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Plenary and Keynote Abstracts

PLENARY 1 The Sustainability of International Supply Chains: Aspirations and Practicality

Roland Clift

Centre for Environmental Strategy, University of Surrey, Guildford, GU2 7XH, UK

President of the International Society for Industrial Ecology

Sustainability has come to be interpreted widely in terms of three “pillars” or constraints: techno-economic, environmental or ecological, and societal. Applying this approach to consumption suggests that the sustainability of supply chains should be assessed by examining the distribution of positive benefits and negative impacts along the supply chain. The economic dimension can be addressed by Value Chain Analysis and the environmental dimension by Life Cycle Assessment; juxtaposing the results from VCA and LCA immediately gives useful insights into the sustainability of supply chains. Tools for assessing the distribution of social benefits are still in development but are equally important in a market where consumers and, even more significantly, retailers require suppliers to demonstrate Corporate Social Responsibility. This approach to assessing sustainability is explored by examining some specific supply chains. The results show both the possibilities and the challenges of attempting to improve the sustainability of international supply chains.

PLENARY 2 Just when you thought it was safe to go back into the water - An exploration of society, business and leadership in the great transition”

Mark Drewell

3 Laws Capital

In this address, Mark Drewell will bring his perspectives as a multi-disciplinary integrator to making sense of the world in which we are living today. He will discuss the dominant forces shaping the world in which we live, provide frameworks for understanding how human society is (and is not) responding to the challenges we face and offer insights into the requirements of leadership in our time. Mark will cover and connect global dynamics with local developing world realities, reviewing growth and sustainability in a world in transition. This systems talk will consider the challenges of delivering effective corporate governance and supporting capacity development and institutional support within the context of life cycle management.

PLENARY 3 Systems Intelligence for Life Cycle Management – Shifting the focus from products to people

Raimo P. Hämäläinen

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The disciplines of management science and operations research have developed tools for structured approaches to the engagement with complexities in systems and organizations with the goal of making things better. Many of these approaches have potential use in Life Cycle Management (LCM). Multicriteria decision analysis is one method which is having increasing importance in environmental management. The core of all the methods is the use of systems thinking. We have introduced the new concept of Systems Intelligence as a necessary step forward in applying systems thinking. It is a perspective and capacity to use systems thinking productively in people’s personal life and action. In this talk the concept will be described and related to LCM.

The roots of the LCA movement go back to the need to take the systems perspective on the assessment of environmental impacts of products and services. In this talk I will try to outline a way forward with a wider systems perspective where systems intelligence thinking is introduced as a new element in life cycle thinking. The static system boundary used in LCA can often be redrawn by looking for opportunities to re-design new products or by re-evaluating our real needs. This means that decision making in this wider setting also takes into account the social,

economic and psychological variables related to the social setting or to the criteria for good life chosen personally by ourselves. We could look into personal consumption styles from the perspective of ways to satisfy our needs by thinking of deeper goals. The focus could be shifted from the analysis of current products to personal values and preferences. Many needs do not require material products to be satisfied.

In today's world we face the challenge of better Environmental Leadership. It is proposed that combining Systems Intelligence and Life Cycle Management we could become ecologically intelligent, a skill needed in the true Environmental Leadership.

KEYNOTE 1 LCM in the FMCG sector: the gap between theory and practice

Henry King

Science & Technology Leader: Sustainability, Unilever - Safety & Environmental Assurance Centre

The world faces unprecedented environmental challenges to move towards sustainable consumption. The time to act is now but industry practice is still primarily focussed on eco-efficiency and meeting the needs of the growing numbers of consumers. The talk will highlight the challenges, current practices and the gap between theory and the systems/initiatives in the FMCG sector. It will also address the need to change the mindset of consumers and marketeers.

KEYNOTE 2 Structures and policies for the successful management of e-waste in Africa

Dr Kirstie McIntyre

Environmental Compliance Manager, Hewlett-Packard Europe Middle East and Africa, Bracknell, UK, RG12 1HN

E-waste is the fastest growing waste stream in many parts of Africa as electronic goods become more popular. Informal collectors, dismantlers and recyclers play an increasingly large role in processing domestic e-waste. The sector also provides valuable jobs for people who can't easily access formal employment. However, there is inadequate legislation and infrastructure for collection and recycling. Coupled with a lack of knowledge and training, this means that waste which could be safely disposed of or recycled becomes a health or environmental hazard.

African countries require policies and infrastructure to prevent e-waste becoming unmanageable. Specific systems for e-waste, from collection to final disposal are needed. Capacity should be built across the spectrum, from e-waste collection infrastructure and material recovery facilities to the treatment of hazardous waste. Multi-stakeholder platforms are crucial to the successful establishment of new systems. In an entrepreneurial pilot, here in Cape Town, it will be shown that informal waste management systems can be effectively incorporated into sustainable waste management facilities.

KEYNOTE 3 "A petrochemical industry approach to managing product life cycles in an emerging economy"

Benny Mokaba

Sasol

KEYNOTE 4 The Niche of Metallurgy in Design for "Sustainability"

Markus A. Reuter

Ausmelt Ltd., 12 Kitchen Road, 3175 Dandenong, Australia

Metals play a pivotal role in society as their properties impart unique functionality to engineered structures and consumer products. Furthermore, metals are theoretically infinitely recyclable. However, among others, design complicates recycling due creating complex structures that produce impure recyclates, hence forcing dilution by the use of virgin pure metal. Metallurgical smelting ingenuity, good technology and intelligent use of thermodynamics

and transfer processes gets metallurgists a far way down the path of creating high recycling rates; it is however the 2nd Law of Thermodynamics that also flags the limitations of recovering all elements. This is also then directly linked to economics of the various process routes. A key issue is the creation of optimal industrial ecological systems (Web of Materials) that maximize the recovery of materials from ores and recyclates within the boundaries of thermodynamics, technology and economics. The excellent theoretical and applied engineering toolboxes of process engineering as well often good understanding of economic and technological constraints make metallurgists an important player in optimizing “closure” of material cycles within the Web of Materials. This paper will discuss some of the tools, issues and provide a brief picture of recycling and design for “sustainability” and its thermodynamic basis. It will be further shown how the discussed tools and approaches can be made to good use to ensure products are designed for recycling, that geographical regions optimize their metallurgical furnace as key unit operations in the industrial ecological system. The importance of managing the recycling infrastructure will further assist in optimizing the recovery of metals and energy from consumer products that flow into these geographical regions such as the EU. Furthermore, harmonizing legislation with this fundamental basis will help to facilitate these objectives and hence reach the thermodynamic limits of recovery. The examples used in the discussion are based on Volkswagen’s 6th framework EU super light car EU project the author was involved (www.superlightcar.com) in as well as the recycling of various other consumer products and recyclates. In addition some of the 50 industrial applications of Ausmelt furnace technology will be discussed to show the state-of-the-art in metal production and recycling. The figure summarizes the flexible and versatile operating envelope required by best available technology (BAT) to process ores, residues, e-waste, post-consumer scrap and/or recovery energy. Extending this theoretical basis it will be shown how a seamless integration is possible to the Web of Water, mitigating the impact of recycling and product design on water quality.

KEYNOTE 5 Bridging the governance and sustainability challenges of being a formal business in an informal industry - a brewing and beverage industry perspective

*Richard Chance
SAB Miller*

The reality facing The South African Breweries Ltd is that more than 70% of its products reach consumers via “illegal” channels. This is the result of historical factors, but is it sustainable and, if not, what needs to be done to rectify it? This presentation will explore these specific challenges from the perspectives of distributed retail supply chains, CSR, empowerment initiatives, and how these resonate with the concept of Life Cycle Management.

KEYNOTE 6 Operationalising life cycle management in a world-leading bio-innovation company, to deliver superior and sustainable solutions for tomorrow’s ever-changing marketplace

*Claus Stig Pedersen
Novozymes*

Abstracts

OR 01 Unit Process Data – Building more relevant LCAs for Developing Economies

Philippa Notten

The Green House, South Africa

A challenge for LCA practitioners in developing countries is that the detailed LCI data available in LCA databases are predominantly for Europe, necessitating a compromise situation to be found between local relevance and LCI detail. A considerable step forward has been the publication of non-aggregated or unit process LCI data. Previously all LCI data was published on a result level, i.e. as resource inputs or final emissions to the environment. However, the ecoinvent database is now available as unit process data, which specifies the input materials into a particular unit process. E.g. a “traditional” LCI for a paper mill would present an inventory with resource inputs, e.g. wood, coal, crude oil etc., and the emissions associated with the production and use of these materials and fuels summed together with the emissions from the paper mill. A unit process inventory, on the other hand, will specify an input of “wood at saw mill”, “heat from coal boiler” and “transport of wood in 32 ton truck”. This allows the LCA modeller to input wood and coal from a specific source, adjust for fuel quality and boiler efficiency, and to specify local transport data. It is therefore possible to create a hybrid inventory with base European data (the material requirements and emissions of the paper mill), but contextualised to the particular country (the wood, coal and transport data).

This approach is demonstrated in a comparative LCA of packaging options for laundry detergent in South Africa (a cardboard carton versus a plastic quad bag). Primary data was collected for the fabrication of the packaging and the packing process, with data on all other life cycle stages supplied by the ecoinvent database. Adjustments to contextualise the ecoinvent data are made wherever a process contributes more than 2% to the total impact of the system, and include changing the electricity input to the South African electricity grid mix, changing transport distances and modes and changing fuel source (i.e. changing from natural gas or oil to coal). Increasing the local relevance of the data considerably improved decision making as it strengthened the degree of confidence that could be held in the results. In particular, substituting data on local fuel sources considerably improved the resolution between the two systems, allowing environmental preferences to be clearly distinguished.

The results for the packaging systems are analysed with and without adjusting the unit process data. The large differences obtained points to the importance of using regionally relevant LCI data, and in particular, the erroneous results that can be obtained if differences in fuel sources are ignored. This is particularly significant where LCA is used to support decision making around global supply chains. Whilst a particular product might well be used within Europe, the extraction and manufacture of raw materials increasingly takes place in emerging markets. This study shows that it is not meaningful to model these full supply chains with European data. Unit process data offers a first pass solution for making these results more relevant to decision makers.

OR 02 Design for Sustainability – UNEP Case Studies in Developing Economies

Carrette Clark

United Nations Environment Programme

Building upon ground breaking work in the area of ecodesign, UNEP in collaboration with the Delft University of Technology, (the Netherlands) and other experts in ecodesign, has developed activities in the area of Design for Sustainability (D4S), publishing ‘D4S: A Practical Approach for Developing Economies’ and is finalizing a more general D4S resource book in early 2009. The D4S concept outlines methodologies to make sustainable improvements (social and environmental) to products by applying life cycle thinking.

In the 1990s, concepts such as ecodesign and green product design were introduced as strategies companies could employ to reduce the environmental impacts associated with their production processes. Like other environmental concepts, ecodesign has evolved to include both the social and economic elements of production and is now referred to Design for Sustainability (D4S). The D4S concept integrates the three pillars of sustainability - people, profit and planet and goes beyond how to make a ‘green’ product and embraces how to meet consumer needs

in a more sustainable way. Companies incorporating D4S in their long-term product innovation strategies strive to alleviate the negative environmental, social, and economic impacts along the product's supply chain and throughout its life-cycle.

Case Study I: Cleaner Production for Better Products (CP4BP) Projects in Vietnam In Vietnam, UNEP is supporting an EC funded project led by the UNIDO UNEP National Cleaner Production Centre, working with companies in targeted export oriented sectors to improve the sustainability of selected products. The project is testing UNEP's D4S approach, developing national capacities and will then work to replicate the results in other sectors and countries. (for more information www.cp4bp.org) New Products and Reuse: Ragbag in India and the Netherlands

Case Study II: The potential in the tourism sector, moving from providing 'a room' to providing 'an experience' Another key application with great potential for change is in the tourism sector. The major assets of a country are its environment and its culture. The global sector has over 1 trillion dollars annual income, employing 230 million people and survey shows that all developing countries rank the tourism sector as having key positive development potential. This sector also has major environmental impacts. It is currently responsible for 5% of climate change emissions, an amount projected to grow. The accommodation sector has a tremendous opportunity to invest in renewable energy and energy efficient solutions that cut operational costs. Research shows that by applying such available technologies, the sector can reduce its carbon footprint by more than 30% with payback periods of less than a year.

Benefits of employing the D4S methodologies in the developing country context were illustrated in the previously presented case studies. As these case studies explored topics from product redesign to radical innovation, the three pillars of sustainability, people, planet, and profit were highlighted. These pillars often complement one another and D4S methodologies aim to address and improve not only the environmental effects but also the social and economic impact of products, systems, and services.

OR 03 A framework for assessing freshwater use within LCA: Results and working progress from the UNEP/SETAC Life Cycle Initiative Project on Water Use in LCA

*M. Margni, P. Arena, E. Aoustin, J.B. Bayart, C. Bulle, R. Juraske, A. Koehler, S. Pfister, F. Vince
CIRAIG, Ecole Polytechnique of Montréal*

Freshwater scarcity is increasingly recognized as a severe problem in many regions all around the globe and will become one of the most pressing environmental challenges of coming decades. Yet, present LCA methods generally do not provide comprehensive assessment schemes and characterization factors for potential environmental impacts caused by freshwater use. They thereby neglect important environmental consequences from the loss in quality and availability of freshwater. The project "Assessment of use and depletion of water resources within the LCA framework" undertaken within the second phase (2007-2010) of the UNEP-SETAC Life Cycle Initiative, addresses this severe methodological deficiency. Building on the previous efforts and recommendations made by the Working Group on Impact Assessment of the UNEP/SETAC Life Cycle Initiative, the present project aims at enhancing the global consensus and relevance of existing and emerging life cycle approaches and methodologies by taking the challenge to develop an operational framework for implementing the assessment of freshwater resources into current LCA practice. Supplying a methodological framework and operational assessment methods as final project deliverables in the next 1.5 years, this project will help to further stipulate the worldwide use of life cycle approaches in decision-making in business, government and the general public.

The presentation will focus on the main developments achieved in the first 1.5 years of the project. A general framework for integrating water resources into LCA is being proposed. The framework includes definitions of relevant freshwater resource types, a description of impact indicators on mid-point and end-point level, the latter reflecting different areas of protection, a set of possible impact pathways, a description of qualitative aspects of the cause-effect chain relationships and a procedure to define which pathways should be followed at which conditions. The assessment framework shall provide recommended guidance for development of LCA methods enabling the modeling of water withdrawal and impact pathways up to the environmental damages as well as the integration of regionalization aspects. The presentation will in particular highlight the impact pathways leading to ecosystem quality impairments and discuss the regional aspects being highly relevant for assessing adverse effects on different types

of ecosystems. The presentation will also provide an overview of the methodological developments and applications (case studies) that are currently pursued within the working group.

**OR 04 The publication of the Code of Practice for a social and socio-economic LCA (sLCA):
The result of an International effort within the Life Cycle Initiative**

*Catherine Benoit and Mazijn Bernard
CIRAIG-UQAM and Ghent University*

A Code of Practice presenting and describing a framework for a social and socio-economic Life Cycle Assessment (sLCA) was recently published by the United Nations Environment Program. This document is the result of 5 years of work accomplished by the members of the Life Cycle Initiative Task force for the integration of social aspects in Life Cycle Assessment. Since 2004, more than 12 meetings, 2 seminars and a workshop were organized to support the development and exchanges between experts in this field. The code of practice represents a major achievement in the life of the task force and in the development of the sLCA methodology. Aiming to promote consensus among practitioners on key methodological issues and to provide a first international reference presenting guidelines for the social and socio-economic impact assessment of product life cycle, this document highlights best practices and future research needs. A social and socio-economic Life Cycle Assessment (sLCA) is a social impact (and potential impact) assessment technique that aims to assess the social and socio-economic aspects of products and their positive and negative impacts along their life cycle encompassing extraction and processing of raw materials; manufacturing; distribution; use; re-use; maintenance; recycling; and final disposal. sLCA complements eLCA with social and socio-economic aspects. It can either be applied on its own or in combination with eLCA and LCC. It is a technique within which methods are being developed for associating company-level information with processes in a life cycle system, and for reporting and possibly bringing together this information across product life cycles.

LCA is conducted following the four phases described in the ISO 14040 standards (goal and scope definition, life cycle inventory analysis, life cycle impact assessment and interpretation). The main specificities of social LCA will be presented phase by phase and illustrated with examples. The task force is also developing a set of key subcategories and indicators. The list of subcategories and the methodological sheets design will be presented and example of indicators, unit of measurement and data sources will be given for a choice of subcategories. The code of practice represents a major achievement in the life of the task force and in the development of the sLCA methodology. Aiming to promote consensus among practitioners on key methodological issues and to provide a first international reference presenting guidelines for the social and socio-economic impact assessment of product life cycle, this document highlights best practices and future research needs. A social and socio-economic Life Cycle Assessment (sLCA) is a social impact (and potential impact) assessment technique that aims to assess the social and socio-economic aspects of products and their positive and negative impacts along their life cycle encompassing extraction and processing of raw materials; manufacturing; distribution; use; re-use; maintenance; recycling; and final disposal. sLCA complements eLCA with social and socio-economic aspects. It can either be applied on its own or in combination with eLCA and LCC. It is a technique within which methods are being developed for associating company-level information with processes in a life cycle system, and for reporting and possibly bringing together this information across product life cycles. LCA is conducted following the four phases described in the ISO 14040 standards (goal and scope definition, life cycle inventory analysis, life cycle impact assessment and interpretation). The main specificities of social LCA will be presented phase by phase and illustrated with examples. The task force is also developing a set of key subcategories and indicators. The list of subcategories and the methodological sheets design will be presented and example of indicators, unit of measurement and data sources will be given for a choice of subcategories.

OR 05 Life Cycle Assessment in developing countries. Cuba case

Elena Rosa Dominguez, Ana M. Contreras*, Nydia Suppen. ***, Mireya Gonzalez ***, Herman Vanlangenhove **, Jo Dewulf **, Ronaldo Santos*, Teresa Cardenas*.
Central University of Las Villas, Cuba*

This work deals with the implementation of Life Cycle Assessment in the developing countries, the fundamental limitations and the possible strategies to achieve the success. The main results obtained in different countries from Latin American are discussed and the development of the LCA networks in each country and their importance for the entire region. An example of application of the methodology is the use of Life Cycle Assessment in Cuba. An analysis of the main sectors, where the methodology has been implemented, is made. The principal industrial sectors are: sugar, foods and electricity generation, as well as the modeling of sites of open-cast, typical disposition of many underdeveloped countries. The main results obtained in each of these sectors are discussed and it is observed that the sugar Industry shows advances in the generalization of the methodology in all productive facilities. The aid offered by experts of developed countries and the cooperation between the developing countries in the region have had a large importance in the obtained results. Several recommendations for future works are offered.

OR 06 New Impact Assessment Method: New Decisions?

*Carmen Alvarado Ascencio
PRé Consultants*

Increasingly more decisions at company and policy level are taken on the basis of LCA results. Often these results are presented in the form of a single score to facilitate the decision making process. Ecoindicator 99 is one of the commonly used impact assessment methods to calculate single scores. The recent release of the new impact assessment Recipe and the increasing interest of companies for limiting the analysis to climate change raise the question of how do all this single scores correlate to each other. Is the relative proportion among the single score of two different materials or life cycles calculated with Ecoindicator 99 still the same if they are calculated with Recipe? In this study more than 400 inventories of Ecoinvent 2.0 were used to calculate single score with Ecoindicator 99, Recipe and IPCC. The single scores were grouped into different categories as plastic materials, metals, electricity, fuels and transport. The correlation of corresponding single scores was analysed for each category. A few outliers were identified. The reasons behind the non fitting of these outliers to the correlations are discussed. In the second part of the analysis a couple of materials which are normally recognized as competitors are analysed. To do this the relative proportion of the values of the single scores for metals and plastics, different sources of electricity and different types of fuels is evaluated for Ecoindicator 99, Recipe and IPCC. As a result this study gives a guideline regarding on which cases the single scores calculated with Ecoindicator 99 and Recipe are not inline; and in which cases climate change scores may not be sufficient to take environmentally sound decisions.

OR 07 Carbon capture and storage: Life cycle assessment and external costs of future fossil power generation

*Christian Bauer, Thomas Heck
Paul Scherrer Institut, Laboratory for Energy Systems Analysis, Switzerland*

Electricity generation based on fossil fuels remains crucial for covering a substantial part of the steadily growing power demand in industrialized countries as well as the rapidly increasing demand of quickly developing economies. An equal installation rate of power plants using renewable or nuclear energy carriers does not seem to be realistic in the short to medium term on a worldwide scale. Therefore, electricity production with Carbon Capture and Storage (CCS) represents a very important option against the increase of atmospheric CO₂ concentration and to mitigate the climate change, while at the same time allowing for the continued use of fossil fuels.

Within the NEEDS project (New Energy Externalities Development for Sustainability) of the European Commission (2004-2008), Life Cycle Assessments (LCA) of power generation systems suitable for Europe were performed. This paper will present environmental life cycle inventories and cumulative LCA results as well as external costs of electricity production for representative hard coal, lignite, and natural gas power technologies with focus on long

term (2025-2050) technology development.

The LCA covers complete energy chains from fuel extraction through storage of CO₂. The power units – pulverized combustion and integrated gasification combined cycle plants for coal as well as natural gas combined cycle technologies – are modeled with and without CCS. The three main technology pathways for CO₂ capture are represented: pre-combustion, post-combustion, and oxyfuel combustion. Transport of CO₂ by pipeline and storage of CO₂ in various geological formations representing the most likely solutions to be implemented in Europe are modeled. Three different scenarios for technology development, from pessimistic to very optimistic, are included in the modeling, covering the range of possible technical progress till 2050. Selected sectors of the used background LCI databaseecoinvent including the European electricity mix are modified for the future time horizons in order to reflect technology advancements in the whole economy.

The LCA results show that adding CCS to fossil power chains, although resulting in a large net decrease of CO₂ emissions per unit of electricity, is likely to produce substantially more greenhouse gas (GHG) emissions than claimed by near-zero emission power plant promoters when the entire energy chain is taken into account, especially for post-combustion capture technologies and hard coal as a fuel. However, a few of the analyzed fossil energy chains with CCS show the potential of achieving GHG emission rates on the level of renewable and nuclear technologies until 2050.

The high energy demand for CO₂ separation and compression at the power plant resulting in lower net power plant efficiencies leads to higher consumption rates of non-renewable fossil fuels. Furthermore, consideration of the full spectrum of environmental burdens besides GHG emissions by application of selected Life Cycle Impact Assessment methods results in a less definite evaluation of energy chains with CCS than obtained by focusing on GHG reduction only. Evaluating the environmental performance of electricity production with CCS by calculation of external costs per unit of electricity shows a benefit of CCS, though sensitive to the monetized damage factor of GHG emissions.

OR 09 Carbon Footprint to support supply chain management

*Antonio Scipioni , Alessandro Manzardo, Tania Boatto, Filippo Zuliani
University of Padova, Italy*

Fight against climate change has been recognized as one of the main challenges for present and future generations. In order to meet consumer needs and to respond to legal prescriptions that have followed the Kyoto Protocol, many Organizations are asked to set concrete programmes of action. In this context the measurement of the impact an organization has on climate change, also called Carbon Footprint, is a tool used to support strategic decisions at organizational level. This study, conducted in 2008, came to the definition of a model to assess, monitor and manage the Carbon Footprint of the supply chain of PALM S.p.A., an Italian firm that produces wooden-pallets. The objective was to get all the supply chain actors involved in the definition of common solution to reduce the Carbon Footprint of the whole supply chain. ISO 14064 standard was considered as the reference to set the monitoring and management system. Within this project three workshop were organized in order to get the different actors of the supply chain (mainly the carriers and raw material suppliers) working together to achieve bigger and profitable results.

To monitor the Carbon Footprint of the supply chain, PALM has developed a green house gas emission management system integrated with its quality management system. The study produced some interesting results. First of all it introduced the Carbon Footprint as a parameter to select suppliers and to design processes in order to minimize the impacts that processes and products have on climate change. Secondly, as one of the workshops outcomes, a short wood supply chain has been created in the region where PALM is located. This solution has created new job opportunities fostering the economic and social local development. Moreover the project outcomes supported PALM in the purchasing of green energy and in the use of the wooden production rejects for energy purpose. These actions entailed immediate economic and environmental advantages. Some limits to the study emerged. Client adherence to the workshop was limited and this influenced the climate change reduction potential. Moreover it was difficult to gather all the data and information to assess the impacts of suppliers. From this experience emerges that Carbon Footprint supply chain management can be a useful tool to support an organization and its supply chain in taking actions to reduce climate change; it support the optimization of resources, and help communication and synergies among the actors of the supply chain.

