the rate of return on investment exceeds the opportunity cost rate.

The initial models were exercised for main commercial species of the Ukraine, and the results of the study have indicated that officially recommended in the forestry rotation ages are substantially higher than optimal, and that the idea of maximum sustained yield remains popular in the country. Further "ecologization" of this idea has led to the fact that official forest harvesting comprises less than 50% of MAI, while in stable economic conditions, the Ukraine has an acute deficit in timber and has to import wood from Russia.

Hence in-depth changes should be brought into the Ukraine's forestry to economically and ecologically address sustainability in its forest sector. From one hand, scientifically substantiated rotation of timber has to be introduced into the forest management practice. It would decrease in most cases the ages of harvesting and would reduce a discrepancy between demand and supply sides of the timber production. From another hand, the program of afforestation (about 2 million ha) is proposed as a sustainable forest policy measure for the Ukraine.

Agent Based Modeling of Gene Flow in Crops

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If Genetic Modification is to be accepted as a sustainable technological development its social, ecological and economical impacts must be understood. One important tool in determining the environmental and human impacts of a technological development is the Quantitative Risk Analysis (QRA). QRA should quantify the risks of a new technology, so that the society can make a choice whether the benefits overweigh the risks. The current QRA for risk assessment of transgenic plants is based on mass flow models. These do not consider the fact that law of conservation of mass does not hold for genes, which are essentially information. They also do not take the imbedded open feedback loops present in life forms, i.e. the ability to self- amplify and reproduce, into consideration. Because of these shortcomings, the current QRA tools are probably inadequate to answer the question whether Genetic Modification is a sustainable technology. Next to the lack of scientific knowledge, there is a lack of social acceptance for Genetic Modification. So far it is unclear whether this lack of acceptance is a result of a principal disapproval of the technology or a lack of understanding of the technology. This uncertainty would have been less if a society-wide discussion on the benefits and risks of the technology were held before large-scale application was started.

By defining evolutionary processes and plant entities in Object Oriented terms an Agent Based Model called GeneScape, has been developed. The model explicitly describes plants as an entity with states, a genome, and interactions, mating. Plants populate an geometry, the Field, through which the environment, The World, enforces the rules for pollen distribution and which determines how the information content of the plant is to be translated into a fitness. The model is not meant as a quantitative prediction tool for Gene Flow, but as an explicit and graphical representation of the mental models of Darwinian selection, Gene Flow and plant ecology. Its strength lies in the fact that it allows the visualization of thought experiments on the behavior of GMO crops and the neighbouring plant populations. GeneScape can only be useful for answering questions about the sustainability of Genetic Modification if it is socially acceptable itself. Therefore a Society Acceptance Forum will be organized to evaluate the perception and acceptance of GeneScape as a model of Plant Gene - Environment interaction.

In the case that GeneScape is found to be acceptable found to be an acceptable representation of the relevant processes it can serve as a basis for development of novel tools for Risk Analysis of genetically engineered organisms and their environmental release. It may ultimately help in answering the questions whether Genetic Engineering has a place in a sustainable world.

The model is implemented in the Java 2 programming language, making use of the Ascape class library developed by the Brookings Institute. It is available for online execution on http://www.dct.tudelft.nl/~nikolic

Green Purchasing Versus Green Lifestyles: Lessons from Improved Breadth and Depth In LCA

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Full paper available: Yes

Breadth in LCA models refers to the set of process categories considered to be part of the system. For example, traditional LCI ignores

inputs of service inputs, capital equipment, ancillary materials, and overhead/infrastructure. Depth refers to the upstream extent of the modeling – that is, the number of supply tiers which are taken into account. Very recent research using Input/Output methods of LCA has begun to quantify the impacts of limited system *depth* on estimated total embodied energy. Here we investigate the joint effects of limits to system breadth as well as depth, including the very important interactions among them. We characterize and attempt to explain differences in impacts of both depth and breadth on estimated inventories for different pollutant categories. We find that increases in system breadth lead to significant increases in the requisite system depth in order to capture a given fraction of the total upstream burden; in other words, the more complete we make our LCA models (in terms of process classes included), the more depth we need to model in order to achieve goals for maximum truncation error. We apply eigenvector methods to shed insights on the convergence properties of life cycle inventory systems, and we systematically investigate the impacts of excluding input categories including service inputs, equipment, ancillary materials, and overhead/infrastructure.

Important findings for LCA and Industrial Ecology include: (1) total environmental burdens of products are routinely underestimated due to present breadth and depth truncation; (2) differences among alternative product environmental performance have been systematically overestimated using currently standard LCA modeling methods; (3) "green purchasing" benefits are not as strong as they now estimated to be, while "voluntary simplicity" or "downshifting" is more powerful than conventional analyses are showing us. We conclude with recommendations for enhancements to traditional LCA practice and directions for research in the Industrial Ecology of consumption.