OR 10 Integrating GHG dynamics in biomass-based products LCA

Anthony Benoist

Ecole des Mines ParisTech - Center for Energy and Processes

Accounting of CO₂ emissions from biomass in Life-Cycle Assessment (LCA) caused and still causes problems: whereas the carbon neutral assumption is still widely stated, a full CO₂ accounting appears as more relevant (Rabl et al., 2007). Furthermore biomass and by extension, living systems imply to aggregate different timescales. Indeed biomass fluxes can be occasional (deforestation), recurrent (savings) or extended (carbon sequestration or emission, from soils or building materials). LCA methodology generally deals with this issue by sharing out all emissions over a given period of time, such as 20 years. This method inherited from industrial equipments integration in LCA lacks relevance for living systems since soils for instance are incompatible with concepts such as lifespan. This work aims at defining a temporal weighting of GreenHouse Gases (GHG) emissions in line with the calculation methodology of IPCC Global Warming Potentials (GWP). The resulting dynamic GWP thus differentiate CO₂, CH₄ and N₂O emissions according to their emission year, and offer a valuable means to assess prospective scenarios and compare phenomena of different timescales. Dynamic GWP can have many applications for LCA. As examples two case studies are considered: a biofuel LCA involving a land-use change, and the definition of a sequestration potential for wood-based materials for buildings. Finally, perspectives of this work are a possible improvement of dynamic GWP calculations, and the integration of dynamic GWP towards dynamic LCA. Indeed since future impact of GHG on global warming depends on future GHG concentration levels, dynamic GWP calculations can be improved by including results from IPCC emission scenarios and climate modelling. Then dynamic GWP principles can be applied to the other impact indicators in order to accomplish a complete dynamic LCA methodology. Rabl A, Benoist A, Dron D, Peuportier B, Spadaro JV, Zoughaib A (2007). How to account for CO₂ emissions from biomass in an LCA. *Int J LCA* 12(5):81

OR 11 Combining Life Cycle Thinking and Carbon Footprinting: Conceptualizing GHG Accounting Within LCA

Sophie Fallaha, Geneviève Martineau, Valérie Bécaert, Louise Deschênes and Réjean Samson

CIRAG / Ecole Polytechnique de Montréal

With life cycle assessment (LCA) still perceived as costly and time-consuming, businesses might be inclined to overlook this tool when implementing their environmental management systems (EMS). However, life cycle thinking is already part of some EMS tools including greenhouse gas (GHG) accounting. This presentation shows a new conceptual approach where corporate GHG accounting could be represented by the annual discretisation of a 3-dimensionnal representation of LCA, focusing on the sole climate change impact category. To build this approach, the enterprise is first viewed as a part of a logistic chain including upstream suppliers and producers as well as downstream end-of-life managers. The enterprise's life cycle (meaning its logistic chain), is pictured as the first dimension of the 3-D LCA's representation, the X-axis. The second dimension of the conceptual approach, the Y-axis, represents the impact assessment. It is fed with the inventory data translated into impacts by means of characterization factors. The Z-axis, and third dimension, is the time dimension. Here, opposing LCA traditional point of view, the inventory is visualized dynamically but accounted for annually. On the other hand, GHG accounting divides the enterprise's annual emissions into three scopes, according to the GHG Corporate Protocol: direct GHG emissions (scope 1), indirect emissions related to energy production (scope 2) and other indirect emissions (scope 3). Then, GHG accounting is positionned towards each axis. On its X-axis, the scoping categorization of the enterprise's emissions refers to the emissions coming from the different actors of the logistic chain. On the Y-axis, GHG accounting's limited inventory is translated by means of emission factors in the sole climate change impact category. Finally, on the Z-axis, as GHG accounting is following an annual accounting procedure, the said inventory is referring to a one year time period.

In order to validate this approach, a case study was conducted, comparing the two kinds of analyses: GHG accounting and LCA. First, GHGs were accounted for the three scopes. Second, LCA was conducted over the same system boundaries and structured into a comparable framework: each LCA process was de-aggregated into the same three scopes. Focusing on the climate change impact category, the results showed a very good consistency

between LCA and GHG accounting for the direct emissions (scope 1) as well as the indirect emissions related to electricity production (scope 2). The importance of the scope 3 emissions was also highlighted. The widening of the impact analysis from climate change to all 14 impact categories considered by the impact 2002+ method, showed that only climate change analysis was not always enough to get a good picture of overall environmental impacts. In fact, the nature of the activity undertaken by the enterprise, could shift the impact toward other impact categories. The results showed that GHG accounting can be considered as embedded within LCA. Moreover, the environmental information gained with the re-deployment of GHG accounting within life cycle thinking framework would lead businesses towards more comprehensive EMS.

OR 12 Material flow and stock analysis and LCI analysis on forest products in Japan

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In this study, material flow and CO₂ emissions associated with the life cycle of forest products in Japan were investigated. First, material flows and stocks of wood products in Japan were analyzed, in which intermediates (lumber, laminated wood and lumber, wooden board, wood chip, and pulp) and final products (buildings, construction, furniture and fixtures, pallet, and paper) were taken into account. The amount of carbon stock in buildings in Japan was estimated as 450 million t-C, which is larger than the total Japanese emissions of CO₂ in the year 2005, 350 million t-C. Second, energy consumptions were quantified for every process associated with the life cycle of forest products. The energy consumptions in major industries were obtained from official statistics, and those in other processes were estimated by using data on Japanese Economic input-output tables. CO₂ emissions were calculated based on the energy consumption. In actual, the emissions in the processes of buildings and construction were mainly caused by other materials than forest resources. Therefore, the CO₂ emissions in the processes were allocated by masses or prices of consumed materials. CO₂ emissions for waste management processes, e.g. mechanical recycling, feedstock recycling, energy recovery, incineration, and landfill were analyzed, as well. Especially, feedstock recycling in blast furnaces was analyzed with Rist model and matrix approach. The Rist model is a model to analyze inputs and outputs of blast furnace process based on the mass balances for carbon, oxygen and hydrogen, and the heat balance in the blast furnace. The matrix approach is effective when dealing with several processes, some of which are self-referring groups of processes, because the exact solution can be calculated for the system without using the iterative method or infinite progression.

It was found that 59% of CO₂ emissions in production of forest products were attributable to paper and pulp production in the year 2000. The share of furniture production, timber production, and chip board production were 11%, 10%, and 10%, respectively. Finally, substitution effect of forest products on CO₂ emissions was estimated. One of major end uses of the forest products is buildings. We assumed that 10 % of non-wooden dwelling; e.g., steel framed dwelling, reinforced concrete dwelling, and etc., was substituted by wooden dwelling based on the floor area. General equilibrium model was applied for the estimation with Japanese Economic input-output table which has five sectors related to buildings; residential construction (wooden), residential construction (non-wooden), non-residential construction (wooden), non-residential construction (non-wooden), and repair of construction. We estimated the change of production associated with increase of residential construction (wooden) and decrease of residential construction (non-wooden). Furthermore, a ripple effect caused by the change of incomes in the two sectors was also estimated. The total of the substitution effect results in reduction of about 250 thousand tons of CO₂ emissions.

OR 13 Analysis of CO₂ emissions from daily life and consideration of the low carbon daily activities in Japan

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Due to the increasing public awareness of global warming, most consumers want to live their lives with low CO₂ emissions. In order to encourage them, many institutes have been publishing household eco-account books.

However, most of them only focus on “direct CO₂ emissions”, which represent residential electric power / city gas consumption, fuel consumption of private cars and disposal of municipal solid wastes. The direct CO₂ emissions from Japanese households amount to approximately 6 kg per day per capita. Because of their staggering size, the Ministry of the Environment of Japan is now promoting the “I declare CO₂ reduction of 1 kg 1 day 1 person” movement. From the viewpoint of LCA, the rest of the emissions are also attributed to households. Considering meals, emissions by use of city gas and hot water for cooking, and by use of gasoline for shopping by car are included in direct CO₂ emissions. On the other hand, lighting and freezing at grocery stores, food transport as well as cultivation and fertilizing in the agricultural industry are also attributable to households. These induced emissions are called “indirect CO₂ emissions”.

In this study, we focus on and analyze both the direct and indirect CO₂ emissions from households. Through analyzing these CO₂ emissions, we propose low CO₂ emitting activities that have not been proposed by the “I declare CO₂ reduction of 1 kg 1 day 1 person” movement, and truly reduce CO₂ emissions from consumers’ lives. Firstly, we analyze domestic CO₂ emissions to understand what kind of final demands induces large direct and indirect CO₂ emissions. This analysis is based on Japanese Input-Output Tables (I-O table) and CO₂ emission intensity according to the industrial sector. We find that the direct CO₂ emissions are about 6 kg per day per capita, but the indirect ones are over 7 kg per day per capita. The indirect CO₂ emissions from households are larger than the direct ones and cannot be neglected when proposing the low carbon daily activities in Japan.

Secondly, we examine two types of household income and expenditure surveys for our analysis. From the statistics we find that the indirect CO₂ emissions still account for half of household ones, and “food” and “reading / recreation” are particularly a large part among them. The individual data on the survey tell us that the standard deviation of “reading / recreation”, “housing”, “food”, and “gasoline” vary greatly among families which consist of the same number of persons. There would be a large potential for CO₂ emission reduction in the items which have so far been unnoticed. Thus, we analyze CO₂ emissions mainly in “reading / recreation”, “housing”, and “food”, and have investigated how we can achieve low carbon lives in Japan.

OR 14 Carbon footprint analysis supporting environmental communication with customers: Case of Agfa Graphics printing plate systems

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Agfa accepts responsibility for its products and supports the international Responsible Care initiative, a voluntary program drawn up by the Chemical Industry. Product Stewardship is one of Agfa’s corporate commitments. It is ‘Responsible Care’ applied to products, in other words, accepting responsibility for one’s products by critically examining the environmental and safety issues throughout each stage of the product’s life cycle. Agfa’s Environmental life cycle management is the application of life cycle thinking to modern business practice, with the aim to manage the total life cycle of its products and services towards more sustainable consumption and production.

During the past years Agfa-Graphics cooperated with VITO for studying the environmental aspects of their products. This was analyzed by VITO using the life cycle assessment methodology (LCA). This cooperation resulted in different projects which are closely related to the state-of-affairs of Agfa-Graphics’ product development. The company is particularly interested in analyzing the environmental aspects of newly developed products compared to existing products. It is not Agfa-Graphics’ intention to compare own products with competing products, their only interest is to monitor the environmental impact of their own products. The LCA-studies are focused on quantifying the environmental impacts in the evolution from computer-to-film (CTF) systems into computer-to-plate (CTP) systems and recently into chemistry-free plate systems. In the presentation we will focus on the process, more specific the life cycle inventory and methodology, and on the results of the product carbon footprint analysis that we perform at this moment in close consultation with Agfa-Graphics for their most important printing plate systems. By means of this LCA-based carbon footprint analysis Agfa-Graphics wishes to gain insight in the carbon footprint of 8 Agfa plate systems. This way Agfa-Graphics wants to communicate their products’ environmental information to their clients.

So the main reasons for carrying out this study are: getting respective information about the carbon footprint of the plate systems, performed by an independent assessor and based upon an internationally accepted assessment methodology; to develop and implement concepts to improve the performance of their computer-to-plate systems with regard to environmental performance; set Agfa-Gevaert in position to answer customer questions with respect to the carbon footprint of Agfa-Gevaert plate systems.

One of the objectives of the presentation is to discuss bottlenecks that LCA-experts and companies run into when gathering information to assess the environmental impacts in general and more specific the carbon footprint of products. Moreover attention will be paid to the opportunities that carbon footprint analyses and LCA-studies in general offer to companies with regard to communication with customers and stakeholders.

OR 15 An investigation into a method to quantify the external social footprint of Procter & Gamble's operations in South Africa

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Businesses have made great strides in measuring their ecological footprints, but very few have measured their social footprints. Businesses need to understand and know the social impact that they have on the societies that they operate in, even more so in developing countries, so as to enhance and improve them, since business can only prosper and flourish if it is part of healthy, stable communities. The concepts of sustainability and sustainable development may be understood intuitively, but they remain difficult to express in concrete, operational terms. The social dimension is commonly recognised as the 'weakest pillar' of sustainable development, due to a lack of analytical and theoretical underpinnings in this aspect of sustainable development. The Global Reporting Initiative provides no specific guidance on how to include social sustainability in context, hence the reports based on the GRI framework are at best top-line trend or efficiency reports, some of which are often perceived as little more than 'green washing'. During 2008, the World Business Council for Sustainable Development (WBCSD) launched its Measuring Impact Framework. However, the means to assess the actual social impacts of corporate action remains a shortcoming, i.e. the degree to which corporate social responsibility (CSR) initiatives actual advance corporates toward true sustainability. The study summarised in this paper set out to establish a concrete method by which the social footprint of Procter & Gamble's operations may be measured. Recommendations are made to advance the method further as part of the normal business practices of Procter & Gamble.

OR 16 Bringing an LCM imperative to strategic planning in the resources sector

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Strategic planning in the resource sector continues to be dominated by "least cost" dynamic optimization approaches over reasonably short time frames, where other sustainability arguments relating to environmental stewardship, social acceptability and governance issues tend to be considered only as system constraints, if at all. The argument given for this approach is that the "problem" is simply too complex, and inherent uncertainty too great, to do otherwise. Consequently, strategic planning tends to follow a "top down" approach, where decision making is assumed to be the prerogative of a single or dominant entity (such as government rolling out relevant policy), and where all entities involved will work collectively to achieve the stated strategic goals. Life cycle management (LCM), however, purports to engage all role players in a value chain around all sustainability arguments, in order to ensure that decision making advances sustainability goals. As such, LCM allows for distributed decision making, involving multiple objectives and multiple stakeholders. The extent to which LCM is able to achieve its stated aims tends to be a function of alignment between management goals and practices of the various role players in a value chain.

This paper poses the question of how strategic planning in the resources sector should change to accommodate an LCM imperative, given that planning is effectively decoupled from management practice. At the same time,

it asks how LCM should evolve to better accommodate the complexity of the resources sector, over longer term strategic planning horizons. In particular, consideration is given to how role players in the sector can better manage transitions (eg. from a dependence on fossil energy to renewable energy); engage with multi-scale elements of the problem (e.g. different decision objectives manifesting over different spatial scales, as in concerns over local pollution versus climate change impacts); and accommodate uncertainty (eg. that relating to the influence of exogenous variables). Critical to this discussion is the need to consider sustainability goals for the system under consideration as dynamic equilibria characterized by robustness and adaptability. Examples from the minerals and energy sectors are used to support the arguments developed in this paper. Some general comments are offered on implications for the LCM of material value chains dominated by primary minerals extraction and fossil energy generation.

OR 17 Consumer acceptance of CO₂ reductive choices in shopping and improvement potential of supporting information

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CO₂ reduction is highly prioritized in the whole world from the viewpoint of preventing global warming and climate change. Even though there is a responsibility for Japan to diminish CO₂ emission compared to the level of 1995, the amount of emitted CO₂ has been steadily increasing in recent years. Especially, emissions related to daily activities seem to be one of the main sources for the increase. In order to reduce CO₂ emissions related to daily activities, individual citizens should consciously attempt to save energy use related to their daily activities. According to our previous research, it was found out that CO₂ emission related to shopping seemed to be no small part of life cycle CO₂ of food stuffs, accounted as around 23% of total emission. Furthermore, there seemed to be large CO₂ reduction potential related to shopping by sifting on-site shopping to delivery system. The previous study showed clear advantage of delivery system in CO₂ reduction, however there might be still hesitation for some consumers to buy goods through delivery system. In this study, questionnaire survey and conjoint analysis were conducted in order to quantify values of consumers on three parameters, the way of shopping (on-site shopping and delivery system), time for shopping and CO₂ reduction per a shopping. Furthermore, the provision of environmental information may promote environmental concerns of citizens and lead to make actions for preventing the increase of emissions. So, the effects of supporting information, which may help consumers to understand the meaning and importance of CO₂ reduction, on consumer evaluation of each parameter were also analyzed.

As a result, it could be found that consumers preferred to on-site shopping, and additional value of on-site shopping compared to delivery system was calculated as marginal willingness to pay (MWTP), around 203 (JPY: Japanese Yen), nearly equal to 1.7 (EUR). Consumers evaluated time saving as almost 30 (JPY/10min), and CO₂ reduction as about 33 (JPY/kg-CO₂). Furthermore, evaluations of each parameter differed to attributes of consumers (gender, age, marriage and so on). In addition, WTP increased by the provision of supporting information about the effects of daily CO₂ reductive activities like "Shorten the time spent in the shower by 1 minutes a day" and "Turn off the main power on my appliances and save standby energy". For consumers, such familiar activities seem to be helpful to understand the meaning and effectiveness of CO₂ reduction. Consumers tend to prefer on-site shopping compared to delivery system. However, there may be possibility to promote consumers to choose delivery system by providing data of CO₂ reduction potential and supporting information to understand the meanings. The results and conclusions of this study can be helpful for leading consumers to more CO₂ reductive activities and will be useful for improving the effects of carbon-footprint and carbon labeling of products.

OR 18 A framework for evaluating different evolutionary pathways of industrial networks

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Life cycle approaches recognise that although activities on an organisational level can improve the sustainability performance of an individual firm, the ultimate impact on the planet depends on the sequence of activities taking

place in and between large networks of organisations operating from cradle to grave. However, little attention has been given to the dynamic features of these industrial networks. The invention of new products and processes, the availability of new or cheaper resource, changing customer preferences and internal or external shocks and shifts affect the structure of these networks and therefore their functional performance over time. Furthermore, the structure of the industrial network is not only determined by which organisations are directly or indirectly connected, but also by feedback loops that exist between different organisations, the actions and potential responses of organizations operating outside these networks as well as information and options that are available to the individual organisations. These dynamics lead to industrial networks that are constantly evolving through the actions and interactions of the organisations involved. This evolutionary process is not homogenous, but evolves through different stages of growth and decline, which are both necessary for successful system evolution (Jovanovic 1982; Holling 2001:395). As such, it is insufficient to assess the sustainable development of an industrial network solely on the basis of its function. Instead, it is argued here that four characteristics need to be considered to evaluate the sustainable development of industrial networks:

1. the function of the network is an emergent property of contributions of the individual organisations within the network,
2. the structure of the network is determined by the relationships between the organisations and the infrastructures within the network,
3. the network operates within a larger context which is constantly changing and affecting the function of the industrial network and
4. the strategic decision making processes of organisations within the network constantly change the function and structure of the network.

This paper presents a framework for evaluating the dynamic performance of industrial networks in terms of sustainable development. First, a life cycle approach has been adopted to explore the consequences of an industrial network to the larger socio-economic and biophysical system in which the network operates. Subsequently, a set of structural indicators has been proposed to evaluate the dynamic performance of industrial networks. These four structural indicators reflect the efficiency, effectiveness, resilience and adaptiveness of industrial networks. Efficiency and effectiveness relate to the operational features by which industrial networks provides a particular contribution to society. Resilience and adaptiveness relate to the system's capacity to maintain or adapt its contribution to society while under stress of temporary shocks or permanent shifts, respectively. Finally, different multi-criteria decision analysis (MCDA) tools have been applied to provide a holistic evaluation of sustainable development of industrial networks. The framework is demonstrated by evaluating a number of different evolutionary pathways for a bioenergy network in the province of Kwazulu-Natal in South Africa.

OR 19 Extending System Boundaries to Capture Indirect Effects on LCA - An Enlightening Example!

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Based on a comparative LCA on light bulbs - incandescent vs. fluorescent - in a Quebecker context, this paper will discuss the importance of properly setting the system boundaries in LCA and its importance for decision making in an energy supply context. Results for three different system boundary levels are presented and discussed in relationship with their capabilities to capture direct, indirect and avoided impacts, respectively. The first boundary level includes all the unit processes required to deliver between 500 and 900 lumens during 10'000 hours (functional unit), i.e. the light bulbs production, distribution, use phase and end-of-life. Results show that fluorescent light bulbs generate 3 to 5 times less impacts compared to the incandescent one on all damage indicators, the use phase being the larger contributor in both systems. Such conclusions, as previously obtained by supposing an electricity production 100 % from coal, are thus also available in a context where the electricity production mix is instead principally based on hydropower. When considering that light bulbs are used indoor, e.g. in households, one should consider the side effects (or indirect impacts) of the heat generated from the light bulbs on the heating system. The system boundary has therefore to be extended including the generated heat as a co-product in winter

season (or eventually a waste to be treated by additional air conditioning in summer). The best lighting option will then strongly depend on the application context. The longer the winter the more important are the side effects of the heat generated. The solution to favour depends therefore on the electricity production mix, as well as the type and the efficiency of the heating system. Typically, the incandescent light bulb is to be favoured when it replaces fossil energy used by the heating system by a renewable electricity (e.g. hydropower). Finally, depending on the type of decision this comparative LCA is aimed to, the system boundary could/should be further expanded to assess the environmental benefits (or avoided impacts) generated by the energy saved, and used elsewhere, when substituting the incandescent light bulb. The results of this study demonstrated that the final answer again depends on which is the marginal electricity production technology. A discussion between short-, mid- and long-term marginal technologies is made in a Quebec context to illustrate the importance of the system boundary setting in a decision-making context.

OR 20 LCA as an accompanying and decision tool in production of biodiesel from waste cooking oils: an industrial perspective.

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The perspective of climate change, rising energy prices and oil supplies depletion has driven a strong interest in alternative transportation fuels. Yet, the social and environmental impacts of first-generation biofuels from energy crops (ex: competition on cultivated areas between food and energy crops, water consumption) remain widely discussed. Biodiesel from waste could therefore provide a relevant alternative. By converting waste cooking oils (WCO) into biodiesel, VEOLIA ENVIRONNEMENT has created a new French biofuel production chain, that relies on the synergy between VEOLIA core competences to create an integrated value chain: waste management and green transportation services. This biofuel production is forecasted to represent 3 to 5% of the French biodiesel production in 2010. Moreover, the glycerol (coproduct of the WCO esterification step) is used as a substitution chemical of the methanol traditionally used for fermentation in VEOLIA's wastewater treatment plants. While still at a planning stage (pilot project supported by the French governmental agency of environment), the environmental performances of this biofuel have been evaluated through an ISO 14040 LCA and compared to diesel and biodiesel from rapeseed. The LCA results showed that WCO as a resource for biodiesel production has a far less controversial environmental balance compared to diesel and biodiesel from rapeseed. The energetic payback time is improved: biodiesel from WCO provides 19 to 25 times the energy needed for its production instead of 4 for biodiesel from rapeseed. It also saves GHG emissions: one litre of biodiesel from WCO avoids 3 kg of CO₂ eq. compared to diesel. Damages on human health and quality of ecosystems are also reduced compared to other fuels (by about 10%). This presentation will provide extensive LCA results on the use of WCO-biodiesel for transportation. It will show its environmental advantages as compared to diesel and biodiesel from crops in the perspective of ecocertification of biofuels provided by the European Directive on Renewable Energies (2008).

OR 21 The sustainability assessment of bioenergy in the UK: participatory policy-making and the use of "narratives"

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The recent UK Energy White Paper and Renewable Energy Strategy identify bioenergy as an important means of meeting the Government's energy and environment objectives, including energy security and the reduction of greenhouse gas (GHG) emissions. In particular, the Strategy indicates that bioenergy will need to be a major contributor to the renewable energy mix by 2020 if EU renewable energy targets are to be met. However, attempts by the UK Government to stimulate the bioenergy sector have so far had limited success. The consortium project TSEC-BioSys was created with a broad remit, to carry out sustainability assessment on multiple scales with a view to providing information to policy-makers and other participants on an ongoing basis.

Developing policy for sustainable development often requires stakeholders to engage with complex issues which

lie outside their common concerns and experience. In this presentation we shall describe and evaluate a two-day workshop designed to develop relevant information on bioenergy for those in UK policy circles. The workshop focus was on the economic, environmental and social effects of UK bioenergy policy in the present and to the year 2050. The participants were drawn from all sectors concerned with the industry and included commercial stakeholders, experts, public policy-makers and public interest groups. They were therefore suitable for taking part in an integrated exploration of environmental life cycle and economic supply chain management. The workshop was informed by “narratives” about the current state of the UK bioenergy sector, recently developed and evaluated within TSEC-BioSys. It involved deliberation in small and larger groups, and presentations on the attributes of the UK bioenergy system and likely scenarios as well as the development of objectives and criteria for the siting of a small Combined Heat and Power plant on a proposed housing development in the South East of England. Evaluations of the workshop will be presented regarding methods employed, recommendations and subsequent developments in policy, with an evaluation of the “narratives” approach in general.

OR 22 Key environmental issues in the agro-food sector. A case study for citrus based products in the Italian context

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As a result of intensive development and the changing social attitudes and behaviors in the last century, the agro-food sector is the highest resource consumer after housing in the EU. From recent studies the agro-food sector emerges as one of the main contributors to the energy consumption and thus to GWP, accounting for about 20% of the total EU fossil fuels consumption. In the recent years the intensification of agricultural practices has substantially increased fertilizers use, which involves a significant contribution to GWP, and freshwater consumption which globally accounts for about 70% of the total water use in the EU.

In this paper the authors present the results of a LCA applied to Italian citrus-based products (essential oil, natural juice and concentrated juice from oranges and lemons). In particular, the study was focused on an Italian company, and the eco-profiles of six citrus-based products were developed, identifying hot-spots in terms of energy consumptions, associated CO₂ emissions and water consumption. The analysis was developed according to the LCA standards of the ISO 14040 series. The related process flow charts, the relevant mass and energy flows and the key environmental issues were identified for each assessed product in the following phases: production and delivery of raw materials and fuels, cultivation and crop of lemons and oranges, manufacturing process of the citrus-derived products, transportation during each step.

Depending on the outcomes of the life cycle impact assessment for each product, particular attention was paid on key issues, such as primary energy consumption, water exploitation and fertilizers use in agricultural activities. Cumulative Energy Demand (CED) was valued as primary energy arising along every FU life cycle. It was mostly due to the fertilizers and fuels used in the cultivation step, to the electricity consumption in the essential oil manufacturing step and to the consumption of methane in the juice pasteurization and concentration steps. Water consumption resulted a critical issue. Direct consumption was mostly due to the citrus cultivation rather than during the processing, but noteworthy was the significant contribution of the water eco-profile in the total resource consumption.

Hence, an improvement analysis was carried out, whereby sustainable scenarios of water and energy saving were proposed to reduce environmental burdens of the examined production system. Further, a sensitivity analysis for estimating the effects of the chosen methods and initial data on the outcomes of the study was performed.

OR 23 A Sector-Based Approach To Carbon Management for the Primary Agricultural Sector In New Zealand

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Popularisation of the Food Miles concept and subsequent development of the PAS 2050 - with associated implications for non-tariff trade barriers – has focused peoples' attention in New Zealand on the topic of carbon footprinting and labelling. More than half of New Zealand's exports by financial value are agricultural products and these products are exported to countries all over the world. Therefore the New Zealand primary production sector has taken a keen interest in this area. In particular, the government has initiated a strategy on greenhouse gas (GHG) footprinting for the land-based primary sectors (under the Sustainable Land Management and Climate Change Plan of Action). A key part of this strategy is development of sector-specific approaches to GHG footprinting and management. A sector-based approach has a number of advantages, including:

1. It is more cost-effective than undertaking individual life cycle carbon footprints for each enterprise (for example, different growers).
2. It enables calculation of a carbon footprint for the product at the individual enterprise level or at a brand owner level (where the product has been consolidated from many enterprises), depending on the way in which it is sold to consumers.
3. A common data collection and accounting system across different enterprises enables benchmarking on the basis of consistent measurement, a recognised technique for driving change in a sector.