Applying the Sustainable Systems Analysis Algorithm to Promote Industrial Ecology Concepts: The Edisto River Basin Sustainable Industrial Development Research Project

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"We act as consumers to get what we want for ourselves. We act as citizens to achieve what we think is right or best for the community"
– Mark Sagoff

The two main conflicting views among the champions of sustainability are the concepts of critical limits and competing objectives. The Sustainable Systems Analysis Algorithm (SSAA) is a decision-support and valuation methodology that is grounded in the competing objectives view of sustainability, yet it strives to incorporate the critical limits view and non-anthropocentric issues via the metrics chosen for measurement. It is intended to be germane to many sustainable systems analysis applications ranging from product to process to industrial facility, from local to regional to global. Herein lies a perceived framework for discussing, specifying and analyzing the inter-relationships across competing dimensions, time and space that could foster sustainable decisions. It provides an opportunity to contemplate and comprehend the potential for sustainable design and development strategies for those attempting to view the system as a whole and collaborate efforts toward implementing those strategies.

In this continuous improvement process, sustainability performance indicators (SPIs) being tracked for progress are first selected based on discretionary screening of active stakeholders, assigned an importance weight value and measured using appropriate methods on the open

system. The resulting calculation of the sustainability directive enables visualization of how current and scenario-derived activities are or are not contributing toward the sustainability of the system.

The SSAA methodology is being applied to promote sustainability and industrial ecology concepts within the wood products sector of the Edisto River Basin (ERB). It is a demonstration of a collaborative effort by a stakeholder group consisting of representatives from government, industry, economic development agencies, NGOs and academia to investigate and guide industrial development decisions within the realm of sustainability. This application has been dubbed the Sustainable Economic Development Simulator (SEDS). It is the intent of this paper to provide an overview of the steps taken to implement the SSAA methodology via SEDS within the ERB and a progress report of the resulting analysis.

Lessons to be Learnt from LCAs for Biodegradable Polymers

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In this paper thirteen LCA studies for biodegradable polymers are reviewed. Six studies deal with starch polymers, four with polyhydroxyalkanoates (PHA), two with polylactides (PLA) and one with other biodegradable polymers. All of these polymers are manufactured from renewable resources. Some of the studies reviewed are rather limited in scope by assessing only energy use and CO_2 emissions but they nevertheless contribute to a better understanding of the environmental aspects by addressing additional types of materials and by providing an indication of the uncertainty of the results. Regarding the choice of the functional unit some of the studies only address the production and waste management of materials in the form of *pellets* while other studies do refer to a specific type of end use. The end products studied are loose fill packaging materials and waste bags.

This review revealed a number of questionable assumptions and data uncertainties. Example are the large uncertainties regarding the carbon balance of composting, different approaches to account for the co-production of electricity/steam in waste-to-energy facilities and the inclusion/exclusion of methane (CH_4) emissions from landfilling. These uncertainties and inconsistencies should be addressed by future research and analysis. Many of the environmental analyses choose a cradle-to-factory gate perspective. While this approach provides valuable results, additional analyses taking a cradle-to-*grave* perspective by inclusion of the waste management stage should also be conducted. Due to the strong impact on the final results several alternatives in the waste management stage should be evaluated.

In spite of these uncertainties and differences in assumptions it is safe to conclude that biodegradable polymers offer important environmental benefits today and for the future. This is particularly obvious for starch polymers. Compared to conventional plastics, the biodegradable polymers studied generally contribute clearly to the goals of saving energy resources and mitigating GHG emissions. At the same time, none of the biodegradable materials studied performs better than its fossil fuel-based counterparts in *all* categories. Polyhydroxyalkanoates are biodegradable polymers for which – under the current state of the art - even the advantage in terms of energy use is very small compared to conventional polymers.

For the time being, it is hence not possible to make a *general judgement* whether biodegradable plastics should be preferred to petrochemical polymers from an environmental point of view. Such a conclusion could only be drawn if the environmental assessment showed clear advantages for *all* the biodegradable polymers studied and for (practically) *all* indicators analysed. If, however, the focus is on energy and CO_2 the results are clearly more favourable for most biodegradable polymers already today. Careful monitoring of *all* environmental impacts of biodegradable polymers in parallel to technological progress and changes in the infrastructure (power

generation, waste management) continues to be necessary both at the company and at the policy level.

To summarise, the existing LCAs and environmental assessments support the further development of biodegradable polymers. For some materials the environmental benefits achieved are substantial already today and in most cases the prospects are very promising.

Primary Aluminium Supply in Germany — A Hybrid Approach to Analyse Economic and Ecological Effects

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The primary aluminium industry is one of the important industries supplying non-ferrous metals. Despite the fact that per capita consumption of primary aluminium is declining in most developed economies, a growing demand for primary aluminium world wide is expected due to industrialisation in developing countries.

The production of primary aluminium is highly resource intensive, being responsible for the extraction of bauxite. Additionally, it is highly energy intensive, as huge amounts of electrical energy are necessary for electrolysis. With respect to both aspects, economic activity is accompanied by ecological impacts. On the other hand, the primary aluminium industry directly and indirectly creates jobs, added value and income by its own production and by the intermediate production from other industrial branches, all being fundamental components of any industrial system.

This paper sets a focus on Germany. Its primary aluminium industry is one of Europe's main producers. Germany is world wide one of the main demanding countries and to a large extent, its consumption depends on imports, resulting in international trade of primary aluminium. The paper concentrates on the analysis of economic and ecological impacts of primary aluminium production to meet Germany's demand either by domestic production or by imports. Specifically, the creation of jobs, the use of energy and resulting GHG emissions expressed as global warming potential are taken into account.

The analysis is based on a hybrid-model, which consists of an economic input-output-model and process-chain-model. The first model illustrates the overall economic context of the domestic primary aluminium production including its direct and indirect linkages with other industrial sectors, factor markets, imports and exports in monetary values. It also allows to analyse ecological effects using additional physical balances for energy or emissions. As the official German input-output-tables do not separate aluminium production, bauxite, alumina and primary aluminium (including semi-manufacturing) have been extracted from the non-ferrous metals sector in order to study the economic and ecological effects induced by the activities of the German primary aluminium industry.

The second model is used to evaluate in ecological terms the imports coming from different countries. It will show energy use and emissions of aluminium production of typical exporting countries like Norway, Russia and others. According to its primary energy resources this countries use different primary energy carriers to produce electricity for electrolysis, resulting in different levels of emissions compared to Germany

A Decision Support System for Product Take-Back Based on Concepts of Industrial Ecology

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Sustainability is a term that has amassed numerous meanings and definitions due to the assortment of contexts and motivations driving its application. Yet, common to most interpretations is the notion of maintenance or continuation of life on Earth in an undiminished state over time into perpetuity. Arriving at sustainability in this respect will require dramatic changes in the way humans and institutions currently operate under today's industrial paradigm. Since the Industrial Revolution, more of nature's biological and physical assets have been destroyed than in all of history. It is this stock of natural products and systems and the services they provide that make human life and development possible. As present trends in industrial development continue and place greater strain on our ecological base, limits to economic development and prosperity will no longer be determined by industrial expertise, but will instead be dictated by the availability and quality of natural assets.

This research explores some of the parameters involved in moving toward sustainable industrial development through analysis of a product take-back system for the Heating Ventilation and Air Conditioning (HVAC) industry. Specifically, a decision support system has been developed via geographic information systems (GIS) software and an Excel spreadsheet to model the reverse distribution logistics of the product take-back process and quantify the resulting effects (i.e. Emissions from vehicle miles traveled) respectively.

Moreover, a sustainable decision support system for the demanufacturing process of product take-back based on concepts of industrial ecology has been developed.

In this system, three comparative scenarios are investigated, which are either already existing or theoretically proposed. The first is the current manufacturing process, using extracted raw materials (primary mining), the second is secondary mining (product shredding), and finally the demanufacturing process (product disassembly). The environmental, economic and social dimensions of sustainability are studied using manufacturer or hypothetical data, or information collected from literature. This work was carried out in conjunction with a local HVAC manufacturer, thus all the generated data and conducted analysis is contributed from their manufacturing processes. At the end of this study, the most sustainable process that fulfills the requirements of industrial ecology is identified.

Evaluation of model output employs the principles of sustainability by investigating the various impacts that occur across ecological, economic and social dimensions.

A Comparative LCA of Olive Husk Combustion for Power Generation: an Italian Case-Study

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Within the new approach of Industrial Ecology the utilization of waste streams as alterna-

tive sources of raw materials for a given function is a major concept. In the field of energy generation, this is even more interesting when waste streams utilization entails the substitution of non-renewable resources.

This is the case of olive husks, agro-industrial wastes which may play a relevant role as a biomass energy source in several regions, such as southern Italy. It is well known indeed that the Environment can benefit by the substitution of biomass fuels for fossil ones, because of a lesser global warming impact of the former. On the other hand, additional processing activities and transportation which may be needed by biomass fuels might originate further environmental burdens.

An overall assessment can be carried out through the adoption of a life cycle approach. Within a broader project aiming at assessing the environmental impact of various technologies to exploit olive husks, this study deals with the implementation of a comparative LCA between power generation from olive husk combustion and from conventional technologies. In particular, this work is based on data collected from an actual case-study concerning a plant using this technology, recently installed in southern Italy. Preliminary results are here presented.

Development of an Industrial Ecology Framework for Magnesium Products

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Several business studies show that the worldwide demand for magnesium is predicted to grow from ~330kT per annum in 1998 to ~ 550kT per annum in 2008. This strong growth is due mainly to the increasing demand for diecast magnesium components for applications in automotive and electronic products. The principal driver for magnesium in the automotive area is the reduction in the emission of greenhouse gas by the weight reduction achievable with the use of components, manufactured with lighter magnesium alloys. The driving force for the use of magnesium in electronic demand goods is weight reduction, while maintaining the required electrical shielding.

In order to meet this growing demand, the construction of new magnesium production plants are being planned in many places of the world. Australia, with its large deposits of magnesite and cost-competitive supply of electrical energy to meet the heavy energy demand for magnesium production, is poised to enter the world market for magnesium and its alloys. The Australian Government has already given the Major Facilities Status to a few magnesium projects (amongst many proposed Projects) to supply annually ~ 230kT of magnesium to the world market.

The production of magnesium is based on an energy intensive electrolytic process, and hence has a very important bearing on the sustainable use of energy and resources. However, the principal eco-efficiency driver for magnesium use in manufactured products is to improve the material intensity of goods by weight reduction. The pervasiveness throughout the society of manufactured goods, which are currently using magnesium to achieve weight reduction, appears to be quite extensive.