This approach is being pioneered by Zespri in New Zealand for the kiwifruit sector. The initial kiwifruit carbon footprinting project was financed by MAF, Zespri and a government-funded research project, and undertaken by Landcare Research (a Crown Research Institute). A scoping life cycle study was undertaken to determine an illustrative carbon footprint for kiwifruit from production through to final consumption in Europe, identifying hotspots in the life cycle. This has shown that the orchard production and storage life cycle stages make a significant contribution to the overall carbon footprint alongside shipping, distribution in Europe, and transport for home consumption. Alongside the scoping study, an Organisational Plus approach has been developed for managing the carbon footprint of sector-specific products such as Zespri branded kiwifruit. For kiwifruit, the approach involves a carbon accounting and management system that is managed at the brand owner level (i.e. Zespri). Individual enterprises at the grower and storage life cycle stages of the supply chain complete organisational GHG emissions inventories, supplemented by measurement of specified sector-specific emissions sources that are relevant from a product GHG inventory perspective. Modelling of the generic downstream distribution, retail and consumer life cycle stages is undertaken by the brand owner. The individual enterprises benefit from understanding and managing their own organisational inventories. At the same time, the brand owner can build the product GHG inventory knowing that all the relevant enterprises have been measured consistently and that all emissions sources material to the product have been included. Furthermore, this system provides a mechanism for driving continuous improvement in the sector by identifying hotspots for individual enterprises, and benchmarking enterprises within each of the orchard production and storage life cycle stages.

OR 24 How to cope best with field emissions of nitrate in a food LCA?

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When performing a LCA of food products and biofuels the question about how to quantify direct field emissions arises. Since the agricultural production phase is crucial for eutrophication for example, the selection of an appropriate model for calculating direct field emissions of nitrate is an important task for LCA-researchers. The aim of this presentation is to break the deadlock: we discuss possible ap-proaches to determine nitrate leaching in an LCA and compare their performance from the point of view of scientific soundness, user friendliness and usefulness. LCA practitioners urge to have one single approach for the whole world. We tried to satisfy this de-mand when contributing to a sustainability quick check tool for biofuels (Faist et al. 2009). For such a rapid assessment, a

regression model based on field experiments can be applied. Yet the advantage of readily available input parameters is counterbalanced by the limited accuracy of this approach outside of the limits the model has been developed for. The user-friendly approach deployed in Ecoinvent Report No 17 (Jungbluth et al. 2007) for crops like palm, is to determine nitrate leaching based on emission factors. But the general assumption of an emission factor of 30% of fertiliser input for arable crops is somewhat arbitrary and has the enormous disadvantage of neglecting effects of crop rotation, soil, fertilizer characteristics and other relevant parameters. It does not allow a comparison of different cultivation practices and improvement options limiting leaching. On the other extreme of the scale, simulation models may consider all relevant parameters and lead to accurate results but require time consuming data collections and are still only valid for the region and crop types, they have been developed for. Cranfield University (www.agrilca.org) shows how they can be used in an LCA-context: Coefficients derived from long-term simulations with the model SUNDIAL are used in conjunction with crop husbandry data and allow the prediction of nitrate leaching for a given input of N. Yet for each crop rotation, soil type and rain regime new simulations are necessary. Our mechanistic model SALCA-NO₃ is tested for use in central Europe and requires only well accessible data. This model, based on an input-output balance, includes crops and vegetables and accounts for mineral and organic fertilising, soil characteristics and related mineralization rates. Further-more the underlying N uptake curves are modelled with the N model STICS. The leaching rate of mineral nitrogen is based on expert knowledge. Detailed analyses of the agricultural processes are possible because whole crop rotations including improvement options can be modelled. This analysis shows that a single accurate approach for the world does not exist since the variation of relevant parameters is large. The approach has to be adapted to given questions and the available data. Criteria for selection will be shown.

OR 25 Eco-Standardization of Frozen Vegetable and Fruits Industries in Chiang Mai Province

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With Thailand's tropical climate, a wide variety of fresh fruits and vegetables are available all year round. The abundance of fresh product provides a tremendous opportunity for the country to export its fruits and vegetables to other countries which constitute an important part of diets in cold climate countries during cold season. Therefore, Thailand has become a significant source of fresh and frozen fruits and vegetables around the world. It is expected that the frozen vegetables and fruits can respond to a new trend of health-conscious consumers. Also, non-GMO products can increasingly penetrate European and Japanese markets. Especially, the economies of Asian countries like China and Vietnam, the important markets for frozen fruits and vegetable, and demand is expanding. However, the production and consumption culture is changing. The increasing of the global problems, such as pollution and waste problems, high energy consumption and so on, are now of interest. Therefore, the energy and environmental management are needed in order to promote and demonstrate the good practice for the frozen fruit and vegetable industries.

The study focuses on the Eco-Standardization of frozen vegetable and fruit industries in Chiang Mai province, in the northern part of Thailand. The objectives of the study are to make awareness of environmental impact of the industry and to improve the efficiency in the energy and material consumption. The standard requirements were then applied to 6 voluntary factories, covering 4 significant issues, i.e., energy and environmental policies, good agricultural practice, energy and material consumption, waste management and corporate social responsibility. As the results, the improvements were implemented to each voluntary. This leads to a more environmentally friendly outcome and hence leads to a more sustainable society.

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Thousands of goods need to be transported from producers to consumers every day. Packaging systems play an essential part in the logistic chain. For packaging fruit or vegetables, wooden boxes, cardboard boxes and plastic crates are most commonly used. While the first two are non-returnable packaging systems and are normally disposed of or partly recycled after one use, plastic crates generally are returnable and therefore washed and reused several times. An analysis of the individual ecological, economical and social performance of these packaging options over their lifetime and life-cycles is carried out in order to identify the performances of the regarded systems according to the boundary conditions selected. Concurrently, optimisation potentials to further reduce the impacts of the packaging systems are identified. For all three systems, production, transport, use / reuse and end-of-life are considered. By addressing ecological, economic and social effects of a system an approach to an LCA-based sustainability assessment in its broadest sense is presented. Contrary to “one-point studies”, which consider fixed sets of boundary conditions and situations, in this study a representative base case is chosen and assessed using the GaBi 4 software system. Data used are primary industry data completed by data taken from the GaBi databases 2006.

A Life Cycle Assessment (LCA) according to the ISO standards 14040 and 14044 is conducted to analyse and assess the environmental effects of the regarded systems using CML indicators for Eutrophication, Ozone Depletion, Global Warming, Summer Smog and Acidification. Additionally, the Primary Energy Consumption is considered. The environmental part of the study was critically reviewed by an external review panel in line with the already mentioned ISO standards. Costs are considered by performing Life Cycle Costing (LCC) for one-way compared to multi-way systems within the same system boundaries.

Social aspects are assessed using the method of Life Cycle Working Environment (LCWE). This method provides an approach to integrate social aspects related to the working environment of a life cycle. Social indicators are used in a way that permits the aggregation of the data following the Life Cycle of the product considered. LCWE indicators dealt with in this study are

- Human labour (amount of working seconds per product), distinguishing male and female work
- Qualification level of labour
- Lethal and non-lethal accidents

The results of the study show the cardboard box option to be the one with the highest environmental impacts for all impact categories considered. Contrarily, the plastic crates system as the returnable packaging option shows the lowest impacts in terms of environment and LCWE aspects and is the most cost-effective of the three options. Optimisation potentials are identified related to the lifetime of the plastic crates, the dimensioning of the cardboard boxes and the transport distance of the raw material for the wooden boxes. As a conclusion, without trying to cover the issue exhaustively, this study shows an approach to measure and assess sustainability in a structured and methodological way and thus contributes to the scientific and societal discussion in this field.

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The impending steep greenhouse gas reduction challenges necessitate huge efforts to reduce direct and implied emissions arising of private consumption. From a household point of view food chain constitutes one of the largest causes of greenhouse gas emissions in EU countries, with mobility and residential energy use. Furthermore, one third of environmental impacts of private consumption are due to eating based on Finnish ‘Eco-Benchmark’ and environmentally extended IO tables. In contrast to mobility and residential energy use the greenhouse gas

emission from food production and consumption are much less obvious to the consumer. Life cycle assessment studies of food products and diets have clearly shown that differences of environmental impacts between different food products are tremendous, and that different products affect in different environmental problems, which is highlighted in this paper as well.

Life cycle assessment (LCA), in communication of environmental impacts of different food products in the context of sustainable consumption, is challenging due to the need of understandable and meaningful results for citizens. The results obtained in recent Finnish Foodchain LCA studies made possible to compare magnitudes of environmental impacts of different foodstuff. LCA case studies were carried out by using similar methodology and system boundaries: all stages from the production of farm inputs to retail stores were included as well as cooking. Results were presented by the environmental impact categories and also aggregated based on the methodology behind the Finnish 'Eco-Benchmark' (EB). In the LCIA phase, site-dependent characterization factors were used for aquatic eutrophication and acidification. Other environmental impact categories included in the EB were primary energy demand, global warming potential and tropospheric ozone formation.

Carbon footprint of certain particular Finnish hard cheese is 13,0 kg CO₂-eq/kg cheese, corresponding approximately driving of 60 kilometers (8 l/100 km). Carbon footprint of marinated chicken product and cucumber (per kg) are under one third of that. Carbon footprints of beer and oat cereals are very small. Based on the aggregation of mentioned environmental impacts, impacts of cheese gets even more bigger compared to other products. Furthermore, environmental impacts of chicken product are double against cucumber (per kg).

Based on the aggregation of these environmental impacts and daily intake quantities, the daily consumption of cheese (30g/day/person) creates ten times as much environmental impacts as the daily consumption of cucumber (22 g), marinated broiler chicken meat (40 g) two times more compared to the rye bread (83 g), and cheese three times as much as marinated broiler chicken meat. The contribution of different food products to the environmental impacts of Finnish private consumption, based on the methodology behind the Finnish 'Eco-Benchmark' (EB) and Finnish IO tables will also be presented.

OR28 Literature review on dairy products for an inventory of key issues: List of environmental initiatives and influences on the dairy sector

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This project aimed to highlight key issues in the dairy sector based on a literature review focused on Life Cycle Assessment (LCA) studies. This study provides a statistical analysis and therefore results are not only based on deterministic values. It also aimed to give an overview of initiatives and labels that play a role in the dairy sector and their implications for various stakeholders. Key issues have been identified based on 60 scientific articles, research reports and theses. Most of the studies are written with a European context, with some for New Zealand, Australia and USA situations. They give information on the different phases of dairy products life cycles: dairy farm, packaging, distribution, retail, use phase and end-of-life. The indicators considered for this literature review are climate change, resources (energy and water), aquatic acidification and eutrophication. The system studied considers the dairy farm (fodder production, cow raising, milking, refrigeration on farm), the packaging, the dairy (processes for production of various dairy products), the distribution (transport and retailers), the use phase (refrigeration but not cooking), and the end-of-life.

The results obtained show that the dairy farm is the most significant phase for all impact categories and all dairy products examined here. For greenhouse gas (GHG) emissions, the dairy farm contributes more than 80% of the impacts for milk and more than 90% for cheese. Among these emissions, about 50% are due to methane (CH₄) emissions from enteric fermentation. About onethird are due to nitrous oxide (N₂O) emissions, mainly from manure management and nitrous fertilizers. The final one-sixth is due to carbon dioxide (CO₂), coming from tractors, trucks and electricity production. Among the non-farming phases, those of most importance for GHG emissions are the dairy and packaging production. One kg of milk at the farm emits approximately 1 kg CO₂e (GWP100). The rest of the life cycle (i.e., at consumer, including end-of-life of the packaging) adds 0.2 kg CO₂e per kg milk. The full (averaged) results (GHG emissions, energy consumption, water use, etc.) will be presented for milk, cheese (8.8

kgCO₂e/kg and 41 MJ/kg), yogurt (12 MJ/kg), cream (19 MJ/kg), butter (42 MJ/kg) and milk powder (58 MJ/kg). This study was commissioned and will be published in 2009 by the International Dairy Federation (IDF) (Belgium).

OR 29 Using a Fruit and Vegetable Dataset to Determine Statistically Independent Indicators for Food Production

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Life cycle assessment (LCA) describes a process for calculating the complete environmental impact of a good or a service. However, for many producers and retailers, it is not possible to perform complete LCA for every product they produce or sell. In addition, the commodity nature of most food markets makes it difficult to consistently transfer and use farm-specific LCA information. Despite these limitations, many producers and retailers are interested in using LCA tools in their business decisions and communications with customers. Because of the complexity of modern supply chains, simplified or screening are more practical than complete assessments. We describe a methodology to determine what information is needed for a simplified life cycle assessment, by examining the statistical independence of a large number of individual environmental indicators.

Although food production contributes to a range of environmental impacts, previous research using the ecoinvent database has shown that many categories or environmental impact are closely correlated. In particular, many categories of environmental impact are correlated with energy use, commonly denominated as cumulative energy demand (CED). Food production is one area where this correlation is weak, and it is desirable to test environmental indicators against a larger data set of food production systems. We describe a methodology to generate over 230 regionally-varying data sets for fruits and vegetables, based on detailed foundational data sets. For many products, detailed information is only available for certain production locations and conditions. Literature and agricultural models can be used to modify these detailed data sets to describe many different kinds and areas of production. Tools to measure the accuracy of these data set extrapolations are briefly discussed.

Using the fruit and vegetable data set, we calculate the statistical independence of over 100 separate life cycle impact assessment indicators, including the new RECIPE indicators. In addition to testing how LCIA categories, such as ozone depletion, were on average correlated with CED, we also examined how different indicators within Independence is measured by simple correlation. As the LCIA scores are not normally distributed, rank-order correlation scores are used. In addition to simple measures of correlation, more complex methods, such as principal component analysis (PCA) are discussed and applied. Preliminary results show poor correlations with CED for land use, eutrophication, and ecotoxicity. LCIA scores for freshwater use are also expectedly to be poorly correlated with CED.

As CED is very closely linked with climate change potential, discussion of the independence and importance of other environmental indicators is an especially important contribution to the discussion on food carbon footprints. Examining the correlation of indicators from different LCIA methods within indicators can also illustrate focus areas for future research. For example, the near-identical results for land use show that more than one model is needed to ensure robust accounting. By assessing the statistical independence of different indicators, one can easily determine what types of information need to be gathered for a screening LCA. This greatly helps in creating a true enterprise-wide life cycle management system.

OR 30 Development of Normalisation Factors for Canada and comparison with Factors from Europe and the United States

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Normalization is an optional element of LCA which calculates the magnitude of an impact (midpoint or endpoint) relative to the total effect of a given reference. Expressing the results of an LCA related to a common basis allows determining the relative importance of the different effects to the selected reference. A reference value, called

normalization factor, is associated to each impact category of a LCIA methodology. It is often referring to a global, continental or regional level as a whole or expressed on a yearly person basis and is directly linked to the context in which the method has been developed.

The goal of this study was i) to calculate specific normalization factors from pollutant emissions and resources consumption in Canada, and ii) to compare them with those calculated for Europe and the United States on a person x year basis. The annual emission inventory has been evaluated by identifying and comparing the main contributors to a given impact category in Canada and Europe. For evaluative reasons Canadian normalization factors have been calculated using the characterisation factors from LUCAS (Canadian), IMPACT 2002+ (European), and TRACI (US) respectively. This comparison revealed for example that concerning the impact category terrestrial eutrophication, the substances contributing most significantly to the impact are nitrogen dioxide (63% of the impact), and ammonium (37% of the impact). In Europe, these substances are also the main contributors, in similar proportions. However, the Canadian factor is 2.6 times superior to the European factor. This can be attributed to intensive agriculture in Canada, which implies important release of nitrogenous substances into the environment.

The comparison shows that Canadian, US, and European contexts are different, suggesting that adapted national normalization factors might be appropriate. To calculate the final set of Canadian Normalization factors the European method IMPACT 2002+ has been used to check that those substances which contributed most significantly to each European impact category were also present in the Canadian inventory with a similar impact. To bridge data gaps the European values were extrapolated in order to complete the Canadian inventory.

OR 31 Development of a management framework for environmental remediation in South Africa

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South Africa, as in all parts of the world, faces enormous challenges in addressing the legacy of polluted or contaminated sites. Not only do we have to solve the issues with regards to previous operations, but we also have to meet the future needs of all society through a system that will be economically and environmentally sustainable. At present there is no overarching environmental framework for remediation initiatives in South Africa. As a result, environmental concerns are not addressed adequately. This paper aims to provide such a broad framework for an integrated and holistic approach to environmental remediation. It does not prescribe detailed procedures for the many challenges and complexities in achieving environmental remediation objectives, and the choices of sustainable solutions. Rather, it proposes a framework of principles, processes, and mechanisms to integrate regulatory governance with sound environmental practices in dealing with rehabilitation and remediation of environmentally degraded sites. The importance of stakeholder participation, regulatory compliance, transparency, and the consequences of transgressions needs to be emphasized. These aspects of the framework are highlighted with DOW Chemicals as a case study, and through interactions with various remediation specialists and other stakeholders that engaged with the specific case study.

OR 32 Car Recycling Management in the Frame of LCM

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There are no technical objects and processes, which do not influence on natural environment. So every product, process or activity affects the environment from extraction of the raw materials, through production and exploitation, to utilization of recyclable materials and neutralization of wastes. The motor vehicles, as technical objects consisting of various materials, are good example of mass products, which became inseparable component of contemporary human's life. In many cases negative effects accompany their entire life cycle. That is why transportation and especially means of transport are the example of human activity, which is identified with the special degradation of environment. Recycling may be one of the possibilities significantly diminishing the destructive human activities in transportation sphere.

The study presented in the paper concerns different aspects of end-of-life vehicles (ELV) management in the frame of LCM. Research was concentrated on Polish car recycling system. Age structure of used cars registered in Poland, import statistics and other data concerning Polish car market are analyzed on the background of forecasted number of end-of-life vehicles. The main problems of development of the recycling network are identified. Real processes of proceeding with wastes recovered from ELV were analyzed. The range of analysis was limited to the period 2002-2006 and only group of passenger vehicles and delivery vans was taking into consideration. Environmental analysis was concentrated on such processes like reuse, recycling, energy recovery, incineration and landfill. The method LCA and Ecoindicator 99 were used for calculations. The main environmental impacts were classified in three general categories: human health, ecosystem quality and resources. Consequences of car utilization processes were identified and potential improvements were suggested.

Obtained results of detailed calculations show the scale of environmental consequences of improper ELV management. Moreover results made possible to choose processes that can be source of the biggest environmental benefits. Results of analysis confirm that LCA method may be helpful tool in evaluation of environmental consequences of end-of-life processes and make possible waste management in the frame of LCM. Considering the situation in Poland it is observed that most of recycling stations have bigger re-manufacturing capacities than it is possible to gain waste materials. Creation of local and national system of the recycling network should be the imperative aim of ecological policy in Poland.

OR 33 Towards an information exchange system on substances in electrical and electronic equipment for safe and efficient end-of-life treatment

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Hazardous substances in waste electrical and electronic equipment (WEEE) are receiving increasing attention worldwide and policies such as the European RoHS and WEEE Directives have been introduced in response to the problems caused by such substances. The current study investigates how relevant information on substances in products can be provided to actors involved in the end-of-life treatment of WEEE. The rationale is that improved knowledge on embedded substances (including both hazardous chemicals and rare metals) can make these operations safer, less polluting and more efficient (larger number of materials recycled, higher recovery ratio and higher quality of recycled materials). This requires that the information is available on a suitable format, tailored to the specific needs and circumstances of each actor.

The study addresses questions such as: What information on substances in products is currently available to the WEEE recycling chain and how is such information used? What information would be needed for the actors at the different stages of the recycling chain to achieve a safe and efficient resource recovery? What would be the benefits of improved information exchange between the supply chain and the recycling chain? What factors influence manufacturers' willingness to share detailed product information with the end-of-life community, and how can they be motivated to increase the information exchange with other actors involved in the life-cycles of their products? How can relevant information on chemical substances in components and materials be generated and passed on in the recycling chain?

The project analyses in-depth the current situation on recycling and information exchange in Japan and carries out preliminary investigations on Korea and China. In addition, the situations in the EU and the United States are surveyed. The empirical research in Japan consists of document analysis and face-to-face interviews with representatives of the recycling industry, electronics manufacturers and industry associations, and other experts. These investigations concentrate mainly on the following tasks: (1) Describing in detail the recycling chains for the selected products and identifying the actors involved, (2) Clarifying the current situation concerning availability and needs for information on the composition of the products at different stages of the recycling chain, and (3) Analyzing existing systems for product information management in the upstream part of life-cycles.

The study also reviews some existing schemes for information exchange on substances embedded in WEEE, and analyses why and how these schemes have been introduced and what effects they have had. The experiences in the EU, where the WEEE Directive requires this kind of information sharing will be given special attention. In

addition, the project studies recycling-oriented information sharing systems for other products, such as vehicles, and analyses how the experiences gained in introducing and using such systems could be applied to the development of an information management system for WEEE. Based on these investigations, the study proposes a set of issues that need to be considered in the development of information sharing schemes aiming at improving recycling operations, and gives policy recommendations.

OR 34 **LeNS_AFRICA. An African Learning Network on Sustainability, for the development and diffusion of teaching materials and tools on Design for Sustainability in an open-source and copyleft ethos**

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In approaching sustainable development from a global perspective, there is a very clear need for significant change in the consumption and production patterns of highly industrialized, newly industrialized, as well as industrially developing countries. This change and its transition will have to respond to the challenges of radical reduction of resources consumption and emissions, together with a socio-ethical improvement in the quality of life; such as poverty eradication and a marked increase in the general well-being of the beneficiaries.

Within this framework there is an emerging acknowledgement that a great deal of this change can be directly linked to decisions taken during the **design phase of products, services and systems** (also referred to as **Product-Services System**). Consequently, **design schools** and **design educators**, need to be able to equip design students with a broad knowledge base, as well as effective methods and tools to orientate the design process towards viable sustainable solutions.

This perspective identifies an urgent need for effective learning mechanisms acting at the education level by enabling design educators in both industrialized and industrially developing contexts to equitably share the consolidated and researched knowledge and know-how in design for sustainability. Further, these actors should be able to respond to the local/contextual and global issues pertaining to sustainable development.

Along this scope it is operating the ongoing **Learning Network on Sustainability (LeNS) project**, Asian-European multi-polar network for curricula development on Design for Sustainability (DFS) focused on (Product-Service) System innovation, financed by the European Commission under the Asia-Links programme. LeNS is a project aiming at developing and diffusing system design for sustainability in design schools in a transcultural perspective. The main output of the project will be the **Open Learning E-Package (OLEP)**, an open web platform that allows a decentralised and collaborative production and fruition of knowledge. It can be described as a modular e-package of teaching materials (texts, slide shows, audio, video, etc.) and tools for designers, that design educators (as well as students, designers, entrepreneurs and interested persons/institutions) worldwide will be able to download (free of charge), modify, remix and reuse (copyleft) according to their own socio-economic priorities and unique geo-political realities.

Apart from the contents, the same LeNS web platform is realised in an open-source and copyleft ethos, allowing its download and reconfiguration in relation to specific needs, area of interest and interested partners. Within this perspective several hypotheses related to the launch of regional networks (e.g. in Italy, Brazil, United Kingdom, and Japan) have been proposed. One of this hypothesis is about the setting up of an **African Learning Network on Sustainability**, which, taking in consideration the local needs, interests and opportunities, could represent a significant enabling platform capable to sensitise, support and empower a new generation of African design educators, designers and entrepreneurs to reach design practice throughout an open collaborative learning approach.

Firstly, the paper will introduce the Asian-European LeNS project and present the OLEP and the web platform features. Then secondly, whilst cognisant of the state-of-the-art of current practices and experiences on DFS in African Universities, it will propose a hypothesis of configuration of the network, with a specific emphasis on expected results and the potential contribution to the process of socio-technical transition towards sustainability.

OR 35 Sustainable Production and Market Economy

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Sustainable Production and Market Economy- Environmental Policies, Legislation and Incentive-based Economic Policy instruments Products have become more complex from the point of view of the number and composition of materials used and in many cases later recycled. These materials need to be recycled to become valuable, useful raw materials again in order to achieve savings of primary raw materials or energy. Most often, after a primary treatment phase, the recycled materials are refined in the same processes as primary raw materials. If it is economically more feasible to make products only from primary raw materials at present, then, where increasing the use of secondary materials and by-products can be shown to be more environmentally sustainable, then there is a need for new policies that not only dictate goals but also promote research and the innovations needed to make greater use of recycled raw materials.

The great challenge faced by economies today is to integrate the paths of environmental sustainability and economic growth - doing more with less, or, perhaps in many cases simply achieving the same with much less. Social, economic and ecological thinking can be an opportunity for all actors where saving raw-materials, using by-products and reducing waste might be the win-win situation for companies and their employees, shareholders and the economy, and consumers' communities and the environment. The impacts of economic policy instruments have been assessed in recent times, concentrated principally on energy and climate policy, where the emphasis has been on evaluating the reduction in emissions and the overall economic impacts, however, such impact research should also consider sustainable development and material efficiency issues. The EU encourages member states to increase the use of economic waste policy instruments, which has resulted in a gradual move towards using a combination of regulatory and economic instruments. In our research project we will try to propose some effective instruments related to material cycles: legal, environmentally sustainable and economically feasible means to control and manage material flows, by-products and production residues.

Our case study is located in the Gulf of Bothnia industrial region of Finland and Sweden. Our objective is to find new ways to use by-products and residues of the forest, chemical, and metallurgical industries in the present situation and in future. In this study the main objective of the policy and legal research is to outline new ways to extend policy instruments, regulate and control industrial by-products and residues, find the balance between legislation and incentive-based economic policy instruments with the Gulf of Bothnia case study as a focus, and explore the question of how the scale of the industrial "ecosystem", either local, regional or global, makes a difference. **Keywords:** Saving of the primary raw material Material Efficiency Sustainable production Utilization of by-products Decreasing waste flows to landfill Environmental legislation Incentive-based Economic Policy instruments

OR 36 Social Impacts in Life Cycles: Part 1: Activity Level Modeling in a Global IO-LCA Model

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Product Life Cycles include many unit processes. In fact, every sector can be found, at some level, in every product supply chain. For this reason, in environmental LCA we use "generic" or industry average data for the "background" processes that make small individual (but possibly large total) contributions to total impacts over a life cycle. We then identify the processes which make a major contribution to total impacts, and these "hot spots" become priorities for data refinement and possibly for environmental progress as well. A similar process of identifying hot spots using average data can be very helpful in the early stages of a social LCA. Social hot spots are unit processes located in a region where a situation occurs that may be considered as a problem, a risk or an opportunity, in function of a social theme of interest. The social theme of interest represents issues that are considered as threatening social well-being or that may contribute to its further development.