In the Australian context, magnesium industry is currently at an embryonic stage, but is expected to grow significantly in the next decade. CSIRO has initiated a study on the industrial ecology of magnesium products. In this paper, some issues relevant to the development of magnesium industry, and related technology and business requirements will be discussed from the industrial ecology perspective.

Development of Key Parameters in the Plastic Packaging Sector in Norway 1990 – 2000

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This paper intends to study the development of some key environmental, economic and material parameters within the plastic packaging sector in Norway from 1990 to 2000. We will, in addition, test the influence of extended producer responsibility (EPR) on the observed development. This will provide new knowledge on the effect of this environmental policy in the plastic packaging sector in Norway.

Industrial metabolism is one important element within the concept of industrial ecology. It is about the input, output and accumulation of the materials in question in a geographically defined system, i.e. the stocks and flows of materials. Tools such as material flow accounting (MFA), substance flow analysis (SFA) and environmental input/output analysis (Env. IOA) are widely used to expand the knowledge of this. In Norway, some limited studies on industrial metabolism have been carried out the last ten years, particularly due to the introduction of EPR in selected sectors.

As for the plastic packaging sector, since EPR was implemented with certain recycling targets stated in the covenant in 1995, there has been an on-going discussion throughout the 90s on the total generated amount of plastic packaging waste. Equally important as the total generated amount of waste, however, is the material flows within the system. Moreover, to every material flow there is a flow of capital, and from an eco-efficiency perspective, it is crucial to combine selected economic and environmental key parameters in one and the same study, which will be done in this paper. The selected parameters are flow of plastic packaging in different phases of the life cycle [kg], net sales [NOK/kg], CO2-emissions [kg/kg plastic], additives [kg/kg plastic] and energy consumption [MJ/kg]. One main purpose of this paper is thus to discuss the development of selected parameters in the plastic packaging sector in Norway from 1990, via 1995 to year 2000.

A process system based model of the entire life cycle of plastic packaging will serve as the basis for the analysis. The life cycle is divided into i) extraction of raw materials (fossil fuels), plastic production (HDPE, LDPE, PP; PET/PEN and PS), plastic packaging production (Foils, cans, PP-bags, reuseables and EPS), plastic packaging in use (Filling and packing of end-user products, wholesaler/retailer/grocery trade, use in households/industry/others, filling and packing of bulk products, receivers of agriculture products, aquaculture products and of industrial and bulk products) and the EoL-phase. Data will be collected mainly through an empirical survey among the companies representing 80 % of the material flows. Statistical data from literature will be employed to complement this empirical data. Estimates of the uncertainty of the provided data will be conducted.

Implementation of Industrial Ecology in the Swedish Building and Transport Sector

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There are similarities between the concept of Industrial Ecology (IE) and the Swedish concept ‘kretsloppsanpassning’. The latter was introduced as a political concept by the Government Bill 1992/93:180. It aimed to change and develop Swedish society in the direction towards ecologically sustainable development. Furthermore, both these concepts have (ecological) sustainable development as an ultimate goal and one central

strategy is to close the material loops (c.f. [1, 2]). However, the Swedish concept address the society as a whole and therefore we have found it appropriate to term this Swedish concept Societal Industrial Ecology (SIE). The society that the Swedish government envisioned has a good natural resource economy; recycling all materials. This ideal materials management would, according to the Swedish government, lead to a minimized generation of wastes and a minimized contribution of emissions into the environment. We have studied the implementation process of SIE in the Swedish building and transport sector respectively. These case studies indicate that the measures emphasized and implemented, focused on material outflows such as reuse of materials. Furthermore, it seems like, in the strive for achieving sustainable development and closing the material loops, there is a lack of the knowledge about to what extent these measures contribute to reduced environmental impact. As an example the quality aspects of reuse are seldom considered and it is often assumed that reuse in all forms contribute to improved environmental performance. To what extent different reuse activities in a broader system perspective really reduce the environmental impact depends on, for example, the material itself and the reuse processes. This is, however, neither discussed nor environmentally evaluated in the implementation process. Thus, it is very important to start to evaluate these measures from an environmental point of view. his paper deals with the implementation process of SIE. Using the transport and building sector as case studies we will describe their goals and measures emphasized to achieve SIE and discuss the environmental relevance of these measures.

References

1] Swedish Government. Policies to develop the society towards closed material loops (In Swedish). Governmental bill1992/93:180 , Ministry of the environment and natural resources, Stockholm, 1993.

2] Erkman S. Industrial ecology: an historical view. Journal of Cleaner Production 1997;5(1-2):1-10.

Life Cycle Engineering of Buildings

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In this abstract is presented the result of two studies finished in 2000. The studies were carried out by the author together with Finnish construction industry.

The aim of the studies was to develop a method for controlling building design that would allow managing both the life cycle costs and the environmental burdens from buildings during their life cycle. The control method presented in the paper was tested in ongoing pilots: a laboratory building project and a residential building project.

The developed procedure for controlling the construction costs and the environmental burden of buildings developed as part of the research consists of the following phases:

Project programming:

- Selection of time horizon
- A budget is set for the construction costs
- A limit is set for the annual energy consumption of the building during use. The limit is based on the users requirements of spaces

Building design phase:

- The construction costs based on the building designs is estimated
- The energy consumption of the building during use based on the building designs is calculated
- In case the construction costs or the energy need based on the design solution exceeds the limit, the designs are improved
- When necessary, ecological-economical value analyses are made on individual building elements. The analyses are intended to shed light especially on potential design solutions that deviate from the prevailing building mode which aim at reducing the life cycle costs or the environmental burdens of the building. Value analyses are especially made on ele-

ments whose impact on the building's energy consumption during use varies between alternatives, or whose maintenance cycles vary between solutions or which contain varying amounts of non-renewable materials

Implementation of construction works:

- In the implementation phase, the ecological-economical values of potential alternative production solutions that can reduce environmental impacts are determined

Use-phase energy consumption was chosen as the key environmental indicator in the presented method. The choice was based on the fact that in Nordic conditions the majority of a building's climatic impacts (warming and acidification) are a result of the energy consumed in the building during its use. By controlling that consumption, the climatic effects of the building can be controlled most effectively.

The procedure developed offers a simple way of controlling the life cycle costs and environmental burdens generated by a building over its life already at the building design phase. It is not enough just to estimate these things from the planned building to be able to control design - there must also be a target level against which the estimated figures are compared. The method outlined in the study provides tools for controlling building designs and bringing them to an acceptable level as regards life cycle costs and environmental loading.

A Conceptual Model of "Knowledge Strategy" in the Telecommunications Industry

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Knowledge is increasingly being recognized as a fundamental 'resource' within the modern industrial economy. Considerable work has been undertaken into what constitutes knowledge, where it is derived from and how it can be effectively nurtured, transferred and assimilated. The interpretation of knowledge as a resource raises a number of other key issues that are central to this paper. It is a renewable resource, and a failure to consider it as such raises the threat of a non-sustainable future. However, unlike scarce natural resources that cannot be replaced knowledge needs to be continually applied, updated, re-appraised and contextualised. Equally, if it is not drawn upon it can become outdated, obsolete and non productive. Organizations therefore must efficiently and effectively create, capture, harvest, share, and apply their organization's knowledge. They must have a dynamic ability to bring that knowledge to bear rapidly on problems and opportunities as they emerge.

Given this, it is imperative that today's firms explicitly address a range of decisions regarding the creation, deployment, and maintenance of their knowledge resources and capabilities. Much has been written about processes and infrastructures for sharing and codifying knowledge especially by using information technologies, communities of practice and workspace designs but little has been said about the strate-

gic perspective regarding knowledge resource decisions. A "knowledge strategy" view and approach is required to reflect this in the current knowledge-intensive environment.

This paper will examine the key drivers and barriers to the generation and assimilation of knowledge within the RandD environment of telecommunications. It will further explore the concept of knowledge as a dynamic process that is embedded in all aspects of the organization and the environment within which it operates. Different types of knowledge will be identified and an understanding built of its varied characteristics. It will propose a need for a "Knowledge Strategy" to build and renew knowledge as a dynamic and interactive process.

The final phase of the discussion will present a conceptual model of "Knowledge Strategy" by which a firm can balance its knowledge resources with its knowledge replenishing capabilities and activities to achieve superior competitive advantage in today's knowledge- intensive environment.

Mass Flux Aspects: Environmental Relevance and Regulatory Use of Surfactant Anaerobic Biodegradability

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This paper presents some key information from the ERASM Report (1999), "Anaerobic biodegradation of surfactants - Review of scientific information." The anaerobic degradability of the major commercial surfactant types under laboratory and field conditions was reviewed and compared. Subsequently, a comparison of the mass fluxes of these surfactants after use and disposal in the environment was made. Measured mass fluxes are in good agreement with theoretical predictions. Aerobic degradation -a legal prerequisite in the EU- is in practice by far the predominant elimination route for modern-generation surfactants. The environmental relevance of anaerobic degradability as a property for surfactants is driven by the amount that can accumulate and potentially cause effects in anaerobic environmental compartments. The analysis indicates that for the aerobically only degradable surfactants less than ~10% of the mass flux has a permanent anaerobic compartment as final sink, while this number is less than ~3% for both aerobically/anaerobically degradable molecules. For the sum of permanent and temporary anaerobic compartments this is ~20% versus ~10%. The report concludes that the environmental relevance of anaerobic degradability for surfactants, and chemicals at large, cannot be separated from other key properties that affect environmental partitioning and mass fluxes. These factors include sorptive behaviour, logKow and aerobic biodegradation kinetics. Usage volumes, waste disposal practices and ecotoxicological profile are another series of factors that drive the risk assessment outcome. Therefore, it seems unjustified to use anaerobic biodegradability in isolation as a regulatory pass/ fail criterion for surfactants.

The Neglected Issue in Industrial Ecology, Management of Resources vs. Management of Material Cycles

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This article critically investigates some of the basic assumptions underlying the IE paradigm. It makes use of the concept supply-side sustainability[1]. It is argued that IE will likely be beneficial to humanity, but it might fail in achieving a sustainable society.

By making use of simple modeling and complex systems theory, this article argues that natural systems are essentially type I systems[2], thus

using sources and sinks instead of closed material cycles. Though, these resources can also be depleted. Nature deals with depletion by means of a simple mechanism; the emergence of a *crisis*. Natural systems are often victim to such events. Individual species can easily deplete their resources. Nature, however, overcomes such crises by redundancy, either in the genes of a single species, or by having another species take over. This causes the overall sustainability of nature, but only at the macro level, not at the micro level.