The presentation is the first of two which will, in sequence, describe the elements of a global social hot spot database and modeling system, and will present results for a case study addressing child labor risk. The system is built upon the GTAP global input-output model. This system provides data for 113 regions, and each is differentiated into 57 sectors. The inputs to each sector, used to produce its product output, are specified quantitatively; so are

the trade flows between each region. The model forms the backbone of a global input/output LCA model. It has been, and continues to be, augmented by open and public databases on emissions and other inventory flows, per sector, per region, per unit of output. To support global social hot spot assessment in LCA, this system has also been augmented with global data on worker participation levels by sector by region. The presentation will describe how researchers and LCA practitioners in any region can make use of the model, to support: a) Development of environmental and social LCI databases for their country, in a way that takes explicit account of global trade flows; b) Identification of social hot spots in product life cycles.

OR 37 Evolution of Life Cycle Thinking Worldwide – Insight into expectations, needs and challenges of Governments in Non OECD Countries

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The Life Cycle Initiative is a joint programme of The United Nations Environment Programme (UNEP) and the Society of Environmental Toxicology and Chemistry (SETAC). It was launched in 2002 in response to the call from nations around the world in the Malmö Declaration (2000) for a life cycle economy that extends beyond the traditional focus on production site and manufacturing processes to include the environmental, social, and economic impact of products over their entire life cycle, “from cradle to grave”. Since 2002 the world has experienced a positive evolution regarding the internalization of Life Cycle Thinking in policy making and business. Key players in sustainable decision making issues such as business and governments begin to see the Initiative as a one-stop-shop for approaches and knowledge. It is clear that there is a direct correlation between the level of implementation of policies on sustainable consumption and production in the countries and life cycle approaches in business. Governments can boost more life cycle practices in the countries. However, there is still a need to better understand key governments’ issues such as their needs, challenges and priorities when asked for more efforts towards the incorporation of life cycle thinking in their policies.

According to a previous mapping of the level of implementation of life cycle approaches in the world, the UNEP/SETAC Life Cycle Initiative identified around 80 countries in the world with existing national networks or associations supporting the multiplication of life cycle based cases. Most Non OECD countries, including the emerging economies, are still at the lowest level. The paper has the aim to understand the needs and expectations of selected Non OECD countries representing three UN regions (the Latin American, Asian and Arab regions) and to draw initial recommendations on steps towards societies with life cycle thinking incorporated in their policies. Six countries from different continents (Mexico, Brazil, Philippines, Jordan, Thailand and Ukraine) were selected to develop the discussions and conclusions which will be taken up by the UNEP/SETAC Life Cycle Initiative in order to refine their life cycle based programs in Non OECD countries.

OR 38 A Comparative Analysis of Sustainability Modernization Dimensions for Eighty-Nine Emerging and Developed Economies

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Sustainability is a major topic of consideration within many organizations today and among researchers in many academic disciplines. This includes product development, manufacturing, distribution, logistics and services (Allen, 2008; Keating, Quazi, Kriz, and Coltman, 2008). On the practitioner side, growing numbers of companies have embraced collaborative practices with the upstream and downstream partners to enhance economic, social and environmental performance, and they are migrating towards a common definition and viewpoint on sustainability and how to integrate this notion in corporate values and strategy. Moreover, a recent survey by the Institute for Supply Management found that sustainability affects supplier selection/management, logistics service provider selection, internal value-adding processes of the firm, and internal decision-making (ISM, 2008). But there is no clear consensus of a definition of sustainability and what it means for corporate supply chains today (Carter and Rogers, 2008).

Academics have accorded much attention to environmental economics since the 1980s, and have made significant use of macro-level data on transport related facilities such as roads, railroad, ports, airports, information and communication technologies (ICT), energy generation, and others. However the link between infrastructure capability and economic or trade performance remains a topic of considerable debate and uncertainty. Yet infrastructure matters since individuals and producers rely on it for various forms of commerce leading to consumption and trade. The result is arguably a relationship between dimensions of logistics infrastructure and trade performance at the national level. Therefore, both corporate managers and public policy makers share this common thread related to decision making. Companies operating in developed and emerging market economies seek to make the logistics decisions based on cost, infrastructure capability and reliability, and the trade environment. One common challenge facing managers and public policy makers in any country is the need to better understand the problems with supply chain infrastructure.

Ecological modernization theory (EMT) supports the use, by institutions and society, of technological innovation to improve environmental and economic performance (Mol and Sonnenfeld, 2000). It is a relatively new theoretical lens to analyze how neo-industrialized societies deal with the environment. A core premise of EMT is that ecological (and social) interests and criteria of companies and government institutions are steadily catching up with economic dimensions. The result is increasing attention on organizing and designing global production, sourcing, and distribution for the consuming society. For example, recent deregulation of the European trucking industry has led to increasing participation of more companies in the sector, with an accompanying consequence of increased traffic congestion and pollution followed by increasing costs to the consumer. Academic attention to emerging markets has not kept pace with the business world's quest for international expansion from the supply chain and logistics perspectives. While researchers do not agree on the extent to which environmental, economic, and transport related factors impact trade there is little doubt that trade is influenced by transport infrastructure (Wiley, 1999), and the extent to which they are used efficiently to sustain supply chains (Wang and Cullinane, 2006; Svensson, 2007). However, little work has advanced the understanding of the relationships. From this, it is inferred that there remains a need to further explore the interplay between dimensions of sustainability, logistics infrastructure, and trade performance.

The perspectives outlined above have at least two common threads: (1) given the expanding complexities of global trade, lowering unit sourcing, manufacturing costs does not necessarily translate directly to lower total landed costs per unit—the total costs associated with importing, exporting, transportation, customs clearance and processing of goods from distant markets, and (2) Ricardian theory suggests that consumer and industrial demand create trade flow between countries to fill the shortfall in domestic production and supply. However, the increased trade flow volume can directly affect supply chain costs, increase congestion and lessen the efficiency of logistics and trade infrastructure. Growing concern from both practitioners and public policy makers on logistics and transport infrastructure capability require attention on efficiency since it is the efficiency with which firms manage their logistics footprint, and policy makers' infrastructure investment decisions facilitate trade expansion into a growing number of markets worldwide. Tirschwell (2007) observes that domestic and global conditions that promote trade and commerce are clashing with obsolete infrastructure. This work steps towards increasing such understanding.

The purpose of this paper is to explore the apparent conflict created by the Sustainability Modernization Theory regarding logistics infrastructure, the environment and trade performance at the country level. To this end, measures of technical and scale efficiency are used to explore several important relationships. Technical efficiency measures to determine how well trade dimensions (as outputs) are generated from the inputs used. Scale efficiency measures the extent of disadvantage that some countries may face relative to others. Finally, using reference set analysis of the methodological results it is possible to make regional comparisons by trading blocs and to suggest directions for efficiency improvement.

OR 39 2nd generation biofuels a sure bet? How to get it wrong

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Biofuels were expected to be a major step forward in the endeavour to reduce transport-related emissions of greenhouse gases. Then life cycle thinking led to formal evaluations of the energy balance of such fuels, and the corn-ethanol debate was vigorously conducted. Just as consensus was building on how to conduct such evaluations and on the likelihood that the energy and greenhouse gas balances of North American fuel ethanol were marginally favourable, came the carbon debt insights, a result of applying consequential LCA backed by advanced economic modelling. Increasingly, hopes have shifted to the 2nd generation biofuels, viewed as a technological home run. Could this also backfire? We show a simple case in which there would be no improvements in greenhouse gas emissions: a sugar mill sells its bagasse, currently used at low efficiency to provide process heat, to an advanced biofuels producer, and buys an equivalent amount of coal without investing in efficiency improvements. How could this be prevented?

OR 40 Life cycle assessment of biofuels in West Africa : what a challenge!

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LCA is a powerful tool for evaluating potential environmental impacts, now widely used in industrialised countries. But the adequacy of its use in the context of developing countries still remains to be demonstrated. Indeed, blind application of LCA in such countries may lead to irrelevant conclusions. For example, in West Africa, access to reliable energy sources is a great limitation for local development. Rural population could produce their own bio-energy based on biomass or oilseeds. The question of competition with food production but also the potential positive effect of a minimal chemical fertilizer input on remaining soil fertility, as well as activity development based on this energy produced must be addressed. Thus, LCA studies would probably show that every single technological improvement using an additional source of energy would have an adverse environmental impact, compared to the current situation, where almost no energy is used. In this perspective, how could rural development be seen as environmentally acceptable?

The idea of this work is to enumerate the main constraints for assessing the life cycle of biofuels produced in West Africa for local use and to show that life cycle thinking concepts should be used to integrate and balance not only environmental impacts but also social and economical. Using LCA in this context faces many problems: lack of data, lack of adapted LCIA method, lack of data for comparison (transport means in Ecoinvent concern European quality of fuels...), lack of knowledge about soil quality and pollutant transfers, high dependency to local agricultural practices, ... to mention just a few. A more fundamental problem is that LCA is a tool developed for assessing different scenarios in a developed world, where most people live over the subsistence level and have the chance to be in a position to choose between different options they can buy. In many developing countries, where essential needs are often not fulfilled (access to food, water, energy, money, education, health system...), the limitations are obviously different, and LCA must deal with basic human rights like access to water, food, etc.. Thus, the question becomes: how can we analyse global environmental impacts while taking into account local social and economic benefits? Is the importance of reducing global environmental impacts supportable in comparison with the need to have minimal living standards? In order to address these questions, a review of related articles is presented and new propositions are made. An adaptation of LCA concepts for West Africa is proposed. In addition to it, this work presents also a new way of thinking rural development in West African developing countries based on agro-industrial symbiosis.

OR 41 Carbon Footprint of Palm Oil Based Biodiesel Production

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Palm oil biodiesel has become a topic of global discussion in its benefits and drawbacks for bio-fuel use. More than 80% is being produced in the South East Asian region namely Indonesia, Malaysia and Thailand though the environmental consequences of its production and use will have global effects. To ensure environmentally responsible production in palm oil industry as well as gaining global credibility is imperative. This study is focused on the tracking of carbon footprint from greenhouse gas (GHG) emissions throughout the life cycle of palm biodiesel.

Carbon footprint of palm oil based biodiesel production has been determined by using life cycle assessment (LCA) as the scientific assessment tool to convey the result which could support the policy maker to identify hot-spots in the industrial systems which are responsible for high carbon emissions. The idea of green supply chain of the whole life cycle production of biodiesel from plantation phase down until use phase has been applied by utilizing of waste and by-products within internal process as well as external processes. Empty fruit bunches (EFB) and trunks have been evaluated for their possibility to turn into the second generation bio-fuel as well as bio-fertilizer. Three scenarios have been evaluated considering current practice and technologies as followed scenario A is the current practice which there are number of crude palm oil millings operate without environmental protection emissions plan such as waste utilization scheme, biogas collection system and engineering waste water treatment plant. Scenario B is the current practice with 70 % efficiency biogas collection system and gained credit for turning it into electricity. Scenario C is consist of the same condition as Scenario B in additional with application of 25% bio-fertilizer combine with chemical fertilizer into the oil palm plantation field and utilization of EFB by converting as bio-fertilizer and mushroom solid state, also credit gain from utilized of EFB as bio-ethanol to replace the use of MTBE.

The study exhibits that carbon footprint of scenarios 1-3 are 2.19, 1.50 and 0.86 kg CO₂-eq./L biodiesel, respectively. On the other hand, carbon footprint of diesel production by considering well-to-wheel analysis exhibits 2.92 kg CO₂-eq./L diesel. The result implied its sustainability process of palm oil biodiesel production by reducing 39% of GHG emissions from Scenario C as compare with Scenario A when measure up to German bio-fuel quota law of 30% minimum GHG emission reduction threshold as sustainability standards. However, in case of current Thailand market blend of 5% biodiesel (B5) between conventional diesel and B100 (from scenario C) found that 4% of GHG emission could be reduced. Hence, increasing of % blend could be one option in leading of biodiesel to the most sustainable fuel. Moreover, system boundary expansion of palm oil based biodiesel production by utilization of its residues also combination with the production of other type of fuel such as bio-ethanol and biodiesel from microalgae could be promising possibility in maximize reduction of GHG from entire system.

OR 42 Greenhouse gas emissions and soil carbon stocks in the agricultural phase of sugarcane-derived ethanol production in Brazil

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Due to its vigorous growth, photosynthetic efficiency, and a production system which often includes the use of crop residues to generate power for the processing mills, sugarcane is one of the most attractive feedstocks for bioethanol production, considering both energy input to output ratios and greenhouse gas emission reductions compared to fossil fuels. In the sugarcane production system, burning the residues has been a common practice in Brazil in order to facilitate more efficient manual harvest and transport operations. In recent years, due to environmental, agronomic and economical reasons, the manual harvest of sugarcane with burning has been gradually replaced by mechanical harvest with maintenance of the dry leaves and tops on the field. The mulch formed impacts the whole production process of sugarcane, influencing cane yields, weed control, fertilizer management, soil erosion, soil water infiltration rates and soil organic matter dynamics, and greenhouse gas balances.

This study is an assessment of the differences in greenhouse gas emissions and soil carbon stocks under these

two harvesting systems, in order to provide input for broader life cycle analyses of sugarcane-derived ethanol. Sugarcane farms in three regions with contrasting climate and soil conditions in Brazil were considered in this study. Greenhouse gas emissions from fossil fuel used in agricultural operations such as planting, disking, harrowing, tilling, harvesting, and input application were calculated in both systems. Embedded emissions from the production of fertilizers, pesticides and insecticides were also accounted for. CO₂ emissions from liming and non-CO₂ emissions from organic residues applied at different crop stages were included in the GHG balance. Soil carbon stocks down to 30 cm were evaluated in both burned and unburned harvesting systems. Direct soil N₂O emissions from nitrogen fertilizer application were measured using static field chambers. The N₂O fluxes were used to estimate the actual percentage of N₂O emitted from the soil due to nitrogen fertilizer application. Indirect fertilizer-induced N₂O emissions, related to leaching and volatilization, as well as non-CO₂ emissions from crop residue decomposition and burning were calculated using IPCC default values.

The results for the GHG balance indicate that the mechanically harvest, unburned sugarcane leads to lower GHG emissions and higher soil carbon sequestration than conventionally harvest sugarcane with pre-harvest burning. The conservation of sugarcane residues prevents emissions from the burning process, promotes carbon sequestration in soils and returns nitrogen back to the soil during the decomposition process, thereby replacing the need for, and GHG emissions from, fossil fuel-based nitrogen fertilizer sources. When converted into CO₂ equivalent, soil carbon stocks represented values in the same order of magnitude, and sometimes higher, than the GHG emissions from the agricultural phase sugarcane-derived ethanol in Brazil. Therefore, our results show that soil carbon stock changes from improved agricultural management, often not included in GHG balances for biofuels, can have a significant impact in the sustainability of ethanol production from a global warming perspective.

OR 43 Wood gasification: a comparative LCA of different supply scenarios alternatives.

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The perspective of climate change, the increase of energy demand and the depletion of fossil sources of energy have driven a strong interest in the development of renewable energies. Within the framework of the researches and the developments of VEOLIA ENVIRONNEMENT on new technologies for energy production, the environmental performances of wood gasification has been evaluated following the LCA rules. Three different supply scenarios are evaluated: wood from sawmill, from forest and from energy crops (poplar). The energetic conversion of the biomass by the gasification system (gasifier, gas cleaning and motor) is the same in the three cases. The goal of the study is to identify the key parameters influencing the environmental balance, but also to compare the combined production of heat and power from wood gasification to a more classical natural gas cogeneration. The data come from a commercial gasification plant, Ecoinvent 2.0 LCA database and literature and the impacts are evaluated with Impact 2002+ method. The results of the LCA show that gasification of biomass has a better environmental balance than the natural gas-based cogeneration: it allows reducing greenhouse gases emissions and non-renewable energy consumption by up to 80%. During the whole life cycle of the gasification of biomass, the contribution to the environmental impacts of biomass supply is small (less than 17%) compared to the energetic conversion itself. However, attention has to be paid on the one hand to the non negligible consumption of non-renewable energy (fuel) when the supply scenario is to use wood waste from forestry, possibly by optimizing the supply chain or by developing less polluting transports and on the other hand to the GHG emissions due to the use of fertilisers in the case of poplar cultivation, by choosing a more environmental-friendly way of fertilisation. Globally, the results show that choosing a supply of waste wood is environmentally better (with a priority for wood from sawmill, and wood from forest in a second time), in front of an energy crop. Furthermore, the question of the land use is less problematic in the cases of wood from sawmill or forest, but is sustainable only if the supply chain of biomass for production of energy doesn't enter in competition with the needs of these materials for the others economic sectors (like biomaterials). The presentation will share the results of the comparative LCA study and will show how the study helped in the industrial decision-making process by evaluating advantages and drawbacks of wood gasification and identifying main contributions to the environmental impacts. Alternative technical solutions currently evaluated will also be analyzed.

OR 44 Influence of time dependency of landfill biogas production in LCA: a French case study aiming to support decision making

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Unlike other European countries, where it is well developed, biogas production is still an emerging activity in France. Because waste is a renewable energy resource, and public policies push towards a larger recycling of waste materials, the recovery of landfill biogas has become a concern for local administrations and waste management companies. In this study, different technological options are assessed for the production and valorisation of landfill biogas from municipal and industrial solid waste in a specific French area. Using LCA principles, assessments of both environmental and economic performances are carried out. This approach aims at including main criteria that can impact the choice of a technology from a decision maker point of view (either local authorities or waste management companies).

There are many processes for producing and collecting biogas from landfills. In the present study, systems that are considered and assessed consist of (i) the collection of one ton of municipal waste, (ii) the pretreatment of ressource in landfill, (iii) the production of biogas in landfill and (iv) the combustion of biogas as fuel in a CHP plant. Four technological options for the production and collection of biogas are compared: open dump, conventional recuperation, digester and semi-aerobic reactor. For these options, time dependency of the degradation processes is a key issue. It usually takes several years to produce gas from a unit of waste. In addition, this production is generally not constant over time, and profiles vary according to technologies. Most analyses circumvent this problem by assuming steady-state production profiles.

In this study, individual biogas production profiles are explicitly associated to the four considered technologies. As a consequence, methane leakages from landfills and CO₂ emissions from the CHP plant are different for each scenario. The selected technologies present a trade-off between the quantity of gas produced/collected and the earliness of this gas production. These considerations are central for assessing the environmental impacts and economic gains of such projects. Displacing the production of biogas over time naturally affects the greenhouse gas emissions profiles for each scenario. The determination of methane and carbon dioxide emissions curves allows computing the 100 years global warming potential (expressed as CO₂ equivalent). From an economic perspective, changing the production profile of the biogas plays an important role, especially if discount rates are high. For processes presenting a strong time-dependency, integration of the dynamics is thus of great importance. Such efforts can be very helpful for decision makers: understanding the displacement of environmental impacts and economic flows over time by means of technological choices is a significant step towards a more rational life cycle management of waste at local scales, by both public authorities and industrials.

OR 45 Gap Analysis of Tools Used to Assess the Environmental Impacts of Biofuels in the United States

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The issue of environmental sustainability related to bio-based materials is a complicated one. Achieving sustainability requires a re-thinking of our systems of production, consumption and waste management and an increased awareness of the need to avoid the shifting of problems, which often occurs with isolated measures. The ecological advantages should outnumber, or outweigh, the disadvantages to the environment and human health. The benefits of bioenergy have come under increasing scrutiny as researchers look closer at the global environmental impact of their production. For example, diverting corn to make bioethanol could result in shifting production to competing crops, such as soybean, or the conversion of lands to use for corn production. The overall impacts of these types of shifts are not well understood. If used properly, bioenergy can help the U.S. meet its needs while maintaining ample supplies of food, animal feed, and clean water. To make this happen, well thought out national bioenergy policies that support the best options are needed for both the short and long-term future.

Life Cycle Assessment (LCA) can assist decision-makers in evaluating the comparative potential cradle-to-grave,

multi-media environmental impacts of their actions in order to prevent unintended consequences. Some studies are called 'life cycle analysis' but focus on a particular issue or pollutant of concern, such as greenhouse gas (GhG) emissions, or the net energy gain or loss question. These focused studies fall short of a complete life cycle approach that helps us recognize how our choices influence each point of the life cycle so that we can balance potential trade-offs and avoid shifting problems from one medium to another and/or from one life cycle stage to another.

This paper summarizes the results of a study that aimed to explore how the application of a systems-based approach helps decision-makers view the potential 'cradle-to-grave' impacts of biofuels and, thereby, choose the most favorable options that will keep us on the path toward sustainability. Nine tools that have been used to evaluate biofuels in the U.S. were studied and compared: Carbon Management, Ecological Footprint, Exergy Analysis, Fuel Cycle Analysis, Greenhouse Gas Life Cycle Analysis, Life Cycle Assessment, Material Flow Analysis, and Net Energy Balance. Specific examples of studies on corn ethanol production and use in the U.S. are provided, where available, to highlight the differences among the tools in the information that they generate.

OR 46 A Life Cycle Assessment on biodiesel in the context of the coal-to-liquids industry

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The production of biodiesel has been given government support in South Africa, as it is believed to have positive environmental and social impacts. Frameworks have been drafted to support the cultivation of biofuel crops, and particular focus is given to crops that are cultivated on underutilised land. Producing biomass-to-liquids diesel commercially could be lucrative in a country where large scale development of Fischer-Tropsch technology is established. This consequential Life Cycle Assessment compares the environmental impacts of diesels currently produced in South Africa for use in motor vehicles using fossil fuels as a feedstock, to fuels that source their feedstock from renewable sources. The following technologies are examined: crude-oil refining, Low-Temperature Fischer-Tropsch (LTFT) synthesis, used to produce coal-to-liquids diesel and biomass-to-liquids diesel, and transesterification, used to produce fatty acid methyl ester (FAME) diesel. A further analysis on the socio-economic impacts of implementing new biodiesel technologies at different scales is made, to gain insight on the environmental impacts of producing biodiesels in the South African political context.

OR 48 Moving Forward, Treading Lightly - Life Cycle Management in Action

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For Amcor Limited sustainability is about creating shareholder value through seeking opportunities and managing risks identified using five dimensions, namely Environment, Community, Workplace, Marketplace and Economy. Amcor recognises that climate change is a challenge for the packaging industry and will impact our suppliers, our customers and our own operations in many ways including: cost of doing business; changes in industry location; the ability of industries to adapt; legislative changes; and changes in community and consumer expectations. Amcor Australasia is working with key stakeholders and taking the lead in reducing the overall environmental impact across the supply chain ensuring a sustainable future for all. We promote and implement life cycle thinking in our business practices by using "The Amcor Sustainability Cycle". Our strategy is to continue to reduce our emissions, water and energy usage and waste to landfill to meet our resource utilisation targets. In addition, we are developing business opportunities that will see Amcor thrive in a carbon constrained economy. We use sustainable packaging design initiatives like life-cycle-analysis (LCA/carbon footprint) in our product development processes to create responsible packaging with minimal environmental impact. Almost half the new products released in the past year have lifecycle impact improvements over our existing packaging. Our design and innovation efforts so far resulted in commercially available packaging products and materials like SureFresh™, HydroArmour™, TrayBon™, Maxipack™, ProtectValve™, Lifespan™, NaturePlus™, to name a few. These products and materials demonstrate the following lifecycle impact reduction benefits: SureFresh™ - An alternative to Returnable Plastic Crates (RPCs) HydroArmour™ - An alternative to Expanded Polystyrene Foam (XPS) Packs TrayBon™ - An alternative to steel baking trays Maxipack™

- A material usage reduction and transport efficiency improvement
ProtectValve™ - A lower energy requirement at the consumer level
Lifespan™ - A lower food waste due to extended product shelf-life
NaturePlus™ - A renewable, degradable material option
We engage our key customers in sustainability projects, sharing our operational expertise. We support the consumers' efforts in minimising their impact by reducing raw material usage, including recycled content in our packaging and in addition to recycling we are conducting other waste recovery projects. Amcor also engages the community and our employees with our Earthwatch and Teamcor programs. Sustainability is integral in the way we do business and underpins our ability to operate at our 264 manufacturing sites across 39 countries. Continuous improvement in all aspects of sustainability is a journey that never ends. Amcor remains committed to constantly challenging itself and our business partners to reshape and improve our sustainability goals.

OR 49 EcoDesign at Grundfos – premisses, interests and competencies

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Grundfos has a wish to develop and implement new EcoDesign tools in their development processes. This paper discusses the wishes and interests for internal stakeholders as well as regulation. The internal stakeholders include product developers, environmental department and management. Their primary wishes for EcoDesign are identification of hotspots as well as assistance for improving the hotspots and develop more environmentally sound products. The relevant regulation primarily addresses energy and chemicals and this has also been the focus at Grundfos so far. However, Grundfos wishes to address other environmental aspects as well. The paper discusses how workshops can be applied as a tool for encompassing the diverse interests. Based on the premises for and the interests related to EcoDesign it is discussed what competencies are needed internally at Grundfos in order to implement the EcoDesign tools.

The first dimension to consider related to EcoDesign is the shift from a technical approach focusing on technical environmental improvements to a social approach with developers participating in the environmental effort. The next shift is from an internal focus mainly addressing changes implemented based on internal changes to a product chain approach. This last shift has its origin in technical aspects, namely life cycle assessments, and develops into a social approach also including collaboration in the product chain and in the network of the organisation. Changing from an internal to an external (technical) approach demands life cycle assessment experts, whereas the external social approach calls for networkers. (Mosgaard, 2008)

This outlines four main types of competencies:

- The technician: Focus is optimisation of internal processes; analysing and assessing the target areas with an in-situ approach. This can both be related to simple changes of procedures, production planning, etc and to implementation of cleaner technologies.
- The facilitator: Focus is implementation of EcoDesign in the company, managing e.g. employee participation and education of developers.
- The LCA expert: Focusing on improvements from a product oriented perspective; the indirect environmental impacts.
- The networker: The network creator collaborates with environmental experts both in the organisation and in the network and works as a broker for introducing new initiatives in the organisation. (Mosgaard, 2008)

The technical approach calls for profound environmental knowledge, whereas the social approach calls for collaborative skills, too. The interplay between the environmental organisation and the developers is discussed in order to identify what competencies are needed and how they are distributed in the organisation.

OR 51 The Sustainable Value Chain: Life Cycle Management to enhance sustainability - business success stories

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By understanding and improving our capabilities to reduce our social and environmental footprint of goods and services along the value chain, the WBCSD and UNEP/SETAC Sustainable Value Chain Initiative will define concepts, incentives and actions necessary for advancing sustainability. What is meant by sustainable value chain? What are the impacts along the value chain? Who are the players, and what can they control or influence? And what actions must be taken individually and/or together to optimize the consumption and production of goods and services that are all critical aspects of sustainable value chain?