It is shown that industrial systems have in fact always been much like natural systems at a micro level, because of a similar system *structure*. Thus, Industrial systems can also be victim of crises. Human history has proven that such crisis are often disrupting to society, causing poverty, poor health, reduced freedom, famine, war or even genocide. Like nature, humanity will likely overcome such events, though, these are disruptive and undesirable. Therefore a sustainable society is defined as one that avoids crises.

This article further demonstrates that IE will not help to achieve a sustainable society if it concentrates at closing material cycles. In this way, it will only be a next step in increasing resource exploitation *efficiency*. It will thus be part of a long history of similar steps in technology, such as agriculture, the industrial revolution, and communication technology.

To demonstrate this, a novel concept is introduced. This is *resource load homeostasis*. Because resources have economical value, trying to use less will likely be a failure. Due to a decreasing price, it will become utilized for a previously uneconomical purpose. The *rate of resource depletion* will not change; it is entirely determined by the effort society is willing to invest in its exploitation, not by its subsequent uses. Approaches foundational to IE such as closing material cycles, LCA, and integration of industrial systems, will enable society to do more with the same, but not reduce the rate of resource depletion. Thus applying such approaches will at most delay a crisis.

In order to overcome this, IE should shift *part* of its attention to the explicit management of resources. IE should actively try to determine the maximum load a resource can sustain without becoming depleted, and what practical mechanisms can be applied to limit it. Hence, the field should not restrict its effort at closing material cycles. Taking resources into account in this way, the IE approach becomes fundamentally different than natural systems because it will thus strive to prevent crises.

[1] T. F. H. Allen, Joseph A. Tainter, and T. W. Hoekstra; Supply-Side Sustainability; Systems Research and Behavioral Science; 16, 403–427 (1999); Elsevier Science Publishers

[2] Type I systems as defined in Allenby, B.R., Industrial Ecology: policy framework and implementation, Prentice-Hall, 1999, p 43-47.

Economic Materials-Products Chain Model With Application to Window Frames

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Process (optimisation) models have a long tradition in project evaluation of base industries and for modelling of the mining sector. These models usually concentrate on modelling of different process stages necessary for production of one base material (e. g. copper or primary aluminium). The model of the global aluminium industry which was developed by the author of this paper is an actual application of process modelling for environmental analysis. This model permits the assessment of future energy consumption and greenhouse gas emissions associated with the worldwide flow of primary aluminium. The economic and ecological effects of policy measures (like eco taxes in the European Union) on the primary aluminium flow can be studied.

In contrast to process models, M-P chain models concentrate on modelling systems of competing final products rendering the same economic service. They can be seen as the economic counterpart to life cycle assessment. Because of their recent origin, existing economic M-P chain models make strong simplifying assumptions.

Most (or all) prices, including those of the main material inputs and final products, are exogenous. Furthermore, foreign trade is not considered. It is highly desirable for the analysis of real-world material flows to develop M-P chain models which include foreign trade and which are based on microeconomic foundations. This paper develops the first steps towards such an approach. Elements of process models are integrated in the M-P chain framework. The model is applied to window frames made from different materials (aluminium, PVC, wood) and reflects German material flows. Future developments of the model will permit an integrated economic-ecological analysis. Policy scenarios can be calculated to evaluate the effects of different policy measures.

Comparative Analysis of LCA and CBA

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Life Cycle Assessment (LCA) is a frequently applied analytical tool in case studies done within the Industrial Ecology paradigm. There exists a standardization of the method such as the ISO 14000, but the method is nevertheless widely discussed among its practitioners and has also been criticized by analysts from other disciplines, such as economy. The main problems pointed out by economists are related to determining the system boundaries, the valuation methods, and the double counting of environmental effects in the presence of green taxes, which becomes of vital importance both in recommending and implementing waste disposal policy. Among others, these factors contribute to the fact that the majority of LCA and Cost-Benefit Analysis (CBA) done on similar projects reach different conclusions. In this paper we are using both methods in analyzing the plastic recycling system in Norway's third largest city, Trondheim. This enables us to analyze why application of the two methods in this specific system reach different results, and hence to pinpoint the strengths and weaknesses of the two approaches.

However, both methods are by nature static and descriptive, meaning that they unveil only one point in time and space. Thus, contributions to decision-makers concerned about what is the best future policy for waste disposal are limited due to the methods lack of dynamic elements. Designing a method aimed at predicting the best future policy is of course a major task leading to several methodological challenges. In our analysis we show that including a cost-curve analysis in the study of the system implies that the information offered by the investigation increases substantially. We estimate the costs of each process in the system and show that there exist some system-internal externalities, i.e. the optimal production level in one stage is not necessarily optimal for the up- and down-stream processes. Based on a system perspective we optimize the use of resources for all stages in the value chain as a whole and are hence able to give a more informed policy recommendation on waste disposal policy.