This paper will outline recent work of the WBCSD - UNEP/SETAC Sustainable Value Chain Initiative to advance improvements in (more) sustainable consumption and production patterns. It will be elaborated what is meant by the sustainable value chain, the role of business, successful approaches to production and business activity, and for novel ways of thinking at the executive level. Starting from the over-arching and related concepts of Life Cycle Thinking and Eco-efficiency, key tools presented by eight companies to tackle the sustainability challenge and to succeed will be highlighted. Business executives interviewed from each company describe that applying approaches such as Life Cycle Management, Life Cycle Assessment, Life Cycle Costing, Material and Substance Flow Analysis, Carbon footprinting and Water footprinting will improve the bottom line, strengthen corporate credibility and enhance shareholder value. As an example, the sustainability capability maturity model implemented by a company will be shown, which provides an intuitive framework for initial assessment in judging where a corporation or its subsidiary elements stand on the way to achieving a more sustainable value chain. Finally, the joint vision on WBCSD and UNEP/SETAC will be presented as well as a series of recommendations of future directions for companies that want to go beyond the traditional way to do business will be given.

OR 52 Orangina Schweppes environmental impact analysis: joint use of corporate carbon footprint and LCA

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Last year, Orangina Schweppes launched an ambitious environmental study, aiming to establish the global environmental impacts of the company, and of some of the company's products. This project reflected the willing of the company to define its future strategic improvements without disregarding the consumer environmental concerns or the new regulations concerning display of Product Carbon Footprint (PCF) and of other impacts.

The environmental impacts of the company and its activities were referred to CO₂ emissions, to obtain the corporate carbon footprint. Orangina Schweppes provided data regarding raw materials, transport (import, export, and transport between sites), production figures, turnover, etc. These data were transformed and analyzed following the protocol established by the French Environment and Energy Management Agency (ADEME), the Bilan Carbone©. The company sites in Belgium, France, Spain, and Ukraine were analyzed. The carbon footprint was obtained for each country; the goal was to clearly identify the higher impacts for each site.

On the other hand, several key products were studied under a Life Cycle perspective. Life Cycle Assessments (LCA) were performed on PET bottles of 2L Oasis and 1.5L La Casera, as well as on Orangina 0.33L cans, and on Schweppes 0.2L glass bottles. For that, different indicators, including carbon footprint, were measured in the different stages of the life cycle (raw materials; packaging; manufacturing; distribution; use; end of life), following the CML method and using the Ecoinvent database. The Schweppes 0.2L glass bottle showed a remarkably low impact, especially due to the returnable glass package, that reduces the use of raw materials and the impact of the end of life stage. Otherwise, higher impacts were due to transport, energy consumption, sugar, and the use of fertilizers

during fruit production.

The joint approach based on the carbon footprint and the LCA resulted in the definition of a detailed current scenario, based on which improvements were suggested to Orangina Schweppes. An improved scenario contemplated the use of lighter packages, as well as the increase of the amounts of recycled PET used in plastic bottles, and the replacement of aluminium by steel in cans. Otherwise, reductions in the impacts due to fruit supply were suggested, especially regarding agricultural practices and long distance transport. Other measures were contemplated in the improved scenario, like reducing the sugar levels, or increasing up to 20% the dependence on renewable energies. The environmental impacts in the improved scenario were reduced between 15 and 20%, depending on the indicators. The main purpose of Orangina Schweppes now is to develop a transparent information policy regarding the environmental impacts of its products, as well as the progressive reduction of such impacts.

OR 53 Cradle to Cradle and its meaning for life cycle thinking and supply chain management

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The founding fathers of Cradle to Cradle, Michael Braungart and William McDonough (2002), have the opinion that present environmental policy takes its basis too much in playing on guilt and too little in reduction of consumption. They argue that everybody can produce and consume as much as they want when following the ideas of Cradle to Cradle. Problems of overpopulation and depletion of resources would disappear if people learned – just as termites – to convert all used materials in the food cycles. In other words, we should design all products such that they can be fully reused and recycled. Waste becomes food in this way. Or even more: Waste = Food. That is also the appealing metaphor summarizing the philosophy of Braungart and McDonough.

The Cradle to Cradle Certification Program (MBDC 2007) claims Cradle to Cradle as a new and revolutionary approach to move human industry beyond simple concerns for “sustainability” toward a new positive paradigm in which growth is good, based on the regenerative productivity of nature that enables to create industry that is continuously improving and sustaining life and growth. The concept of Cradle to Cradle or Waste = Food has a strong resemblance with the earlier concept of Closing Cycles in the first National Environmental Policy Plan (NEPP 1989). The NEPP marked a turning point in Dutch environmental policy and served as a source of inspiration for similar plans in several other countries as well as for the Fifth Environmental Action Program from the European Commission in 1993 (Lieferring and van der Zouwen, 2003). Life Cycle Assessment developed as the analytical tool developed in support of the philosophy of Closing Cycles as implemented in Integrated Product Policy. Integrated Product Policy, Life Cycle Assessment as its supporting tool, and the underlying philosophy of Closing Cycles experienced a diminishing societal and political attention over the years, but were initially just as ambitious and appealing as the concept of Cradle to Cradle or Waste = Food is now. It is therefore a major contribution of Braungart and McDonough and their philosophy that they make stakeholders burning with love again to implement Cradle to Cradle in their own practice.

Cradle to Cradle happens to be an extremely powerful framing for communicating and mobilizing societal and political action. This is of crucial importance as policy makers, industry and consumers are the carriers of sustainable change. Hair-splitting about similarities and differences between Cradle to Cradle and Closing Cycles seems little useful, but Cradle to Cradle on the other hand might like to avoid pitfalls by learning from developments and experiences in Closing Cycles. This presentation evaluates the contribution of Cradle to Cradle to life cycle thinking and supply chain management by reviewing present Cradle to Cradle initiatives against the background of the history of Closing Cycles.

OR 54 Ensuring a sustainable use of freshwater resources: overview of tools for corporate and product water use accounting and possible way forward

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In order to face the ever-increasing imbalance between entropic water needs and freshwater availability, public and private stakeholders have to ensure the long-term sustainability of their development strategies with respect to freshwater resources. Initiatives have been launched to elaborate tools that quantify the stress generated by human activities on water resources.

One major initiative is the “water footprint” method that measures the water intensity of products. It accounts for the direct freshwater use for on-site production processes and the indirect freshwater use by the off-site supply chain. This method thus provides industrials with a picture of freshwater use: they may identify improvement within their own processes, as well as challenge their suppliers for lower water usage. However, the “water footprint” does not make any distinction among water withdrawals, whatever the quality of the exploited resource or the water availability in the local watershed. Hotspots identified by the “water footprint” are therefore not necessarily correlated to highest environmental impacts of water withdrawals and may thus lead to set misleading priorities.

A second initiative, the Global Water Tool (developed by the World Business Council for Sustainable Development) consists in a Geographic Information System, within which companies may map water withdrawals of their facilities according to local water availability. This tool provides industrials with an overlook of their worldwide freshwater use and highlights hotspots (e.g. facilities in water scarce areas), where their activities are particularly stressing water resources. Being mainly dedicated to environmental reporting at a corporate level, the results of the Global Water Tool are difficult to translate into technical recommendations; it limits its relevance as a decision support tool.

Accordingly, industrials lack a process-oriented tool, with which they could objectively assess and improve the environmental performances of their products with respect to freshwater resources. Life Cycle Assessment (LCA), used and acknowledged for the environmental benchmarking of alternative scenarios, provides an appropriate framework for such water accounting tool. However, the LCA methodology currently does not account for the environmental impacts generated by freshwater use. A working group of LCA experts has therefore been launched in 2007 within the UNEP/SETAC Life Cycle Initiative to overcome this shortage. An extended life-cycle inventory framework has been proposed that differentiates water flows according to their use within processes (e.g. quality degradation, evaporation) and the quality of the withdrawn water resources (e.g. ground/surface, high/low quality). Regarding Life Cycle Impact Assessment, spatially differentiated impact pathways have been developed linking freshwater use to damages on human health and ecosystems. However, this methodology is still in development and more researches are required to get an operational tool.

This presentation shows the advantages and drawbacks of these product and/or corporate water use accounting tools. It then highlights how the business community is using them to date and what potential cross-contributions could foster their mutual way forward.

OR 55 Characterizing the Impacts of Water Use in LCA: an Operational Method and Case Study Application in the Pulp and Paper Industry

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Although freshwater resource issues are continuously arising, Life Cycle Assessment (LCA) models are not yet adapted to address this environmental problem. Through the project «Assessment of Freshwater Use and Consumption within LCA», accepted by the 2nd phase of the Life Cycle Initiative, a conceptual framework to characterize impacts of freshwater use was proposed. Building on this framework, this paper aims to provide an operational method applying its concepts and to illustrate them using a case study in the pulp and paper industry.

The method presented here calculates a new midpoint indicator quantifying the volume of freshwater rendered unavailable because of its use as a function of the type of use (ex: degradative or consumptive), regional water

scarcity, water quality and type of resource used (groundwater, surface water). This indicator provides a country level regional assessment, translating a volume of water used into a drinking water equivalent volume unavailable for human uses (ex: Canada:0; South Africa:0,54; Jordan:3,88). Using this indicator quantifies the impact generated from this change in availability of water through the new midpoint impact category Freshwater Deprivation for Human Uses. In agreement with the general framework mentioned above, it was considered that freshwater deprivation occurs only in areas where compensation cannot occur based on limiting socio-economic parameters, such as the GDP per capita. These parameters act as indicators of the adaptation capacity of downstream users to water shortage. Seven different users are considered: domestic use, agriculture, industries, fisheries, hydropower, transport and recreation. Impact on human health caused by freshwater deprivation is not the focus of this paper.

Default compensation scenarios for four of the different users are identified, and this for several countries considered able to compensate water uses. Examples of these compensation scenarios include water desalination for domestic use in United Arab Emirates or wastewater reuse for agriculture in France. We modeled the impacts generated by these compensation scenarios with respect to their geographical location up to the mid-point and end-point impact categories with an existing LCIA methodology, namely IMPACT 2002+. For different examples of agricultural production, impacts from these backup technologies were modeled and combined with the Freshwater Deprivation for Human Uses indicator, resulting in all impacts from freshwater use being included in the LCA results. This paper presents an operational methodology and discusses how it can be used as a decision-support tool to minimize the adverse effects of freshwater use.

For the case study application, data from the pulp and paper industry was used to model the impacts avoided as a consequence of a plant's improvement in water use efficiency. The change in environmental impacts occurring with the implementation of water reduction strategies was modeled using data from a plant having undergone a significant change in water efficiency, and this, for several hypothetical locations around the world.

OR 56 Assessment of urban wastewater re-use alternatives from an environmental point of view

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Population is continually growing and the contamination of both surface water and groundwater is also increasing. The uneven distribution of water resources and periodic droughts has forced governments to search for new sources of water supply.

The main function of a Wastewater Treatment Plant (WWTP) is to minimize the environmental impact of discharging untreated water into natural water systems (rivers, lakes, seas, etc). Another function of wastewater treatment that is being promoted is the re-use of treated water. In this case a tertiary treatment is mandatory in order to comply with reclaimed water specifications.

Water reuse is already an important element in water resources planning and implementation. The major areas in which water is reused are irrigation, industry, recreation, surface water replenishment and groundwater recharge. It should be taken into account that reclaimed water reduces the consumption of potable water (thus also saving the electricity and reagents required to treat it).

Although wastewater reuse can be assimilated as a water resource, social opposition is significant. Some of the reasons for this are the potential effects of trace contaminants on human health and the environment (important pollutants, pharmaceuticals and personal care products, etc.). In order to guarantee that wastewater is safely reused, effective tertiary treatment processes must be applied to the water line of conventional WWTPs.

The main objective of this work is to use Life Cycle Analysis (LCA) techniques to assess the environmental loads associated with wastewater reuse (based on actual operation data from Spanish plant) and to establish their environmental profile, identify the stages that have the highest environmental impact and evaluate alternatives for the final destinations of waste water.

The alternatives evaluated are:

- No-reuse: treated wastewater is discharged into a natural water stream (leading to the sea).
- Direct re-use: brine (residue from desalination plants) is diluted with water from a WWTP after a secondary

treatment.

- Direct re-use: after tertiary treatment wastewater is used instead of potable water
- Direct re-use: after tertiary treatment wastewater is used instead of desalinated water

Some examples of direct re-use are applications in agriculture, industry, cleaning, etc.

Therefore, final decisions can only be taken after considering such issues as regulations, distance between desalination plant and WWTP, tertiary treatment, reuse application, etc. The reuse of water must be planned by taking all factors into account and trying to emphasize its advantages and to minimize its disadvantages.

We have borne in mind that the recommended hierarchy on waste management establishes the following order: reduce, re-use, recycle, treat and finally dispose. We can conclude, then, that wastewater re-use should be promoted as much as possible. However, our results will help us to verify and quantify this final conclusion.

OR 57 Assessment of water use in LCA: state-of-the-art and case study

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This work reviews and briefly evaluates the existing methods that allow an assessment of water use in LCA, illustrating their strengths and limitations by applying them to two case studies. Water use can be divided into in-stream and off-stream use, and consumptive and degradative use. Only freshwater is assessed, saltwater being outside the scope of this work. Ten methods and tools are identified and evaluated against each other: 1) the Global Water Tool; 2) the Simple Water Inventory differentiating between non-turbined water use and turbined water use; 3) the Water Footprint (WFP) methodology; 4) the Cumulative Exergy Demand (CExD); 5) the Cumulative Exergy Extraction from the Natural Environment (CEENE); 6) the Swiss Ecological Scarcity method (SES); 7) the method of Maendly and Humbert; 8) the method of Milà i Canals and colleagues; 9) the method of Bayart and colleagues; and 10) the method of Pfister and colleagues.

Using the case study of coffee, a consistent result is obtained whichever method is used, with the overall water impact score of a cup of instant coffee being approximately half that of a cup of drip filter coffee. The dominant phase is generally the use phase, due to the amount of water required for the production of the electricity used to run home appliances (mainly heating the water to make the coffee and wash the dishes), and followed by cultivation and irrigation. Though all methods give the same ranking between the two alternatives, they give different magnitudes and units. Turbined water generally represents the largest share of the water impact score. However, not all methods allow the assessment of turbined water and non-turbined water in the same way. For example the Swiss ecological scarcity method provides regional characterization factors for a practical and consistent assessment of non-turbined water use, but is more difficult to apply for cases of turbined water use. The Water footprint, on the other hand, does not reflect water scarcity. The method of Maendly and Humbert only focuses on impacts to aquatic biodiversity from turbined water.

According to the preferences of different users, the choice of which method to apply might change from one application to the next. It is therefore crucial to provide a framework to consistently assess the use of water in an LCA context. In the meantime we suggest that a combination of the Swiss ecological scarcity method for non-turbined water use and the method from Maendly and Humbert for turbined water use can meet the needs of a wide range of issues. In the future, once the methods currently in development (e.g. Pfister and colleagues) are operational, application and interpretation of the stress on human health and ecosystems caused by water use are expected to improve significantly. However, we also suggest that attention is given to the development of methods that can capture the impacts on humans related to hydropower production.

OR 58 Sanitary systems: Life cycle thinking leads to distributed infrastructure

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Life cycle management arose within a sphere focused on products and technologies. Our view is that infrastructure is at least, if not more, in need of life cycle thinking and management than isolated technologies. Our reasoning is two-fold: firstly the life span of infrastructure is in the order of decades, even up to a century or more, exposing it to drastically changing contextual conditions (population growth, changing climate, economic instability). This means the decisions we make now have consequences that reach far into an uncertain future. Secondly, currently dominant sanitary infrastructure represents highly significant, path-fixing investments – exhibiting strong economies of scale which once embarked upon, reinforces the argument to add incrementally to the existing system, rather than creating something new, even if the alternative offers more sustainable outcomes. Sanitary infrastructure is fundamental to public and environmental health, particularly in densely habited urban areas.

Our historical approach to sewage management was removal, with treatment being optional. More recently, end-of-pipe treatment increased as we sought to meet environmental objectives. With urban growth, we extended existing systems, inadvertently or otherwise creating highly centralised systems that served us well in many respects but also limited our scope for moving towards sustainability. Increasingly, water authorities are recognising that a sustainable sanitary system requires sewage to be viewed as a set of resources to be captured and reused – life cycle thinking in its broadest sense – instead of a useless waste to be removed. In infrastructural terms, this means finding the most appropriate mix of centralised and decentralised technologies and management approaches.

This paper discusses the initiative of metropolitan water authorities in Melbourne, a city of about 4 million people in south eastern Australia, to step boldly down this path. Last year, our Institute was invited to identify what it would take, in terms of principles and practices (technological and institutional) for Melbourne to transition to a sustainable sewage system over the next 50 years. Our scope began at the point at which wastewater is added to the sewer, and continued to the final resting place. In turn, we invited 20 experts at the leading edge of sewage technology, development and practice from around the globe, to join us in contributing their case studies and thought experiments. We synthesised these into a wonderfully rich resource, now publicly available. This paper will report on the key challenges and recommendations that arose throughout the process, as well as presenting details of the concepts and case studies.

OR 59 Economical benefits tied to ecodesign

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The advantages related to ecodesign are numerous according to the literature on the subject. Ecodesign, considered to be an efficient environmental approach, is also said to carry a number of other advantages for the firms using it, among which is the potential increase in profitability. However, industrialists are still skeptical about the real profitability tied with the implementation of environmentally sound strategies. Indeed, the economical factor is of great importance for most firms when considering favoring or not the implementation of ecodesign. As long as such profitability is not demonstrated, firms will hesitate to adopt an ecodesign path. It is thus obvious for us that we have to clearly identify the real economic fallouts related to ecodesign, which will give sound economic arguments to firms wishing to integrate proper environmental approaches in the design of their products. It's this economical perspective that serves as the background for the research project outlined here.

Following 18 months of research and after interviews with 30 firms on their related ecodesign experience (15 in France / 15 in Canada), the following results were reached pertaining to the economical benefits tied to such an approach, all the while adding certain clarifications and difficulties encountered. With few exceptions, all the firms canvassed encountered significant improvements in their running budgets. The analysis of the data showed that the results related to direct economical gains (increase in revenue and/or lowering of costs), due to the implementation of ecodesign, are positive. We have also identified other qualitative gains that are beneficial to the enterprise. It turns out that such less tangible gains - like an improved image, better relations with the parties involved, the development of creativity – are also important. A thorough analysis of the enterprises having reached a particularly

interesting profitability allowed us to put forward the favorable conditions for success. A further analysis of the motivations and functioning of the enterprises interviewed helped us identify 4 main patterns, from the least to the most environmentally involved firms.

1. Ecodesign as an alternate activity: it concerns a few of the firms in our survey that are at the very beginning in the use of ecodesign. For some, it's their very first experience in the field, but not for all.
2. Systematic use of ecodesign: the enterprises grouped here are convinced of the advantages related to ecodesign in the development of their products and have often put in place LCA methodologies or other such systematic methods.
- 3- Sustainable development approach: as far as the environmental factor is concerned, these firms are committed to a thorough sustainable development taking into account socioeconomic factors.
4. Firms with an ecodesign foundation: the enterprises concerned here are those which develop products wholly respectful of the environment and whose administrators are personally involved in matters pertaining to a sound environment. Often, these enterprises are very profitable.

OR 60 ProdTect: a Tool to Facilitate LCM in the Automotive Industry

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Complex products like passenger cars, consisting of several thousand parts and a wide range of materials are a time-consuming task to conduct LCA. To make the assessment of environmental impact in the design phase of a vehicle or component of a vehicle feasible in daily industrial routine, ProdTect as a tool has been developed by KERP, Centre of Excellence in cooperation with Magna Steyr Fahrzeugtechnik and BOKU University and TU Braunschweig. Potential users are product developers in the automotive industry with the task to consider besides technical features also environmental aspects. As input data into ProdTect, a hierarchical structured product model (the vehicle consists of assemblies, sub-assemblies and parts) is built up based on ISDM data. ISDM (International material declaration system) is an international convention to support data transfer along the supply chain. Typically the producer of a part provides data for material composition of a part. As a second source of data, process data are used. The Ecoinvent database was chosen for this purpose, but extended by specific processes in automotive manufacturing.

For all parts, the user assigns processes of material acquisition and manufacturing, supported by a "Wizard", a feature to propose typical processes for a selected material. The use phase is modelled based on fuel consumption data and a chosen mileage. Processes at the end-of life stage of a vehicle are described by a recycling profile, modelling the state of the art in vehicle recycling in the chosen region. The result of the impact assessment is displayed in impact categories, chosen by the user (eg. CML – categories). The results can be shown by parts, used processes or life cycle stages. Specific features of the tool are approaches to streamline data processing without a significant loss of information, eg. by grouping small components like screws and nuts. For each material class, a generic material mix is supplied, replacing materials with unknown properties. It is also scheduled to reduce the number of manufacturing processes by deviating typical process chain for selected assemblies or sub-assemblies (e.g. body in white). Assemblies from previous modelling can be applied in a new context; a scaling by weight is possible. The paper describes the features of this tool and gives case studies from application of the tool.

OR 61 Life Cycle Thinking and Assessment in a Stakeholder-based Learning Process for Multi-stakeholder Decision Making and Collective Action

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While life cycle thinking and assessment (LCT/A) is gaining increased recognition in assessing the sustainability of interventions, there are increasing concerns regarding the transparency of the analyses, the communication of results, and the robustness of the conclusions. The concerns are escalated when multiple stakeholders have

a role to play not only in making decisions, but also in committing resources. In current practice, analyses are typically conducted by experts, and stakeholders are primarily involved in interpreting and communicating the results and conclusions. However, when the stakeholders represent different disciplines and sectors, the decision making environments are complex and political. An important aspect in reaching consensus for collective action in complex environments is to build shared stakeholder perceptions and understanding of the prevailing issues and the potential solutions [1]. For this essential task, it is mutually beneficial for the stakeholders to be engaged in a learning process. Life cycle assessment has the potential to be integrated into a stakeholder-based learning process, rather than a stand-alone method for experts to generate results and conclusions. In transdisciplinary planning, which is a process where the aim is to enhance mutual learning among the experts, practitioners, and relevant stakeholders, life cycle thinking and assessment can be modified to be embedded into a multi-stakeholder decision making process. The framework of the process can examine upstream and downstream phases of issues and solutions, eliciting information such as stakeholder involvement, resource requirements, and economic, social, and environmental costs, benefits and effects together with the stakeholders. This paper presents aspects of transdisciplinary planning and how the LCT/A can be embedded into such learning processes using some examples from a field-study conducted in Sri Lanka.

OR 62 The Global Carbon Footprint of Knorr; assessing one of the world's largest food brands

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Knorr is one of the world's largest food brands, and the largest Unilever brand, with presence in ca. 90 countries. Its product portfolio includes dry and wet soups, bouillons and sauces as well as frozen meals and 'meal-makers' (i.e. seasoning mixes for specific dishes, e.g. stir fries, stews, casseroles etc). Knorr product supply chains are truly global with many thousands of ingredients sourced from around the world. The complexity of Knorr's product portfolio (including over 15,000 different 'stock keeping units' (SKU) - i.e. product units reflecting individual recipes, pack sizes and formats), makes a bottom-up, conventional product-based carbon footprint approach impractical. A "meta-product" approach was thus used whereby "product types" which are representative of the Knorr portfolio (e.g. dry soup – instant; dry soup –cook up; wet soup. . .) were assessed. The production impacts for each one of these meta-products were derived from the dominant production technology and average recipe composition (derived as a weighted average of the top10 SKU recipes for each product type). Meta-products were defined for each region in which Knorr products are marketed (e.g. Europe, the Americas). This allowed for regional differences in the product portfolio to be reflected in the assessment, as well as differences in impacts due to variations in energy provision, technology, distances and modes of transport etc. The total, global Knorr CF was derived by multiplying the impacts calculated per tonne of each meta-product with the regional sales volumes in 2007. The complexity of ingredients and food processing technologies required for the production of Knorr products is such that a certain degree of simplification in the data collection and calculations was necessary. Ingredients and processes that can be regarded as similar were aggregated (e.g. 'dairy products' instead of milk; cream; etc.; 'drying' instead of air drying; spray drying; drum drying; etc.). Such groups form the 'building blocks' of the assessment, and allow the flexibility to explore future innovations and changes in the brand's product portfolio. However, it is acknowledged that, the inherent variability in bio-based products is further increased by this grouping exercise. In order to ensure the robustness of the results, the variability of each building block was individually assessed and propagated through the calculations. The main advantage of this 'meta-product' approach is that it simultaneously allows for the assessment and comparison of individual product types as well as for the estimation of a brand's total CF. The former is important in terms of finding ways to reduce GHG emissions associated with existing products as well as driving innovation for lower carbon products. The latter provides a baseline against which the brand can set targets and track performance. Ultimately, both product-based improvements and progress monitored at the brand-level can be used to support external communication / claims.

OR 63 Technological fix vs. the understanding of human interaction

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There is a strong conviction in the life cycle community of the need to spread the use of life cycle thinking in business, and there have been many attempts to make it more widespread. Many efforts made embody a strong engineering faith that better tools are the key to success. A typical approach has been to focus on “technological fix”; to reduce the technical and economic barriers by, for example, developing standardized methods or simplified tools (see e.g. Pennington et al. 2007). During the last years, however, recognition of the importance of social and organizational aspects of the implementation and use of life cycle thinking is slowly gaining ground in the life cycle community. For example, the EU-financed project.

OR 64 Development of an input-output model and database for South African hydrogen infrastructure products

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Growing concerns over global warming have increased interest in the production and use of alternative energy carriers towards the establishment of more sustainable global energy systems. In mitigating this climate change challenge, the liberalisation of multilateral trade to offer the global populace access to less polluting products and processes has been a key argument made by globalisation proponents in the international community. However, it has also been contended that such trade liberalisation might also produce other adverse effects for the environment. Towards addressing this globalisation debate, integrated economic input-output (EIO) Life Cycle Assessment (LCA) approaches are showing promise in furthering efforts to reach scientific consensus in elucidating the trade-offs associated with the drivers of globalisation. While such IO models are increasingly describing the environmental profiles of developed country economies, there has also been a growing recognition of the need to include products and services from developing economies. In South Africa, while industry and government have been slow to realise the benefit of these IO approaches, the potential for the production of South African hydrogen infrastructure products for the international hydrogen economy has precipitated new interest. The South African government subsequently initiated a study to consider whether existing developed-country IO models may be adapted sufficiently to provide sustainability data and information of hydrogen infrastructure products from South Africa. This paper seeks to draw on international best practice in the development of IO models to propose a general framework for positioning South African hydrogen economy-oriented products within such models and databases. The state of the art in IO models is described based on a preliminary benchmarking study analysing the environmental and social performance approaches used in three developed-country environmental IO models as case studies: the United States, Australia and Portugal. It is then proposed that environmental and social performance metrics, where possible, be combined with conventional LCA and Life Cycle Costing (LCC) approaches for economic flows at a sector level to compile the IO model and database for ‘hydrogen infrastructure’ as a sector with ‘production’, ‘storage’ and ‘transportation’ as sub-sectors. In this manner, environmental and social data for South African hydrogen infrastructure products can be computed. This approach is expected to significantly improve the marketability of South African hydrogen infrastructure products internationally. Furthermore, by comparing the environmental and social profiles of South African products with those of other regions that apply such a standardised approach, product improvement requirements may be highlighted to prioritise further product value chain oriented R&D.

OR 65 Assessment of sustainability of national energy scenarios

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Energy is deeply intertwined with economic, environmental and social issues of sustainable development. While certain forms of energy production and consumption can diminish environmental sustainability, energy is crucial for economic growth and social upliftment. To this end the South African government initiated a study to develop a tool to assess sustainability of energy scenarios at the national level. The tool is based on the Long-range Energy and Alternatives Planning (LEAP) energy planning system. It is based on the LEAP software which is freely available for research, government and NGOs use and has been used in over 160 countries. The developed system quantified the national energy demand for domestic, commercial, transport, industry and agriculture sectors and supply of electricity and liquid fuels and the associated emissions. The LEAP system was developed for South Africa and populated with detailed input data for the base year 2005 and for a limited number of plausible future scenarios that may have significant implications (negative or positive) in terms of environmental impacts. Three scenarios were modelled: a reference scenario, a low carbon development path and an oil peak scenario. A comprehensive analysis of indicators used internationally and in South Africa was conducted and the available data was accessed to select a reasonable number of sustainability indicators that could be utilised during the energy planning processes. A consultative process was followed to determine the needs of different stakeholders on the required indicators and most suitable reporting. A set of ten indicators measuring the economic, social and environmental performance of the national energy sector, as well as energy security, were proposed, tested and quantified. The suggested group of indicators were incorporated into the LEAP system and a number of reporting formats were added that describe clearly the positive and negative impacts of projected changes in the energy sector for the selected scenarios. The developed system is suitable for municipal, provincial and national planning processes and it is recommended for adaptation for routine reporting by government and for any large energy related project as a part of an environmental evaluation. The application of the enhanced LEAP system helps to quantify sustainability and will promote integration of sustainability considerations into the preparation and adoption of policies, plans, programmes and projects. A one shortcoming identified is that there as yet are no targets for sustainability indicators in South Africa and therefore no performance assessments could be done. Nevertheless three of the indicators were used for international benchmarking: GHG per capita; electrification of low income households, and energy productivity. Although LEAP has been used widely in South Africa for energy planning at municipal, provincial and national levels, this study is the first application for sustainability assessment. Recommendations are made to develop the tool further.

OR 66 Implementing Ecodesign for Single-Use Products: Combining LCA and Functional Characterization

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One of ecodesign's guiding principles is to increase the useful life of a product. However, in the case of single-use products such as personal hygiene or sterile medical products, this principle simply does not apply. Designers require methodologies to analyze and improve this type of product. One of the best available tools for ecodesign is life cycle assessment (LCA), however, only a few case studies concerning single-use products have been published thus far and even less on ecodesign examples. To analyze this type of product, it is essential to dissociate the main and secondary functions (e.g. absorption, filtration, sterility, durability, low cost, maintenance time and effort to reuse). These functions allow the understanding of the reasons why products have been designed to be used only once. For example, the sense of cleanliness and the discretion are key characteristics for incontinence pads based on the users' perception.

A case study of a single-use product has shown that these functions are already taken into account during regular improvement process. In order to avoid reducing the ecological footprint by reducing the functionality of the product, they must be characterized during the ecodesign process. However, it is difficult to include these functions into LCA, especially the qualitative ones. Therefore, an ecodesign methodology that considers qualitative functions

and the environmental life cycle has been developed. This methodology is based on the Eco-functional matrix developed by Lagerstedt et al. at the Department of Machine Design of the Royal Institute of technology (KHT). It has been developed to be used at the early design stage but it can also be useful for the case of existing products. The proposed ecodesign methodology combines the Eco-functional matrix and Screening LCA. The main steps of this methodology are 1) to identify existing product functionalities, 2) to identify environmental hot-spots, 3) to generate improvement options and 4) to create environmental rules based on the Screening LCA results. This will help designers to understand the influence of the product's improvements not only in terms of the environmental impacts but also in terms of functionality.

OR 67 ecoSpold version 2 – An improved data exchange format

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The ecoSpold data format is the most widely used data exchange format for Life Cycle Inventory data worldwide, implemented in all leading Life Cycle Assessment software. A new version 2 of the ecoSpold format has now been developed and is presented here to the public for the first time.

The ecoSpold data format version 2 have been developed to further facilitate database maintenance and extension (including forecasting), provide better support for alternative modelling options (e.g. consequential and attributional), and support for mass balances, energy balances and monetary balances, language versions of text fields, and better documentation. Facilitating data exchange with the ILCD format has also been among the considerations in the development.

The main improvements will be described, such as an option for parent-child relationships between processes, expressing geographical information using GIS coordinates, the use formulas and variables in numerical fields, the use of unique identifiers (UUIIDs) for internal references in datasets, options to declare multiple properties of exchanges, as well as options to use transfer and emissions coefficients. Issues of backwards compatibility and implementation will be touched upon.

OR 68 Land Use Impact Assessment according to biodiversity indicators in Brazil

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On the continuous effort to improve the Life Cycle Impact Assessment methodology in Brazil, the adaptation of current characterization models was made necessary. A specialists' panel, constituted by researchers within various fields related to LCIA regional impact categories (e.g. acidification, desertification, etc), was applied in order to figure out the hierarchic importance of models adaptation to the Brazilian environmental conditions. The result was the identification of main priority categories for adaptation, among them, land use impact category. Considering the global efforts on the development of indicators for land use impact assessment in LCA – biodiversity, ecosystem functions and services and ecological resources -, within Ecosystem Quality, biodiversity indicators were the one chosen for the assessment. The main reasons were its importance on sustaining ecosystem functions and the core need to focus the sustainability and conservation of Brazilian biodiversity. An evaluation of the existing models for land use assessment, according to biodiversity indicators, has been carried out. The aim has been to analyze the applicability of current mostly used indicators – and their weak points on the assessment - and check out the possible correlation of other indicators which could improve the analysis of land use occupation and transformation effects on biological diversity in Brazil. Further, the main types of land uses in Brazil were identified and the main focus was given to priority areas for the conservation of national biodiversity, as defined by the Ministry of the Environment. The main diagnostic elements available for the assessment were species richness, endemism, degree of threat, richness of rare and threatened species and the biological value of species. The result is the improvement of the LCIA methodology in Brazil and the contribution to a future and reliable application of LCA tools on the national context.

OR 69 Regionalization of life cycle impact assessment: geographic differentiation vs archetypes

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The regionalization of impacts in life cycle assessment is a topic of increasing interest. It can considerably increase confidence in results of 'non-global' impact categories, such as human health, ecotoxicity or water use. Regionalization reduces the uncertainty of generic characterization factors and enhances the accuracy of LCA. Several models have been developed to calculate characterization factors for specific regions in the world. However, because of the diversity and variations within each region, the number of situations required to calculate a specific characterization factor soon become computation and data intensive (e.g., regionalization based on country level already requires a calculation of about 200 CFs per pollutant and per media of emission). Rather than using specific global regions and sub-regions, another viable option is the approach of archetypes. This approach groups several regions with similar defining characteristics, such as population density (urban, rural, remote, etc.); ecoregions (temperate, tropical, boreal, arctic, etc.); water scarcity; etc. Such an approach can significantly reduce the number of regional characterization factors to be calculated, providing at the same time a simple and easy-to-implement solution for life cycle inventory modeling. To make this approach operational, different archetypes must be carefully defined and results must be compared with a geographically differentiated model to demonstrate to practitioners and decision makers that the results obtained with this approach are in line with a 'true' geographically regionalized approach.

Based on previous research focusing on regionalization, this work explores the discrepancies in results from the 'true' regionalized approach and the archetype approach for different impact categories (human toxicity, respiratory inorganics, ecotoxicity, and water use). For each of these categories, we propose a list of relevant archetypes and corresponding characterization factors, and we explain why the archetype approach proposes a practical solution toward addressing regionalization. This approach uses a multi-criteria (i.e., different impact categories) analysis and will help life cycle assessment better address the issue of regionalization when considering extended supply chains.

OR 70 Adding Lifecycle Assessment Information to Data Exchange Standards for the Electronics Industry

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The electronics industry has been evolving as manufacturing processes and supply chains respond to emerging global environmental regulations. These new regulations, aimed at protecting human health and the environment, have left the industry scrambling to come up with methods to ensure compliance. These methods require information to be exchanged between supply network stakeholders. For the most part industry, standards organizations, and governmental agencies have been able to create data exchange standards that can be used to address very specific regulations such as the European Union's Restriction of Hazardous Substances (RoHS) Directive. While this approach has had some success in developing individual standards, such as version 1 of the IPC-1752 material declaration standard, reacting to legislation is not a viable long-term option for the industry. Being reactionary, solutions often focus on the minimum requirements to ensure compliance leaving much of the potential to improve the entire electronic industry manufacturing process by the wayside. Companies that wish to go beyond regulatory needs and focus on issues such as lifecycle assessment, product management, and designing for sustainability have been left to find their own way. This does not have to be the case as it is possible to develop data exchange solutions that can provide greater flexibility and ease supply network information exchange. By using software development practices and developing analysis and design models for the different types of information that might be exchanged during the manufacturing process robust data exchange standards can be created to meet present requirements and easily modified to support future needs as they develop. This paper discusses this standards development approach and uses the IPC 1750 series of supplier declaration standard to add lifecycle assessment information to an existing supplier data exchange standard.

OR 71 Operational Analytical Uncertainty Propagation in Life Cycle Inventory and Impact Assessment: Application to an Automobile Front Panel

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Quantification and communication of uncertainties related to LCA results is vital for their correct interpretation and use. Operational uncertainty estimation methods for both inventory and impact analysis used to calculate measures of confidence for the superiority of one scenario over others, would greatly enhance the reliability of LCA studies and the trust in their outcomes. Routine uncertainty analysis is hampered by the difficulty of finding and assigning uncertainty and variability information to the usually numerous parameters and models used in LCA. So far, parameter uncertainty propagation has mainly been studied using Monte Carlo simulation which has several disadvantages related to 1) its need of computational resources, especially for the comparison of multiple scenarios, as well as 2) its instability for very large confidence intervals, and 3) the fact that it does not automatically assess the sensitivity and contribution of individual parameters to overall uncertainty. If performed at all, uncertainty assessment in LCA is often limited to research or to inventory only.

Using an explicit and transparent analytical approach based on Taylor series expansion for lognormal distributions and applying it to both inventory and impact assessment, this work demonstrates its application to single and multiple LCA scenarios. The latter accounts for dependency, because it is crucial in LCA to account for both common inventory processes and common impact assessment characterization factors between the compared scenarios. A method is proposed to easily determine a range and a best estimate of a) the squared geometric standard deviation (GSD2) on the ratio of two scenario scores, A/B, and b) the degree of confidence in the information that the impact of scenario A is lower than B (i.e., the probability that $A/B < 1$).

The approach is tested on an automobile case study for a front-end panel made of four different materials, and resulting probability distributions of climate change impacts are compared to classic Monte-Carlo-based distributions. Overall uncertainties from Taylor series expansion are virtually equal to those from Monte Carlo simulation, while being significantly simpler and differentiating between common and independent parameters, with GSD2 ranging from 1.09 to 1.77. The analytical method explicitly provides contributions of each parameter to overall uncertainty. For the steel front end panel, the factor contributing most to climate change score uncertainty is the gasoline consumption (>75%). For the aluminum panel, the electricity and aluminum primary production, as well as the light oil consumption, significantly contribute to the uncertainty. The probability that the climate change impacts of the steel panel are lower than the aluminum scenario varies between 0.02% and 7.9% depending on parameter uncertainties and dependencies.

The results demonstrate the feasibility of the analytical method and illustrate its simultaneous and consistent application to both inventory and impact assessment. The explicit and innovative analytical solution provides the contribution of each parameter to final uncertainty and strongly reduces calculation time. This detailed and modular approach is therefore a very relevant and efficient way to estimate an accurate overall LCA uncertainty.

OR 73 Dismantle or shred? Analytical tool for design for disassembly in electrical and electronic equipments

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With growing interest in recovering materials and subassemblies within products at the end of their lives, there has been an increasing interest in developing decision-making methodologies that determine how to maximize the economical and environmental benefits of end-of-life processing under variable end-of-life situations, i.e. disassembling, shredding, recycling and landfill, etc. Many researchers have tried to develop methods for detecting the optimum disassembly sequence for a given product by mathematical programming. Recently, Lambert made a great progress in developing a method to optimize manual disassembly sequence, which is based on a binary integer programming approach. In most cases of WEEE (waste electric and electronic equipments) recycling, some

valuable parts are primarily recovered by manual disassembly. The remainder of the product is then put into a shredder machine to recover materials used in the end-of-life products. However, few studies have been conducted to consider alternative end-of-life processes, i.e. shredding, recycling and landfill in their methods to optimize economical and environmental benefits of end-of-life processing.

This study aims to develop an analytical tool for WEEE to optimize the economical and environmental benefits of end-of-life processing. Case studies were conducted for WEEE to demonstrate our optimization tool. First, information on the product was prepared as a joint-part matrix from the structure, material, weight, type of connection in the product, and restrictions of order in which joints are disassembled. The joint-part matrix was converted to AND/OR graph by determining possible subassemblies, in which links between each parts or subassemblies were taken into account. Then the optimal disassembly sequence from view point of economic or environmental benefits was determined by the blind seeking method in which end-of-life processes, i.e. shredding, disassembling, mechanical recycling, and landfill were considered. Life cycle assessment (LCA) was used to evaluate the environmental impact of end-of-life processing in terms of CO₂ emissions. This tool can evaluate CO₂ emissions reduction potentials when the design of a product is improved by DfD and can be applied to all products.

OR 74 Using Life Cycle Thinking and Assessment for Industrial Waste Management Policy Making

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According to the Council Regulation (EEC) No 259/93 of 1 February 1993 on the supervision and control of shipments of waste within, into and out of the European Community, from sentences by the European Court of Justice one may deduce that restrictions to waste shipments to and from Catalonia can be applied, demanding that the environmental gain associated to specific a waste treatment option be larger than the inherent loss due to the same treatment, as established in Directive 2006/12/EC on wastes. Knowing the life cycle of certain waste flows could be a proper tool to validate waste management practices that are presented as a net improvement for the environment.

The Industrial Waste Management Programme of Catalonia (PROGRIC) is the regional authority's tool to establish the actions to be developed in relation to waste management in this Spanish region. The 2007-2012 PROGRIC gives continuity to the planning tasks initiated in 1994 with the Special Waste Programme and, more recently, to the previous 2001-2006 PROGRIC. In the last two revisions of the latter, the use of a life cycle perspective (and life cycle assessment) for waste policy was called for. Consequently, the Waste Agency of Catalonia contracted the GiCa research group at Escola Superior de Comerç Internacional (ESCI-UPF) in Barcelona to include a life cycle perspective within the next version of PROGRIC.

The aim of the project is to prepare a number of simplified mathematical models, applicable in a generalized way to a large variety of waste types, with the aim of helping the decision-making process of whether to allow the transit of specific waste flows from specific industrial plants. The models allow the company to find out the longest distance the waste should be allowed to travel from Catalonia, in order to receive a different kind of treatment from the one it would otherwise receive in Catalonia (many treatment comparisons are possible, but only four have been approached initially). In addition, for certain types of waste flows, like those which include solvents, the model allows the user to calculate the minimum solvent recovery yield needed to justify travelling a specific distance, e.g. from the industrial plant to the solvent recovery plant. Energy consumption has been used as a unified proxy indicator for the whole set of impact categories.

Parts of the models have been developed as full LCA studies, i.e. transport systems, while others are dealt with by using mean values or proxies. For instance, the energy required to produce any aliphatic solvent is calculated by using the isopropanol life cycle as a proxy; also, the energy consumption for solvent recovery is calculated as a mean of literature values. Therefore, the model is not strictly ISO 14044 compliant, although individual parts of it are. In fact, the almost infinite number of cases and combinations would make it virtually impossible to develop such a full model a priori.

Because of the required simplicity of the models, the legislation will then allow individual users to perform a full LCA of their own specific waste flows, in order to provide an alternative to the result produced by the simplified model, if the latter is not agreed upon.

OR 75 How LCA can help identify the right priorities in waste management for local authorities

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This work aims to assess waste management for households (including municipal and recycling wastes) from a life cycle perspective and identify critical environmental issues and responsibilities along the entire life cycle chain of household wastes. This LCA is oriented toward decision making and thus allows the consideration of the system expansion rule, by accounting for the avoided burdens of recycled material and energy. The results show that impacts and credits of waste management are mainly dominated by the processing, i.e., processes saving energy through incineration and saving material recycling. The transport represents less than 10% of the impacts (individual transport (4%) and transport truck for recycling or incineration (6%)). Lastly, containers used for collecting wastes generate 2% of the total impacts. Although the avoided burdens of material recycling are often higher than energy recovery (by incineration plants), there are some cases where this is not true, or at least where there is no significant difference between recycling and incineration. The results show, for example, that recycling is more advantageous for plastics and metals than for paper or cardboard (results for these last two are highly dependent on the incinerator performance and the type of electricity that will be replaced). It is also interesting to note that metals, and especially aluminum wastes recycling which represent a small proportion of total wastes in a household (1%), represent more environmental credits than the credits from the recycling of the rest of the household waste (potentially helping to avoid half of the greenhouse gas net impacts). Therefore, though metals represent only a small percentage of the unsorted household waste, priority should be given to metal sorting and recycling. In conclusion we demonstrate that the key environmental parameter for the decision maker is the choice of treatment option, with this decision more important than the impacts resulting from the collection and transport. Overall, the benefits of waste recycling are generally more beneficial than energy recovery in an incineration plant, especially if this latter is not extremely efficient.

OR 76 Impacts and potential of reuse and development of organic wastes in the French-speaking Switzerland

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The waste management area of La Côte (SADEC), based in the Lake Geneva Region of Switzerland tries to minimize the costs of organic waste management by being eco-efficient. This region is one of the fastest growing regions of Switzerland. More than two thirds of the actual waste could be capitalized upon instead of being incinerated. Indeed, incineration is still twice as expensive as other waste disposal methods. The real potential of household organic wastes (sum of decomposable wastes and green wastes) has been calculated for the region to be 17'000 tons, i.e., 40% more than currently reused. About 20% of waste in the region is composed of organic material, which could be collected separately and sent to be developed, a more cost and environmental friendly approach than incineration. Establishing a door-to-door collection of food wastes in the area is a practical possibility. A life cycle assessment of the different reuse chains can identify the least impactful and the most environment friendly. Beyond incineration, options include: field composting, industrial composting, dry biomethanization and wet biomethanization. The functional unit is one ton of organic wastes collected.

The results show that the critical issue is the water content of the waste. For incineration, the break-even point is 70% moisture. Beyond this level, incinerating organic waste creates more impacts than credits (from energy recovery). Below this value, incineration generates more credits than impacts. However, in all cases, composting and biomethanizing generate systematically more credits than incineration if the compost is used as fertilizer in agricultural fields in need of organic matter. Note that spreading the fertilizer in the fields generates less than 5% of the total impacts for the compost and bio-methanization alternatives. Incineration creates credits through energy

production. Composting produces credits through the substitution of compost for the fertilizers normally used in farming, called a farm bonus. Biomethanization gains credits both ways. The farm bonus is the most important credit and is linked to increased productivity, diminished erosion and carbon storage, which occurs when compost is spread (through composting or bio-methanization). However, this significant credit only occurs when compost is used in fields in need of organic matter and where it increases its productivity above what is achieved with simple NPK additions. With regard to the types of waste, it should be emphasized that the reuse chain is not as advantageous for garden wastes (which are around 50%-70% moisture) because the impacts are almost the same in all break down processes. On the other hand, food organic wastes (70%-90% moisture) should not be incinerated. Indeed, because of their moisture levels, a significant amount of energy is needed to evaporate all of for the water. The emphasis should be on increasing the collection of food waste and their reuse in a process such as bio-methanization.

OR 77 An integrated concept for assessing policy instruments for a more sustainable waste management

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An on-going Swedish research program, Towards Sustainable Waste Management (TOSUWAMA), funded by the Swedish Environmental Protection Agency during 2006-2012, aims at formulating new waste policy instruments that may contribute to the development of a more sustainable waste management, shifting waste management towards the upper levels of the waste hierarchy. TOSUWAMA is an interdisciplinary research programme in which many different aspects of waste management - environmental, economic, cultural and social - are studied. Seeking the broadest scope possible, economists, ethnologists, environmental psychologists, systems analysts and futurologists carry out the research in close co-operation.

The primary target groups for the findings of Towards Sustainable Waste Management is the Swedish Environmental Protection Agency and other policymakers in the field of waste management at European, national, regional and local levels, recycling companies, waste management companies and R&D organisations in waste management.

TOSUWAMA surveys existing and potential policy instruments and formulates and evaluates promising instruments. An important part of the assessment is made through refining and combining a set of existing, quantitative tools:

- the Environmental Medium term Economic model (EMEC), a general equilibrium model of the Swedish economy
- NatWaste, a systems engineering model of the Swedish waste-management system, and
- a life cycle assessment (LCA) tool, developed for the purposes of TOSUWAMA to take into account environmental impacts of waste management from "cradle-to-grave".

Such an integrated concept of tools presents a powerful way of exploring and understanding in depth the possibilities of waste management to contribute to a more sustainable waste management from a life cycle perspective, and how this can be achieved through a range of different types of policy instruments. Scenario analysis is used to deal with the large uncertainties inherent in the long-term future: each policy instrument is assessed in four different scenarios with different assumptions regarding the future development of external aspects of politics, economy, technological development etc.

At the end of the year 2008, a list of 57 policy instruments had been compiled, ranging from fiscal instruments, such as taxes and subsidies, to "soft" instruments including support for various cooperative solutions. The actual assessment of policy instruments will begin in mid 2009. Assessments cover, with a few exceptions, all generated waste flows in Sweden. This means that in total 20 sectors (19 industrial sectors and households) and 48 waste types (hazardous as well as non-hazardous) are covered.

We will present our insights so far in combining LCA with other tools for analysing policy instruments for

sustainability as well as some early quantitative results, with a focus on assessing policy instruments from a life cycle perspective. The ultimate goal of the research programme is to provide useful input to actual decision-making and strategy development which can lead to a more sustainable waste management.

OR 78 LCM of Olive Oil Extraction Wastes in EU

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Olive oil production represents a food market segment relevant for the European Union (EU) 82,5% of the world olive oil production takes place in Europe, i.e. 2.28 vs. 2.76 million (M) tons. In Europe more than 12M tons of olives are annually produced (mostly in Mediterranean area) and processed in ca. 12.000 mills, involving 800.000 jobs. Olive oil extraction has been, and still is, a highly water-demanding and polluting activity, although the use of 2-phase decanters has slightly improved the process, giving rise to 800 kg of slurry waste per ton of olives. In EU more than 8M tons of water are used for processing, giving rise to 4.6M tons of liquid waste (OOLW) and 6.8M tons of solid waste (OOSW; ca 60% humidity). The possible uses of the solid waste include land filling, composting, feed for cattle, anaerobic digestion, combustion, pyrolysis/gasification. However each use presents some disadvantage: (bio)gasification is cost-ineffective, the feed has low protein content and bitter taste, combustion produces air pollution, land filling reveals to be toxic for soil. Composting has been recently achieved, and the process is here reported, through the use of appropriate microbial strains, isolated from decaying ligno-cellulosic material. The selected microorganisms are different strains of yeasts (*Rhodotorula*, *Pichia*, *Sporopachydermia*), filamentous fungi (*Trichoderma*, *Chaetomium*, *Arthrotrichy*, *Phanerochaete*), bacteria (*Pseudomonas*, *Bacillus*, *Serratia*), and filamentous actinobacteria (*Streptomyces*). They are able to decompose the OOSW in 90-120 days to give a high-quality odourless compost rich in humic substances. One disadvantage is the decrease of weight due to CO₂ production, up to 40-50% with respect to the starting material. These findings open new perspectives in the choice of the management strategies for a sustainable use of OOSW as a renewable biomass. Pros and cons of the different uses are comparatively discussed in terms of sustainability, cost effectiveness, energy recovery and thermodynamic. Compared to uses of the solid waste as an energy and feed source, the composted OOSW can be regarded as a useful organic matrix for flexible uses, including soil bioremediation, plant protection, and plant growth stimulation. If anaerobic digestion will prove in the future to be feasible and cost-effective, the digested solid by-product could be further processed via co-composting to upgrade its technological and agronomic value.

OR 79 Findings for LCIA and LCI in the mining sector – A regional approach from South America

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South America is rich in mineral resources and the first world producer region of several engineering and luxury metals, such as copper, iron, tin, silver and gold, among others. Moreover, to some South American countries the mining sector represents an important part of their national GDP. Although the mining industry in these countries has dramatically advanced toward cleaner production and social responsibility, there is a gap in terms of its perception about its position and the capacity to influence the improvement of the environmental impacts of the whole production chain in which it is involved. In this context, the South American Project of Life Cycle Assessment for a sustainable mining production (PROSUL), has conducted different studies to better understand the site specific and generic aspect of the industrial and artisan mining, with the objective to set up a baseline to further assess the environmental impacts and produce models oriented to systematically and continue improving the mining production systems.

This paper outlines recent work of PROSUL and results achieved during 2006 and 2007 of joint work between three of the major mining countries of the region, Brazil, Chile and Peru, in the field of copper and gold LCIA comparative studies and LCI databases. In case of copper production big-scale mining sites were researched and life cycle impact assessments elaborated. Specific goals of the copper study was to establish main characteristics of a LCA modelling for primary metal production in South America by identifying, through a gate to gate comparative study, main

generic and local aspects. As for the gold studies, life cycle inventories for small-scale and artisanal mining were the focus of the research. The specific aim of the gold case study was to understand the relevance of the impacts from these activities in the South American region and to collect lessons on the elaboration of life cycle inventories for two artisanal and small scale mining operations under poor-data scenarios. In both case studies amalgamation with mercury was the key process to concentrate gold. Conclusions and lessons learned are drawn as well as an analysis about their applicability in other mining sectors of the region.