Case Study: Design Student Teams Use Industrial Waste Stream as Resource for New Products

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Three teams of design students from the Integrated Design Curriculum at Parsons School of Design in New York City have addressed the challenge of utilizing the waste stream from industrial operations as resources for new product development. Working with West Harlem Environmental Action, Inc. (WE ACT) and NY Wa$teMatch, the student teams have designed products from discarded materials. As a part of its mission, WE ACT works to encourage the most efficient use of resources and to improve the quality of life for the largely African-Ameri-

can and Latino residents of Northern Manhattan. This includes the development of community-based green businesses that generate jobs in healthy and safe settings. The goal of NY Wa$teMatch, funded by the NYC Department of Sanitation, is to reduce both the volume of waste and the cost of raw materials for manufacturers. Wa$teMatch identifies waste generators and potential re-users and matches them together.

The student teams were required to identify materials from Manhattan industrial waste that were available in a reliable and predictable volume and appropriate for re-use/re-manufacturing in a local production site employing community residents. Concurrently, WE ACT is renovating an abandoned building in Harlem to turn it into an Environmental Justice Center. This is being done in a way that provides a model of environmentally responsible design in its re-construction and operation. It will be furnished with products that are consistent with the green philosophy affirmed by WE ACT in its educational and advocacy programs. So, in addition to the requirements to use the materials from the waste stream for products, it was necessary that these new products be both usable in the new building, and models of responsible design appropriate for the group's educational mission.

Products developed by the student teams include

1) a family of desk accessories and small storage/furniture products made of the paper tube cores from textile rolls used in the garment industry and paper chipboard from the printing industry;
2) a range of urban-site gardening accessories made of waste from the sheet metal, plumbing and cabinet shops serving the city's construction industry;
3) sets of illustrated learning kits using material samples of manufacturing waste for exploratory, hands-on industrial ecology studies with students and community groups.

The next steps are to complete the business plans and launch the community-based, re-use enterprise.

LCA of Hydrogen Production from a Steam Methane Reforming Plant with CO2 Sequestration and Deposition

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Full paper available: No

Hydrogen is seen by many as the most promising future energy carrier, continuing a historical trend towards cleaner, less carbon-rich fuels. In combination with fuel cells, which convert chemical energy to electrical and mechanical energy more efficiently and have no direct emissions other than water, hydrogen has a very positive reputation among the public. In fact, it seems to be the common perception that this technology will solve most of the health and environmental problems related to transportation.

In Norway, hydrogen has received a lot of attention as a future energy carrier, both in academia and in the oil and gas industry. A comprehensive report on the existing hydrogen technologies available and the ongoing research in the respective fields was published last year as collaboration between the largest research and educational institutions in Norway. However, no environmental assessment of these technologies was performed. The application of LCA methodology to this technology is important to allow for a better understanding of the environmental impacts that will be imposed if, or when, this technology is introduced.

From our study of the literature we found, not surprisingly, the environmental impact of fuel cell vehicles (FCV) is very sensitive to the environmental burdens related to the production of the fuel hydrogen. Another interesting finding was that CO2 free hydrogen is required for FCV to substantially contribute to climate change mitigation. As the published data on H2 production and CO2 sequestration is both insufficient and conflicting, we found it necessary to investigate this in more detail.

The largest challenge in this work was to perform an life-cycle inventory of a non-existing process plant. Working together with experts

from both academia and industry, we where able to perform a detailed study of a steam methane reforming plant with CO2 sequestration and deposition.

The design of the plant was performed using Pro II, a chemical process optimisation software. With this design as basis material choices where performed, and models of each of the process components were made allowing for inventory data to be constructed. This combined process design — inventory construction methodology should be of general applicability to analysis of other process plants. State-of-the-art impact assessment methods are applied to compare different environmental impacts, using both the environmental themes approach and the damage function approach. The flexible design of the project allows for the results to be used to develop and evaluate different scenarios and applications.

Promoting Environmental Quality in Italian Micro Enterprises: The Case Study of Wood Windows

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A research project (SCILLA) for promoting environmental quality in Italian micro enterprises has been recently completed. The entire activity has been carried out with the financial support of the European Regional Development Fund for Objective 2 areas, managed by Emilia Romagna region and in strict cooperation with LegnoLegno Consortium, that associates about 150 enterprises in the region. The industrial sector has been selected because of the economic relevance of wood working enterprises in Objective 2 areas. Moreover, the environmental relevance of wood window in assuring good thermal performances of buildings is well known and, as no agreement on size standardisation has been reached, about 90% of Italian windows are custom-made by micro enterprises.

The main objectives of the project SCILLA were:

- to identify the environmental critical stages of the product's life cycle;
- to provide the company management with guidelines for minimizing the environmental impacts in each stage of the product's life cycle;
- to propose the adoption of cleaner technologies that also micro enterprises can acquire and manage;
- to carry out an experimental program for testing and optimizing different construction options;
- to verify the economic feasibility of a recycling center runned by a SMEs consortium to maximize components reuse and materials recycling.

To reach these objectives a complete Life Cycle Assessment of a "reference" wood window and of selected alternatives has been carried out. In this paper the methodological approach and the final results of the study will be discussed. The project showed that remarkable environmental improvements can be obtained also in micro-enterprises working in traditional sectors without introducing radical changes in the production processes. The highest improvement potential is achieved when environmental performances are taken into account in the early stages of product development and with the cooperation of all decision makers which influence the product's life cycle.