OR 81 Research for Low LC-CO₂ Consumption using by Importance-Performance Analysis

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In Japan, CO₂ emission, especially the emission related to the consumption behavior, is actually increasing. The realization of alternative lifestyle with low CO₂ emissions is essential to decrease CO₂ emission. Therefore, many institutes are proposing some alternative consumption behaviors. However, most of behaviors have the following problems. First, these only focus on "direct CO₂ emissions" which is directly emitted from the households by residential electric power and city gas consumption and fuel consumption of private cars. But, from the viewpoint of life cycle, most of greenhouse emission by industries, transportation, and businesses are derived in the process of production and shipping of home consumer goods and services. In a word, it is also necessary to consider indirect emissions.

Second, such alternative behaviors are not practiced easily. One of the reasons is that such behaviors, while beneficial to environment, have disadvantages, tend to require extra work or are bothersome. To put it differently, to increase consumers' voluntary awareness to change their daily behavior against global warming, it is important to suggest alternative behaviors that address their concern or provide satisfaction through actions while reducing CO₂ emission. Considering then, the purpose of our research is to search for potential behaviors that decreases Life Cycle CO₂ (LC-CO₂) emissions and achieves consumer's demand. To achieve this purpose, we adopt marketing science techniques, social psychological approach and Life Cycle Assessment (LCA). First, we investigated consumer's demand and dissatisfaction about various behaviors in daily life. Meanwhile, we research the behaviors that substitute the extracted behaviors with low LC-CO₂ emissions. After that, we examine people's evaluation on specific alternative behaviors using by social psychological approach.

In this presentation, we introduce the first phase which examine about consumption behaviors which cancels consumer's dissatisfaction and achieves their demand by using the marketing science technique. Importance-Performance analysis which is one of marketing techniques identifies improvement point of goods and services. We investigated the level of importance and satisfaction about various behaviors in daily life using by this analysis. The consumers evaluate behaviors on clothing, food, housing, transportation, housework and leisure. Each behavior is placed into one of the four quadrants, which are of the importance-performance grid. The behaviors that are placed in the quadrant of High importance & low satisfaction of this matrix are that the consumer has strong dissatisfaction and demand. This behavior group is a target by which we propose alternative behaviors with low LC-CO₂. The result of Importance-Performance analysis is planning to present at the conference.

OR 84 Practical consequences of different interpretations of the Area of Protection 'resource depletion'

*An De Schryver
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Within Life Cycle Assessment (LCA) the development of the impact category 'resource depletion' is less mature than emission related impact categories. The environmental effects of mineral and fossil resource depletion are considered by several Life Cycle Impact Assessment (LCIA) methods, but the way of covering these impacts is still under discussion. Within the project "Analysing existing LCIA methodologies and existing approaches" (commissioned under the European Platform on Life Cycle Assessment and coordinated by the European Commission's Joint Research Centre in collaboration with DG Environment), a recommended preferred model

had to be selected. During the process of analysing and evaluating the most interesting existing resource depletion characterisation models, several conceptual differences between the methods were encountered. A lack of consensus on the interpretation of the Area of Protection resulted in several discussions and the question “what does society actually want to protect?”.

In this presentation we outline the practical consequences of the different interpretations of the Area of Protection ‘resource depletion’ reflected in different methodologies. Six different impact assessment methods, namely EDIP 2003, CML 2000, EPS 2000, Exergy, Eco-indicator 99 and ReCiPe 2008 are included in the analysis. All methods cover the impacts of non-renewable resources depletion minerals and fossil fuels but apply their own modeling principles and position on the environmental cause-effect pathway. The exergy method relies on the physical properties of the resource and therefore is located at the start of the cause-effect pathway. The CML 2000, EPS 2000 and EDIP 2003 methods are based on the use to stock ratio, while Eco-indicator 99 and ReCiPe 2008 look at ‘the increased efforts that future generations need’ as basis to determine the characterization factor for resource depletion. For a range of ecoinvent processes, covering several product groups, the resource depletion impact category indicator result is calculated using different impact assessment methods. For each product group, the differences in results due to different modeling principles are presented and the reasons behind are explained.

The results indicate that the chosen methodology can determine the results and change the ranking of the different processes analyzed. A high rank correlation between methods implies low changes in product ranking. For example, for construction materials we found a high ranking correlation (0.98) between the EPS2000 and EDIP2003 resource depletion damage scores, while the ranking correlation between the exergy and EDIP scores was lower (0.85). We outline and explain the conceptual differences between the methods responsible for the differences in results and based on this summarize future research recommendation and needs.

OR 85 Simulation based life cycle assessment and capital cost estimation to guide sustainable bioprocess development:

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In the development of a chemical process, simulation can be used to enhance our insight and understanding of the process and aid in identifying bottlenecks and potential improvements. The task of the simulation model is to serve as a quantitative and qualitative tool in early stages of development to generate estimates on which sound decision making can be based. The case study compares the industrial production of citric acid using the alternative substrates beet molasses and starch as the main raw material input. The overall task is aimed at bringing together various tools for sustainable bioprocess assessment in early stages of process development. A generic flow sheet simulation model, developed and implemented in MS-Excel, is used for the first estimation of material and energy balance calculations of the processes. The results of the generic flow sheet material and energy balance calculations are used as the inventory data for a Life Cycle Assessment (LCA) of the processes. In addition, the process capital costing is estimated by variant-based cost estimation using order-of-magnitude estimates. The study showed that rapid simulation of a process using the generic flow sheet approach and subsequent evaluation of associated environmental burdens using LCA allowed for the identification of process hot spots. Mitigation of environmental burdens can be achieved by comparing alternative processing routes in early stages of process development and quantifiably supporting decision making toward a more environmentally benign process. In addition to potential environmental benefits of process alternatives, decision making is supported by considering the cost trade-off of the process options. Process profitability and the sensitivity thereof is evaluated by integration of the environmental assessment and capital costs estimations in the process sustainability evaluation. It is shown that early process simulation and environmental and profitability evaluation can reduce future environmental burdens and capital expenditure. Assessments in early stages of process development can contribute to a robust and simplified approach to improved sustainable process development.

OR 86 **Managing global value chains – linking emerging and developed markets with knowledge-based Web-Portals**

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This paper describes the concept, the design and the future implementation of a knowledge based internet portal - ECORADAR Shakti India - aimed at small and medium sized enterprises of the Indian megacity Hyderabad. The portal sets out to use the simplest and most persuasive means to motivate and enable sustainability management in those enterprises that have so far taken little or no interest in this aspect of management. The issue is how to manage global value chains with the knowledge-based web-portal. The motivation for the cooperation of the SME is to create a global value chain, which links emerging and developed markets with knowledge-based Web-Portals. By this, the results shown in this paper build a bridge between the topics sustainability, international cooperation and knowledge management.

Hyderabad, a prime example of an emerging mega city, is a laboratory where the goal of becoming a sustainable megacity faces of difficult challenges. The intention to work towards a sustainable future will be difficult to achieve without adequate data, tools and implementation strategies - so "How can the development of future mega cities be manageable in a sustainable way?" The research idea of this approach in Hyderabad was set up in a research programme funded by the German Federal Ministry of Education and Research (BMBF).

In the **first part** the Ecoradar-framework as originally developed for the German market is presented. The framework is aimed to combine external (e.g. expert knowledge, market information) with internal (e.g. process & tools) knowledge content. Internal and external cooperation support for staff-members is another feature provided by ECORADAR. The framework was developed cooperatively by a workgroup of scientists, practitioners and experts. The knowledge content is structured in a way to directly support the objectives and processes of the European Union's **Eco- Management and Audit Scheme** (EMAS) as well as the internationally accepted *ISO 14000 environmental management standards*. These two environmental management standards were conceived to strengthen and promote a self-responsible dealing of SMEs with environmental issues in contrast with a strong regulation framework induced by governmental authorities.

ECORADAR is based on a dual concept of *Knowledge Management*. A *Knowledge Warehouse* builds the core of the portal. It is mainly fed by either external or internal experts providing explicit procedural knowledge focused on the actual processes of environmental management (= People to Document). A Knowledge Network supports the application of tacit knowledge by offering means to transfer knowledge between the users (= People to People).

The **second part** deals with the specific requirements of SMEs in India related to sustainability management. We summarize the results of our preliminary research work in Hyderabad. As expected, sustainability management does not play a major part in Indian SMEs today. A poor knowledge base within the companies meets with a likewise poor information supply by local authorities and chambers of commerce. Even worse, the strategic role of sustainability management as a means to cut costs and to achieve a better strategic positioning in export markets is not widely recognized by Indian SMEs.

The **third and last part** describes the basic design principles applied to an ECORADAR-Knowledge Portal aimed at the community of SMEs in the city of Hyderabad. The design principles must take into account the specific situation found on-site. A 1:1 transfer of the methods applied in the German project is not feasible. Among others, four issues are especially emphasized:

1. The cost-cutting potential as well as the fast growing strategic importance of sustainability criteria in mature markets as represented by Europe and the US should both be addressed in a suitable manner. Otherwise the motivation for SMEs to become part of the community is expected to be low.
2. While in Europe the communication between local and national regulating authorities is generally well practised, this is not the case in India, at least this is true related to environmental management issues.
3. The still lower knowledge base of Indian SME in advanced managerial expertise in the area of environmental and other advanced management systems like quality management has to be taken into account when designing knowledge content.

4. While social and health issues are strongly regulated and therefore are playing a minor role in mature markets like Germany, in India the situation is seen different. Having in mind the efforts of sustainable developments the social part within the sustainability triangle balancing economic, social and ecological criteria has to make up some ground. This will have to shift the current knowledge contents focus from environmental to social criteria.

The article closed with a brief summary of the current project state and an outlook to future activities.

OR 87 TOSCA - Towards Sustainable Supply Chains

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Social and environmental concerns are increasing in both scope and severity. Ecosystems are experiencing a decline in productivity and both the quality and quantity of resources are shrinking as the human population and its consumption levels increase. Companies have been increasingly called upon to assume greater responsibility for social and environmental impacts throughout their supply chains, and if businesses wish to prosper in the future, they must respond. To this end, to be competitive in the envisioned sustainable society, companies need to integrate sustainability aspects in their strategic as well as daily work and also in their communication within the supply chains. Procedures for this integration, based on life cycle thinking, provide prerequisites to decouple environmental pressures from economic growth.

The TOSCA project – “Towards sustainable value chains through a common approach for company strategic work and daily operations” - is jointly funded by the EU LIFE+ programme and AkzoNobel, SCA Hygiene Products and Chalmers University of Technology. AkzoNobel and SCA Hygiene Products have a long tradition of working with sustainability and life cycle management. Through co-operation and with help from Chalmers University of Technology, both companies will in this project further improve and strengthen the work towards sustainable development, as well as disseminate experiences from such work to the outside world. The TOSCA project will formulate and disseminate a systematic approach to how a company can work towards sustainable development, both within the company and in its supply chains. The approach will build partly on the tools presented in the EU LIFE project DANES (2002-2005), but TOSCA will put the tools into the wider context of sustainable development.

The project includes different work packages:

- Within the companies and their supply chains, an inventory and assessment will be made of:
 - tools and data used to assess and track sustainability aspects,
 - communication practices concerning sustainability information, and
 - strategies in the work with sustainable development
- Based on the inventory, a systematic approach will be formulated to describe how a company can work towards sustainable development, within the company and in its supply chains.
- The approach will be introduced in AkzoNobel and SCA Hygiene Products and in their supply chains. This systematic approach will be described on the project website, both through an interactive learning tool and through presentation of experiences from applying the approach. By increased co-operation in the supply chain, engaging both suppliers and customers, a substantial improvement of the overall environmental performance is expected.

OR 88 Promoting Life Cycle Thinking in School Environmental Education: Visualization and Recovery of the Missing Link Towards Sustainable Consumption

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Creating a sustainable society requires changes in people’s consciousness and lifestyles in addition to the development of technologies and use of economic incentives. Environmental education has an important role

to play in promoting people's environmental awareness and responsible actions. The goal of this study is to develop teaching material and program that demonstrates the importance of the life cycle thinking as an essential component of effective environmental education.

Focusing on the current situation where daily consumption activities are not linked, in a cognitive sense, to production activities and the natural environment, this study proposes a hypothesis that to recover the "missing links" based on life cycle thinking will contribute to an increase in pro-environmental behavior of consumers. Based on this hypothesis, environmental education material was developed that aims to make people realize the "link" between daily life and global warming through the life cycle of consumer products (e.g. mobile phones, notebooks, pens). In order to visualize and effectively recover the "missing link", LCA software "Global warming even in your bag?!" that runs on a personal computer and is easy to handle was newly created as the core of the material.

The material developed was applied to an education program for high school students, and a questionnaire survey was conducted to evaluate the effect. Analyses of the survey data indicated that the material is effective in making the students realize the "link" between their daily consumption activities and global warming as well as encouraging behavioral intention towards pro-environmental behavior. In addition, the analyses found that the possibility that the realization of the "link" helps boost their sense of responsibility and improves behavioral intentions toward the carbon dioxide reduction.

The use of life cycle thinking in environmental education is considered effective in encouraging people to engage in more pro-environmental behavior. In the future, first, the authors will more appropriately measure the effects of the material developed and elucidate the mechanism of behavioral changes of students. Second, we plan to improve the material from a practical perspective, and provide a material package available for school education.

OR 89 Sustainability in the supply chains – analysis of current work practices and way forward

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The TOSCA project – "Towards sustainable value chains through a common approach for company strategic work and daily operations" – has been launched in response to the need for more effective progress towards sustainable development. The project is jointly funded by the EU LIFE+ programme and AkzoNobel, SCA Hygiene Products and Chalmers University of Technology, and will run 2009 through 2011.

AkzoNobel and SCA both have a long experience of applying life cycle assessment (LCA) in product development and production improvement. LCA results are also used in market communication through e.g. environmental product declaration. Other tools in use are e.g. environmental impact assessment, eco-efficiency assessment, and environmental risk assessment. By further work in this area, the companies want to strengthen the co-operation within their supply chains, in order to improve the overall environmental performance and, furthermore, to create a common view on sustainable development and how each actor in the chain can contribute to it.

The TOSCA project will formulate and disseminate a systematic approach to how companies can work towards sustainable development, both within the company and in its supply chains.

In the initial phase of the project an inventory and assessment will be made of:

- tools and data used to assess and track sustainability aspects,
- communication practices concerning sustainability information, and
- strategies in the work with sustainable development

Thorough surveys on data handling and current work practices are presently being performed in the participating companies. In addition, data and information are being collected from the web pages of each company, existing environmental and sustainability documents, and through in-dept semi-structured qualitative interviews with key persons in the companies. This will be complemented with a state-of-the-art description based on contacts with external parties and research.

Results from the inventories show that both companies apply a wide range of sustainability tools; the preliminary list including 45 tools. These have tentatively been categorised into management tools (e.g. key performance indicators

and sustainability targets), assessment tools (e.g. life cycle assessment and environmental risk assessment), communication tools (e.g. websites and sustainability reports), supply chain tools (e.g. supplier audits and assessments), data management tools (e.g. internal databases for environmental data), and social and employee management tools (e.g. community programs).

Results on communication practices and sustainability strategies rest largely on the interviews being performed in the two companies. As the series of interviews is not yet completed at the time of writing this abstract, these results cannot be presented here, but will be included in the oral presentation at the LCM conference.

OR 90 Research and development needs for methods and tools within sustainable product management

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This work has been carried out to identify how stakeholders want life cycle approaches in general, and the LCA tool in particular, to develop in the future to become more useful in sustainability decision making, in particular relating to product management. The work was part of the project CALCAS within the Sixth Framework Programme of the European Commission. This survey targeted the following main groups of stakeholders in the EU: Public authorities, Business (industry, retailers), NGOs (incl. consumer associations), and R&D programmers (national funding organizations and research institutes). It was found that industry wants to use LCA tools in the future primarily for strategic decisions within the company, direction for business and product development. For many companies it is important to have a strategic position as a green company. It is also very important for the industry to use sustainability analyses to compare/competing equivalent products to inform consumer choice and for internal information. It was also found that LCA is not frequently applied in public decision-making. It was however stressed that life cycle approaches are needed in public decision-making when addressing, for example, the precautionary principle and in setting the best solution at a given time. LCA was thought to provide some solid scientific evidence, as support to such decision-making situations. However, challenges remain regarding capacity building, both in how to apply LCA for a given policy target or how to interpret LCA results.

Several strong messages have emerged across the stakeholder groups about the use of life cycle approaches and its challenges, and about future development and visions on how they want life cycle approaches to develop to become more useful as sustainability decision support. While the life cycle approach are used on a fairly regular basis in business, compared to their use in public authorities, NGOs and R&D programmers, comments on, i.e. challenges and future needs of life cycle approaches were also more frequent from business stakeholders.

The priority messages regarding life cycle approaches and its challenges are:

- ISO-LCA is considered to be an “expert model” which takes too long time and the results are often complicated
- too few are interested in the results of an full LCA, and
- difficulties to find methods that meet actors’ needs.

The priority messages regarding future needs and evolution of life cycle approaches are:

- simpler interfaces (adapted to the required application or sector),
- clear standards for data gathering,
- less time consuming models,
- greater transparency,
- integration of economic (& social) elements in LCA models, and
- data representative to different levels of resolution (geographical coverage)
- better modes of communication of results from LCA and other LC tools

OR 91 Stakeholder engagement within the sustainability assessment of bioenergy: case studies from the UK

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The progress of the fledgling UK bioenergy sector is held back by the slow development of the market and supply chains for biomass, resulting in part from potential market entrants' and other stakeholders' unfamiliarity with its emerging technologies, and in part from lack of coherent policy support. The nature of the sector demands mutually reinforcing activity on local, regional and national scales. Assessing the sector's sustainable development requires life cycle thinking and evaluation (including the application of environmental life cycle and economic supply chain approaches) in policy development and management. This suggests the need for participatory processes involving producers, consumers, other stakeholders, members of the public, experts, regulators and policy-makers.

TSEC-BioSys is a UK-based consortium research project that addresses the development of the sector from economic, environmental, social, regulatory and policy perspectives. A participatory sustainability assessment framework is being developed and tested, based on systems thinking and approaches and using stakeholder engagement methods derived from Multiple Criteria Decision Analysis (MCDA). A series of case studies and workshops is being used to test the framework.

We describe here the initial development of sustainability objectives and criteria from focus groups on (1) woodfuel for heat and co-firing for electricity generation and (2) perennial and annual energy crops for heat and electricity generation. The focus groups were composed of local producers, consumers, other stakeholders, members of the public, experts, and regulators. Each lasted for one day. During the focus groups, issues of concern, objectives, and sustainable development evaluation criteria for emerging bio-energy systems, as well as barriers and drivers to the development of the sector were elicited from the participants. The workshops revealed that some chains are resource-driven (i.e. the availability of the resource is the driver for supply chain development), while others are demand-driven. These situations were considered to be sufficiently different to merit discussion in two subgroups. Considerable variations in issues of concern, objectives and evaluation criteria were found between the focus group cases and among the participants in each subgroup. Although the information gathered was informative for the development of the emerging sustainability assessment framework, it is concluded that with such a diversity in perceptions and perspectives among stakeholders more creative and possibly novel approaches to problem structuring (including techniques for problem identification and system description) are required. Subsequent work on this project has thus focussed on the development of (1) problem structuring processes to enable actions from descriptions, and (2) ways of describing actions within "narratives" or storylines.

OR 92 Integration of LCM in Urban Planning as a Tool for Diminishing Greenhouse Gas Emissions: the Case of Concrete Sidewalks

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Although much attention on mitigating climate change has focused on alternative fuels, vehicles, and electricity generation, better urban design represents an important yet undervalued opportunity. In fact, it can be said that it is in cities where the concept of sustainability must, in the long term, succeed or fail and, at the same time, where there is larger room for change and improvement. In this context, there is a need for guiding the design process with solid and objective environmental tools such as Life Cycle Assessment (LCA). LCA is a tool that has been widely used to assess the ecodesign of products of mass consumption. However, there are very few experiences where LCA has been applied to guide the city planning and infrastructure design. Considering international papers published on LCA, the number of articles devoted to urban and infrastructural issues are one order of magnitude lower than papers devoted to product, process or system analysis.

Noticeable steps towards greenhouse gas (GHG) mitigation can be done in the short term, especially if we focus

on the public space of cities. Obtaining environmental gains from actions on the building stock is a crucial but slow process due to the multiple and private properties. However, ecostrategies on the public space are easier to apply, provide a close example of urban environmental management to the citizens, and represent an important share of the urban surface with a considerable use of materials. Fortunately, these spaces are well within the reach of local governments and leaders and can reduce long-term carbon emissions.

The objective of this paper is to determine the potential saving of GHG emissions that could be achieved in an urban scenario adjusting the sidewalk characteristics to the functional requirements, based on the quantitative results of the Life Cycle Assessment (LCA) of concrete sidewalks presented by the same authors. According to the types of sidewalks that are currently installed and the backpack of GHG emissions associated to the life-cycle of each of them, the contribution to the global warming potential originated in the sidewalks of an urban area will be quantified. A new urban planning that diminishes up to a 75% GHG emissions from the lifecycle of concrete sidewalks is possible thanks to the integrated application of quantitative tools like LCA, and the premise that infrastructure in the public space has to be suitably adapted to the functions fulfilled.

OR 93 A cross-neighbourhood life-cycle approach in urban planning: case study of Estonia

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Life cycle assessment and management could serve as an invaluable tool for assessing environmental sustainability of urban planning. The life-cycle approach is a source for new knowledge about urban spaces, their ecology, the material and energy flows. This study advocates for integration life-cycle assessment under a framework of urban planning. The current wave of suburbanization is very expansive and has the sprawling pattern in Estonia alike in other Central and Eastern European countries. Urban problems shift to suburban and rural surroundings both in environmental and economic aspects, and on account of this, the area life-cycle assessed should be defined as city region. Our study aims to adapt LCA methods for urban energy and substance flux, focusing on residential sector and households. The life cycle approach screening inputs such as material, energy, water is applied on a city region level.

Survey is carried out in the mid-size regional pole Tartu, Estonia. Tartu's neighbourhoods fall roughly into three types, forming a centre core, including archetypal historic wooden housing neighbourhoods, Soviet-era apartment buildings, and an expanding single-family-dwelling's settlements representing three generations of urban living, i.e. life-cycles. Neighbourhoods are the scale of most people's daily life activities and form an important part of the city system. The direct and indirect impacts in the life cycle of goods and services consumed by households are assessed through urban neighbourhoods. Household consumption is related to the urban shape and pattern, location, design and other features of houses. This applies to energy use for all household operations, transport, and lifestyles. Three life-cycle consumer categories are assessed related to residential, housing-related consumption. The first is energy consumption with regard to heating and operating housing. The second is material and energy consumption of household in order to operate a housing unit reflecting consumption pattern of its residents. Third, everyday travel, the most prominent feature of suburban consumption patterns is the huge increase due to recent suburbanization and motorization. The density ratios play crucial role. The downtown mixed use core is quite dense. The neighbourhoods of the Soviet era blocks feature medium-density housing, and neighbourhoods in the fringe are built at very low densities. The primary energy mapping of neighbourhood is elaborated. The model provides valuable information for the development of life cycle management strategies for the sustainable urban planning. The total growth of environmental impact of city dwellers is expressed in the increase of ecological footprint, specific resource and energy consumption.

The results showed that energy use and efficiency is closely related to the location, the physical and structural properties of model neighbourhood, housing type, and lifestyle characteristics derived from socioeconomic and socio-demographic reference data on the individuals living in the neighbourhood. The increase of built land and infrastructure happens as a rule at the expense of arable land, natural or semi-natural areas. One fundamental principle of sustainability and life cycle is the secondary use and re-utilisation of urban environment, which is still rare and exceptional. The prevention of urban sprawl, for example, by creating settlements with mixed building

types, offers environmental advantages, as the life cycle cost per person of land use, transportation and heating is smaller. So far we can notice in traditional urban development uncoordinated land-planning mechanisms at various planning levels, ad hoc practice, modest use of life cycle approach limit sustainable development of urbanizing areas leading to functional confrontations and affecting cohesion of infrastructure and green network.

OR 94 Housing Energy Performance: Case Study

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The Directive 2002/91/EC - Energy Performance of Buildings Directive (EPBD) of the European Parliament and Council on energy efficiency of buildings was adopted, on 16th December 2002 and came into force on 4th January 2003. The EPBD is considered a very important legislative component of energy efficiency activities of the European Union designed to meet the Kyoto commitment and respond to issues raised in the Green Paper on energy supply security. The EC Action Plan for Energy Efficiency identifies energy efficiency in the building sector as top priority. The EPBD has a key role for realising the savings potential in the building sector, which is estimated at 28% and which in turn can reduce the total EU final energy use by around 11%. In Portugal the EPBD along with other related directives came into force in April 2006. The Portuguese regulations require that new buildings comply with minimum requirements on energy performance and must have an energy performance certification through which an energy efficiency label is attributed to the housing.

A building service life is normally expected to be at least 50 years. An energy-efficient design can led to considerable savings over its lifetime. Apart from reducing fuel and electricity bills, an efficient energy design can provide higher interior thermal comfort for occupants while being less vulnerable to the increase of energy costs. An energy-efficient design has to be planned from the beginning of the design phase until the end of the construction. It is extremely important to develop a study in the architectural phase of the project, to achieve a correct building orientation, the window and shadowed zone projection and high thermal performance of the envelope. Higher levels of envelope insulation than those required in the thermal building regulations are in many situations economically justified, with a solution with well distributed insulation against all the elements being more efficient, for example, a highly insulated floor with no roof insulation.

The aim of this paper is to present the study of the energy performance of an apartment block from its initial construction solutions and energy supply systems to varying improvement solutions. The energy savings and the CO₂ emissions reduction well as the cost-effectiveness will be shown. For a better understanding of the Portuguese building thermal comfort specifications and of their impact in concrete applications, a simulation of the energy needs for diverse constructive solutions was carried out. This simulation combines solutions without thermal solar systems and for different climatic zones.