Combining LCA, Input-Output and Linear Programming in the Assessment of Waste Management Policies: An Integrated Approach

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Life cycle assessment and environmental input-output analysis are well-established evaluation methods in environmental science. LCA takes a bottom-up approach for a specific product or system, whereas input-output analysis takes a top-down approach focusing on the economy-environment interactions of sectors. The current debate in Norway concerning waste incineration versus recycling of waste materials shows that these different evaluation methods result in different policy recommendations for waste management.

LCA suffers from subjective boundary definitions, are data intensive, and less flexible for analysis. Input-output models, however, have consistent boundary definitions and are more flexible in use, but the aggregated level of data ignores important characteristics when applied on site-specific systems. This is demonstrated in our case study of waste treatment in Trondheim, Norway's third largest city. We also show that site-specific characteristics are better represented in LCA models.

We approach this problem by applying a LP (linear programming) framework, where the material flows of household waste fractions are represented in a network flow model. Each process of this model, from material extraction, to production, use, transport and recycling/incineration – is associated with an environmental index based on LCA studies. The objective function is to minimize the environmental impact of the material flow network, where a disaggregated input-output table represents economic-environment interactions in our model. Finally, the LP formulation provides a flexible method for evaluating optimal policies for waste management.

Waste management, whether recycling or waste incineration - require large investments in infrastructure – and it is therefore of importance to sort out the methodological controversies to support efficient policies for waste management. Efficient solutions of recycling/incineration and their sensitivity to technology changes are studied. Experience from integrating both LCA and input-output models in a LP framework is also evaluated.

New Master Programme - Chemical Engineering with Industrial Ecology

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A new master programme will start at the Royal Institute of Technology, Stockholm, Sweden in fall 2001. The name of the programme is Chemical Engineering with Industrial ecology. The curriculum will mainly follow the existing one for Chemical Engineering, but several courses have been and will be developed specially with focus on Industrial Ecology.

Example of new courses are:

- Introduction to Industrial ecology

- Environmental system analysis
- Environmental and Safety management
- Waste management

The new courses will contain several projects with case studies from the process industry.

In the paper the curriculum as well as examples of case studies will be presented.

Energy Analysis of E-Commerce and Conventional Retail Distribution of Books in Japan

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Full paper available: Yes

Energy use associated with distribution via e-commerce and conventional retail is compared for book sales in Japan. The simulation of energy consumption includes the following factors: fossil fuel used by trucks in distribution from distributor to bookstore or e-commerce firm, transport fuel used by the consumer or courier service production of packaging, and energy for appliances and climate control at the point of sale (home or bookstore). Results indicate a crossover in environmental performance according to population density. Conventional retail uses less energy than e-commerce in dense urban areas, mainly due to avoided packaging, but can consume more in suburban and rural areas due to the inefficiency of personal automobile transport.

Evaluation of Eco-Industrial Park as Societal Experimental Site in Japan

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Full paper available: Yes

In the present research, an inverse manufacturing system for industrial pumps and a strategically combined input/output system are examined in an eco-industrial park in Japan where associated societal experiments for recycle-oriented complex had been carried out under the authors' contributions.

The eco-industrial park model describes collaborative actions of recycling among factories, logistics and consumers sectors, which will establish mutual system to utilize by-products derived from their partner sector as their own resources in the regional community. In addition, this is expected to couple with the introduction of design for disassembly and maintenance system of industrial pumps.

Ebara corporation has made an attempt to take back post-consumed industrial pumps at Fujisawa factory in Kanagawa. An experiment was carried out in 1999, and about 250 post-consumed pumps were taken back to the inverse manufacturing experiment line in the factory. The effect of design for disassembly is examined for industrial pumps based on collected data by the

take back experiment. The study indicates that joint and sealing parts are dominant for disassembly time, and "parts reuse-scenario" gives great cost reduction in life cycle cost and carbon dioxide emission compared with "waste disposal-scenario". Further more, the effect of reuse and positive maintenance is examined for mass of industrial pumps in a certain urban building facility. In the case of reuse and positive maintenance-oriented facility management, life cycle manufacturing costs can be reduced to 14% of usual operation in spite of additional capital cost for inverse manufacturing.

In the eco-industrial park, annually wastes of 280 tons and 5000 tons are generated in a residence flat and a factory, respectively. When considering utilization of waste converted resources between residence and factory in the eco-industrial park, the conversion technology is determined depending on the type and quality of material and energy needed between. Each conversion method has its optimal scale and merit. In the eco-industrial park, a gasification plant was installed for technological certification.

Therefore simulation analyses are attempted to couple each conversion technology with the gasification technology for improvement eco-efficiency in the eco-industrial park. The results indicate that the eco-industrial park with conversion technologies give reduction of 26% in primary energy consumption compared with a conventional industrial park, and particularly, the combination of gasification and fuel cell with aerobic digestion gives great reduction of energy consumption.

Finally, incentives and barriers are discussed to the development of eco-industrial parks in Japan. One of important features in industrial site policy in Japan is that major government policies are implemented particularly for industrial structure change. Therefore a government tended to give incentives such as subsidiary rather to a set of specific industrial accumulation, not to industrial site. In considering enhancement of eco-industrial park development, government industrial policy should be rather push type, for example de-regulation for industrial land use, in order to stimulate flexible individual arrangement and alliance.

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