OR 95 LCA of renovated buildings

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The built environment is a sector with a huge impact on the environment. The sector represents 30 to 40% of greenhouse gas (GHG) emissions, 25 to 40% of energy use worldwide and 30 to 40% of solid waste generation [UNEP & OCDE, 2006]. During the last few years, the effort was concentrated on energy performance during the use phase for new buildings. But in European countries, the stock of old buildings is very large and thus, to reduce in a significant way the energy use of the building sector, the main effort should be put on old buildings too. For example, in France, the old stock represents more than 31 million of square meters and the new stock is around 400'000 square meters per year [ADEME, 2006]. While efforts were put on energy performance during the use phase, the scope of the environmental impacts of buildings was also lately extended from the use phase to the whole life cycle of the buildings given that the share of construction, materials, demolition and waste treatment are important too.

With an objective of helping owners of existing buildings to improve the energy performance of their buildings as well as the environmental performance, VEOLIA Environnement has developed packages of technical solutions enhancing thermal insulation, heating and ventilation systems. In order to be able to evaluate the environmental performance of these renovated buildings on their whole life cycle, the ISO 14040 Life Cycle Assessment method was selected. Developing an LCA approach to evaluate the environmental performance of buildings is nothing new. A number of software dedicated to LCA of buildings has been developed in the last few years. However, most are mainly applied to the conception of new buildings. Our study focuses on these softwares to evaluate their relevance for the case of existing buildings being renovated. A panel of existing softwares was reviewed. As already stated in a former European project (PRESCO), a major outcome is that the interfaces will need to be adapted for the case of renovation, and in particular for replaced components such as windows. The study also highlighted significant differences between the softwares such as the completeness of the databases used and the lifespan considered for materials. The presentation will share major results of this study, with the help of case studies of buildings renovation integrating packages of solutions.

OR 96 Life cycle management within the Belgian clay roof tile and brick sector

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The presentation will describe the importance that the Belgian clay roof tile and brick sector attaches to sustainability aspects and life cycle management (LCM) that are related to their business and products and focuses on a recently performed life cycle assessment (LCA) project. This LCA-project is part of a broader platform, where the three pillars of sustainability will finally meet each other. The environmental aspects are assessed by means of the LCA-methodology. The economical and social aspects of the clay sector in Belgium are analyzed by a socio-economic assessment. Also the environmental aspects not taking into account in the LCA are studied.

At the LCM2009 conference we will focus on the environmental pillar of the project which uses the LCA-methodology to model the environmental impacts of four specific clay products, from the cradle-to-the-client: clay roof tiles, traditional clay blocks, newly developed clay blocks and facing bricks. The LCA quantified the potential environmental effects of the different clay products from the cradle to the client, meaning that the extraction of raw materials, the production of the materials, transportation of raw materials and materials to the producers, production and packaging of the clay products, and finally the transport to the client are taken into account. The cradle-to-client LCA-study resulted in a comparative environmental profile in which the four clay products are compared along ten environmental impact categories. The results show that the newly developed clay blocks are a nice example to illustrate that life cycle management within the clay brick sector can reduce the building environmental impacts. Due to an improved production process the sector could realise reduction objectives concerning air quality (CAFE – Clean Air for Europe). In addition a combination of the use of paper fibre (as raw material) and afterburning led to reduced emissions. Due to an increase in waterway transport instead of road transport for raw materials and final products, the sector contributes to sustainable mobility. By implementing broken ceramic material and paper fibre as an alternative for primary raw materials, they realised savings regarding the extraction of primary raw materials (sustainable material use).

During the presentation at the LCM2009 we will highlight the importance of LCA for the clay sector in Belgium, the sector approach, the goal and scope of the study, the procedures for data collection, the importance of stakeholder involvement, the results of the LCA and its main findings.

OR 97 Environmental impacts of the building and real estate management sectors

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One of the key features of the environmental policy integration in Sweden is the sector responsibility. This requires that environmental aspects are not only considered within an environmental policy context, but within all policy

areas. The National Board of Housing, Building and Planning has the sector responsibility for the building and real estate management sectors. As a part of this responsibility they should make an assessment of the environmental impacts of the sector.

The aim of this study was to suggest a method for such an assessment and provide results. The assessment should take as a starting point the National Environmental Quality Objectives (NEQO) and evaluate the impact of the sector in relation to these. The assessment should include environmental impacts in a life cycle perspective as well as health impacts associated with the indoor environment of the buildings. The study may be described as a life cycle assessment of the building and real estate management sectors in Sweden. The basis of the study was an input-output analysis with data from the System of Environmental and Economic Accounts.

Characterization using the CML base line methods and weighting using Ecotax06, Ecoindicator and EPS were applied in order to identify the most important environmental interventions. This part of the study included data on energy use, traditional air pollutants, some water pollutants, amounts of hazardous and non-hazardous solid waste and use of hazardous chemical products. A checklist was made based on the NEQOs and additional information was sought on aspects that were not included in the input-output analysis.

The results confirm previous findings that the sector is responsible for a large part of the environmental impacts in Sweden. Heating of the buildings stands for a large part of the total energy use. Upstream energy use is however also significant and also for emissions. Especially production of non-renewable building materials such as concrete and metals are significant for the upstream environmental impacts. Also transports are of relevance. Also for emissions of greenhouse gases, the heating of buildings is important. In relation to the energy use, heating is however less important with regards to greenhouse gases. This is because production of both electricity and district heat is made largely by renewable energy sources and nuclear power.

According to the Ecotax weighting method, the most important environmental aspects are climate change and possibly human toxicity. The latter is however plagued with data gaps and the results are highly dependent on assumptions made. The assessment of the indoor environment indicates significant health impacts of different types. For example it is estimated that 200-800 building-related cases of lung-cancer from radon exposure occur each year. Approximately 150000 Swedish persons have sleeping disturbances from traffic noise, which may lead to fatigue, stress, hypertension, reduced working ability etc. Approximately 1000 cases each year of children's asthma in Sweden can be caused by damp buildings. The results of the study will be used for prioritization and for defining indicators for the sector.

OR 98 The Application of LCA within LCM for Municipal Water Systems – Are We Closing the Loop?

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Water is a scarce resource in South Africa. An increasing demand for water is projected, together with increased accessibility for previously disadvantaged communities which do not have access to clean water and sanitation. In this context South African municipalities need to make urban water systems more efficient and to find innovative solutions and tools in the life cycle management of these systems. The aim of this paper is to review how environmental life cycle assessment (LCA) and life cycle management (LCM) thinking have been used internationally and nationally in the management of urban water systems and to present some solutions for water challenged South African municipalities.

From the comprehensive literature review undertaken and briefly presented, two different levels of application of LCA in the water sector have been identified. Process (or project, including materials) applications are the most widely used and this approach brings about focused analyses and improvements. It has been used for a variety of processes within the urban water cycle – e.g. the provision of water (including desalination), the treatment of wastewater and assessment of sludge disposal and reuse and for the investigation of the environmental burdens associated with the use of different materials for water infrastructure. However, from a LCM point of view these process applications have to be complemented with studies in which the larger urban water systems are

investigated. The systemic losses which are typical of water distribution and collection networks are ignored by the process approach and are the most important reason why the urban water loop will never be fully closed (if one takes into account a narrow definition of the water cycle). For South African municipalities faced with the challenge of increasing water and sanitation service delivery, certain recommendations are made for improving the LCM of urban water systems and making them more sustainable. These recommendations focus on reducing losses in the distribution and collection networks, the implementation of a water demand management programme, water recycling and on-site sanitation. An investigation into more decentralized approaches for the re-use of rainwater, storm water and grey water is also recommended.

OR 99 Environmental Impacts of Multi-Storey Buildings Using Different Construction Materials

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This paper presents the LCA component of the project “Environmental Impacts of Multi-Storey Buildings Using Different Construction Materials” sponsored by New Zealand’s Ministry for Agriculture and Forestry. The research project was based on a comparative LCA study that has been undertaken on the design of an actual six-storey office building with a floor area of 4,247 m². The building was modeled in four designs, namely Concrete, Steel, Timber and TimberPlus. The main objectives of the project were to determine influence of construction materials on life cycle energy use and global warming potential (GWP) over the whole life cycle, and to compare the LCA results with the results of a “greenstar assessment” based on the ‘office tool’ developed by the New Zealand Green Building Council.

The results of the study will be used to inform policy making and to engage with the New Zealand Green Building Council with regard to the review and further development of their tools. The study also has also confirmed the need of New Zealand specific data and supported the initiative to develop Life Cycle Inventory data for New Zealand. The LCA study considered the full life cycle of the buildings including embodied energy of the materials and maintenance, transport, operational energy and two end-of-life scenarios, where deconstructed materials were either land-filled or reutilised. New Zealand Life Cycle Inventory data is only available for very few building materials. The study has therefore been undertaken once with a consistent set of European data and again with New Zealand data where available.

Key results were that all four buildings, designed for a 60 year lifetime, had very similar operational energy consumption that accounted for 10 to 20% of the full life cycle impacts. Increasing the amount of timber used in the buildings resulted in decreased embodied energy and GWP of materials and decreased total energy consumption and GWP over the 60 year lifetime. Thermal reutilisation of timber (burning) provided greater benefits than land-filling. Recycling of steel and timber further reduced impacts. The assessment of the same buildings in the materials and energy section of the Green Star assessment have lead to different results. Based on the Green Star results the concrete building would have been most beneficial from an environmental point of view, whereas the steel, timber and timberplus options would have been equal. In comparison the LCA results have shown the following ranking for primary energy use as well as GWP: 1. TimberPlus, 2. Concrete, 3. Timber and 4. Steel. The peer review from the Green Star consultant has confirmed that “In the long run the integration of LCA tools into whole building assessment systems will yield significant benefits, not only will it improve understanding and appropriate rewards for environmental performance, but once established future LCA will be less complex and expensive. A paradigm shift is required away from conventional wisdom and related procurement decisions toward minimisation of life cycle flows to and from nature.”

OR 100 What does “Climate Neutral” really mean, and what are the implications for sustainable development?

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An operational approach to sustainable development is being “Climate Neutral”. But what does carbon neutral really mean for each and every one of us, and further how to translate this information into our day to day activities. This paper explores and discusses carbon neutral first in an international context, before it is operationalized with respect to Norwegian emissions, and where a development projects like Brøset should focus its efforts.

IPCC has warned us about passing the 550ppm CO₂ concentration threshold in the atmosphere. We have therefore chosen this concentration of CO₂ in the atmosphere as an operational limit to for sustainability in our calculations. This does however mean that our annual emissions of CO₂ must decrease rapidly, especially towards 2050, but all the way towards 2100. At the same time the world population will increase to approximately 9 billion in 2050. This means huge reduction in emissions – especially in the developed world.

We looked at the emissions for Norway (2005) from two different perspectives; the production perspective, and the consumer perspective. We have limited this survey to green house gasses.

The household consumption is the single most important driver for Norwegian emissions, responsible for ca. 70%, or 36 million tons CO₂e.

Thus if we operationalize “climate neutral” to mean that the climate change should not exceed the 2 degree increase in temperature for a population of 9 billion, and that the distribution of emissions should be evenly distributed to all inhabitants on earth, that each should have an average emission of 3 tons CO₂ annually, or 2 tons per capita in households

We have also shown that with the consumer perspective that the emissions cannot be traced back to a few components, but that they are interlinked through the economic system. Thus there is no “quick fix”, and that a holistic approach to the problem is necessary. The picture changes if we look at the same emissions from a production perspective. The most important category is then electricity production abroad.

This paper has thus identified key design areas to focus on in future developments in Norway (and comparable economies): energy, transportation, buildings and infrastructure and local production and consumption.

OR 101 Brøset – Towards a climate neutral housing settlement in Trondheim, Norway.

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Norway has ambitions of being carbon neutral within 2030. If we shall reach this ambitious but necessary goal, we must be able to construct local carbon neutral settlements within few years from now. Thus, we must act now and identify what this goal means for the development of building and physical infrastructure on a local scale. Trondheim is one of 13 cities in Norway whom has engaged in developing such developments through the national project “Fremtidens byer” (Future cities). The municipality of Trondheim has identified Brøset, 350 da large greenfield close to the city center for such an development, and has started the planning process with the assistance from the researchers from NTNU and SINTEF Building and Infrastructure, in order to identify where to focus on in such a development.

In parallel it is established a large research project, focusing on how to develop sustainable settlements, as well as investigating the planning and implementation of such developments.

This paper is presenting the initial phase of both the development project and the research project.

SP 01 Goodbye to carbon neutral: building carbon-stock changes into biomass carbon footprints

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Most guidance for carbon footprinting, and most published carbon footprints or LCAs, presume that biomass heating fuels are carbon neutral. However, it is recognised increasingly that this is incorrect: biomass fuels are not always carbon neutral. Indeed, they can in some cases be far more carbon positive than fossil fuels. This flaw in carbon footprinting guidance and practice can be remedied. In carbon footprints (not just of biomass or heating fuels, but all carbon footprints), rather than applying sequestration credits and combustion debits, a 'carbon-stock change' line item could be applied instead. Not only would this make carbon footprints more accurate, it would make them consistent with UNFCCC reporting requirements and national reporting practice. There is a strong precedent for this change. This same flaw has already been recognised and partly remedied in standards for and studies of liquid biofuels (e.g. biodiesel and bioethanol), which now account for land-use change, i.e. deforestation. But it is partially or completely missing from other studies and from standards for footprinting and LCA of solid fuels. Carbon-stock changes can be estimated from currently available data. Accuracy of estimates will increase as Kyoto compliant countries report more land use, land use change and forestry (LULUCF) data.

SP 02 Comparative Life Cycle Assessment of Charcoal, Biogas and LPG as cooking fuels in Ghana

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According to the Ghana Energy Commission, the non-commercial sector of the country's economy accounts for almost 50% of its total energy consumption. During the 2000-2004 period, woodfuels (firewood and charcoal) averaged about 90%, electricity 6.6% and petroleum products 3.2% per annum of the consumption attributed to this sector. While charcoal is consumed mainly in the urban areas, firewood is the main fuel for the rural areas. Therefore, with the current rapid urbanization, demand for charcoal is expected to rise more than firewood.

Due to the negative effects of the intensive use of woodfuels for cooking, such as deforestation and indoor air pollution, the Ministry of Energy has been promoting the use of liquefied petroleum gas (LPG) as a shift from fuelwood to a more efficient and cleaner burning fuel. Biogas, a renewable gaseous fuel produced from biomass, is becoming increasingly interesting as an alternative to the non-renewable LPG.

This paper presents the results of a comparative environmental analysis of the three cooking fuels – charcoal, biogas and LPG over their life cycles. This is a partial results of an ongoing study to determine the social, cost and environmental implications of cooking fuels in Ghana from a life cycle perspective. Inventory data have been acquired from company primary documents, questionnaires, literature and commercial LCA databases. The functional unit chosen was the supply of 1 MJ of useful heat for cooking.

The results show that global warming is the most significant environmental impact associated with the cooking fuels and charcoal makes the largest contribution to this impact (about three times that of LPG, the next major contributor to the impact). LPG shows relatively higher impacts in acidification, eutrophication, ozone layer depletion and human toxicity potentials. Direct comparison of the results shows an environmental advantage to biogas in all the investigated impact categories.

SP 03 LCA of biodiesel production from micro-algae coupled to Anaerobic Digestion of oilcakes

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Fossil fuel depletion and climate change have led many research groups and private companies to focus on use of biomass to produce renewable energy and fuel. Production and use of bioethanol and biodiesel have usually a lower global warming potential than petrodiesel but they create other environmental impacts and compete with feed crop for the land use. Micro-algae have been pointed as an interesting alternative: their very high photosynthetic yield allows one to obtain high biomass production spread over the whole year and their ability to

accumulate lipid lead to potential productivities (in terms of oil production per year and per hectare) far higher than rape seed or sunflower. The lipid fraction can be converted to biodiesel by trans-esterification after proper harvesting and extraction. Moreover thanks to the semi-controlled culture systems, micro-algae culture can be used to use an industrial source of CO₂ like cement factory or power plant fumes.

A virtual facility has been designed from reasonable assumptions in agreement with bibliographic data and observations of comparable processes. It was then used to carry out a Life Cycle Assessment of the whole process chain, from the biomass production to the biodiesel combustion, including infrastructure building and recycling. Potential environmental impacts have been assessed with the CML method, and energetic balance determined with the Cumulative Energy Demand method. Potential impacts have been compared to the ones obtained in former studies for first generation biodiesel and petro-diesel. First analysis highlights the imperative necessity to decrease the energy consumption during cultivation and drying of micro-algae. It stresses the importance of extracting energy and nutrients from oilcakes and finally it shows the relevance of applying nitrogen-stress during algae culture. Anaerobic digestion has often been proposed as a relevant coupled process to recycle part of the nutrients stored in the oilcakes; in addition produced biogas can be used to produce heat and electricity on the facility. The former system has been modified and coupled to anaerobic digestion of oilcakes in order to evaluate potential of anaerobic digestion of oilcakes to reduce environmental impacts and improve energetic balance. Oilcakes are processed with another biomass to facilitate its anaerobic digestion by increasing the C/N ratio. This second assessment shows a far better environmental footprint of bioenergy production from micro-algae cultivation when coupled to anaerobic digestion. It should reduce most of the most impacting steps of the production chain, reducing the use of energy and fertilizers. However drying remains a critical step for which alternative options should be experimentally evaluated.

SP 05 Strategy for Developing a Life Cycle Inventory Database for the Cane Sugar Production Process in Cuba

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Life Cycle Assessment (LCA) is viewed as the quantitative assessment component of industrial ecology. The basis of LCA is the Life Cycle Inventory (LCI), which is the quantification of material and energy flows associated with a product system under study. The majority existing LCI databases were built for European or other conditions, which strength the necessity to create databases for the real conditions of the Cuban industry. The development of a national LCI database considering the Cuban Sugar Industry (an important sector of the Cuban economy) will remedy this situation and considerably enhance the usability of LCA in general and it will create the basis to develop a Cuban National LCI Database, including all economical sectors of the country.

The objective of this work is to develop a research guideline and establish research parameters, including products, processes, data categories and data quality, such that the resulting database would be credible and useful to interested parties. The Group of LCA of Central University of Las Villas and Ghent University has begun to apply this important tool to study the environmental impacts in different industries in Cuba. The most significant results have been obtained for the sugar industry. All these studies have been realized using models and LCI developed in different conditions to the Cuban Industry. Currently, there is no available any source of LCI Database for Cuban conditions. According to the criteria above mentioned, the primary requirement is to establish a Cuban Sugar Industry LCI Database to supply the needs of a wide spectrum of potential data users. The results state a research guideline consistent with ISO standards and with guidelines for LCA studies and establish research parameters, including products, processes, data categories and data quality. The working group's organization and coordination have been developed. The organization and statistical processing of all data collected in different Sugar Mills shows the main statistical characteristics of the data, using the Statgraphics Plus 4.1 software and the uncertainties ranges for all studied variables was defined.

SP 06 The Environmental and Energy benefits of using bio-ethanol on Life Cycle aspect in Thailand

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After Thailand government has promoted the use of bio-ethanol for transportation fuel. Over 10 ethanol producers have sent their product to gasohol blending system about 0.8 million liter /day. In Thailand, bio-ethanol are produced from molasses and cassava which known raw materials for food and many industry. However, how to manage those crops to use as biofuel and others industry is still in question. From these problems lead to aim of this paper which studied the environmental and energy benefits from using bio-ethanol made from molasses and cassava for blending gasohol. In addition, It is important to evaluate the key impacts of product throughout its entire life cycle using Life Cycle Assessment (LCA), which is an effective tool for evaluating. In this case, studied from well-to-wheel. Net energy gain and environmental impact are evaluated and analyzed with economics impact from utilize molasses, cassava and oil price. How utilizing biomass for biofuel to reduce greenhouse gases will be question. Detailed results and suggestions for the environmental performance improvement and economics were presented in the paper.

SP 07 Web-based tool for streamlined biofuels' LCA

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Upcoming regulations like the Swiss ordinance on mineral oil tax and development of standards for sustain-ably produced biofuels like those of the Roundtable for Sustainable Biofuels require often calculations of the greenhouse gas emissions or even of the environmental impacts on an LCA basis. For many small produc-ers, such an evaluation is too costly and would prevent them to enter the market for biofuels. This project develops a web-based tool which allows the evaluation of biofuels on an LCA basis.

The Swiss LCA study on biofuels from the Empa shows distinctly that the most relevant step in the LCA is the agriculture followed by the processing step. The transport of biofuels is not relevant. A sensitivity analysis of the agricultural step showed that the most relevant factors for the greenhouse gas emissions are the dinitrogen oxides emissions in agriculture and the carbon dioxide from land transformation. For the calculation with the Swiss method of the ecological scarcity (ecopoints 2006) the most relevant factors are nitrate emissions in groundwater, phosphorus in river water, heavy metal and pesticide emissions in soil. The content of the questionnaire was based on these insights.

The user enters own data for the most relevant parameters of the product life cycle like e.g. yield or fertilizer use. The user can give values for mineral and organic fertilizer as well as pesticide use, and gives information on land use for the plantation of biofuels. He enters also the energy use and allocation data for the processing step. The questionnaire offers the possibility of using standard values if specific data are not known. In this case, the sustainability quick check tool relies on theecoinvent database for the background data. The model uses simplified factors for the calculation of emissions in the agriculture and for the calculation of processing step. Main challenge of the tool is the simplification of the LCA calculation so as to keep the data entry easy.

Results show the greenhouse gas potential as well as overall environmental impacts of the biofuels' life cycle in relation to a fossil fuel reference. With this tool, the user is able to assess if the biofuels produced comply with the Swiss sustainability standards and how the value chain could be further optimized. Thanks to its modularity, it should be possible to adapt the tool to make it valid for other certification schemes as e.g. the Roundtable for Sustainable Biofuels.

SP 08 Environmental management systems as cooperative governance tools to promote sustainable development in South African metropolitan cities

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Cities provide a range of services to their citizens and have to do so in an environmentally responsible manner and also promote sustainable development. With growing concerns around cooperative governance in both the private and public sector, there is a need to have in place mechanisms and tools to express commitment to environmental stewardship in all aspects of strategy, processes or methods and activities. In the private sector, tools such as Environmental Management Systems are widely used to manage the impacts of operational aspects of the business. Adequate legislative frameworks to guide cooperative governance exist, however such frameworks may be inadequately applied in the public sector, especially in cities. This paper examines the appropriateness, relevance and extent of application of Environmental Management Systems in selected South African cities. In order to integrate and embed sustainable development at a corporate level, a conceptual model based on systems engineering principles was introduced and evaluated against a city that was advanced in terms of EMS implementation.

SP 09 Development of Renewable Energy Resource by Strategic Planning: A Case of Indian Energy Industry

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The work has focused on Strategic Planning for the Distributed Power Generation. As the world Energy requirements are increasing and the conventional sources such as petroleum, coals etc are diminishing, there is a need to look into the future of energy generation. Recognizing the importance of renewable energy sources as the best alternative to conventional fuels and also the Indian's energy industry vision is to become the world-class competitor in power generation made them to forecast the future of distributed power generation. The present study is based on judgmental data of the people involved in the business. This Project gives more emphasis on Strategic Analysis and Strategic Evaluation by AHP and ANP tools in Wind Power Generation.

SP 10 Multicriteria decision-making for sustainable development programmes: A case of biofuels

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SP 11 Life Cycle Assessment to evaluate social impacts of services

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Always growing attention to the sustainable development carries governments and international and local economies to take account of the environmental and social impacts of the economic choices. Responding to the approach proposed by Integrated Product Policy and Life Cycle Initiative, LCA is growing at international level: the methodology allows to assesses the environmental impacts of the products and services from a cradle to grave point of view.

The international community is showing growing interest for the social impacts evaluation of services/products, but at the same time scientific international literature hasn't still detected useful tools to realize such evaluation.

The last increases in LCA subject consider the possibility to adopt this methodology even to evaluate the social impacts generated by products/services along their life cycle. That's the Social Life Cycle Assessment (SLCA).

In this project a Social Life Cycle Assessment model has been developed to test the application of the LCA methodology to social issue. The validation of the SLCA model has been tested through its application on waste management services such as waste collecting process and disposal.

Research conducted has allowed us to detect the hotspots of this approach but also to highlight the eventual weaknesses of such application. The main difficulties we met with are concerning the subjectivity of the social issues and therefore the classification and assessment methods which have not one point of reference but many.

So, the first activity, definition of the goal of the SLCA, was an embarrassed step because we'd have to choose one reference to define what need stands for, to characterize needs and to weigh different needs.

In this project the need definition proposed by the International Labour Organization and Maslow (Pyramid model, 1956) has been adopted to characterize society and individual needs.

The second difficulty concerned the choice of impact categories. We'd define a list of impact categories as Urban Ecosystem Europe (2007) developed for social development and we'd integrate with the social and environmental dimensions proposed by Hunkeler (2006). Six social impact category have been constructed. Each category has been hypothesized associate to a mix of social indicators proposed by the main international organizations: World Health Organization, European Organization for Cooperation and Development, Eurostat, Global Reporting Initiative, Social Accountability International.

Another difficulty was relating to system boundaries definition which has consistent with the goals of the study and with the public and stakeholders involved. In fact, one of the main critical issue in a SLCA is the stakeholders characterization who can influence the study's activities, data collection especially. In this project we'd try to identify the stakeholders for each life cycle phases.

About impact assessment, SLCA should be able to resolve impact weighting process issue. This is a delicate question because it's necessary to be consider not the LCA applicant point of view but stakeholders' opinion. Last, the interpretation step of the SLCA will be consistent with all hypothesis adopted at the beginning of the study and consider stakeholders' information needs.

SP 13 Biodiesel supply chain optimisation

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SP 15 Challenge of Life Cycle Management of WEEE in China

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As the biggest ITC manufacturers and consumers in the world market, China's management strategy of WEEE(Waste Electric and Electronic Equipment) will definitely effect both China's WEEE flow and the world flow. The indisposed treatment in the informal sectors has led to some environmental damage and resources lost.

In this paper, the framework of life cycle management of WEEE is proposed and the related challenge and suggestion are analyzed. In this system, the domestic WEEE flows are calculated based on the life-span model. And the legal imported WEEE flows are analyzed by the statistic data from government agency. It will clarify the potential of resources recovered and environmental impacts from WEEE recycling.

Some important life cycle stages of WEEE like eco-design, use/reuse, recycling and final disposal was reviewed and analyzed based on the China's domestic WEEE flow. It is shown that eco-design of ITC products in China is just in the very young age. There is no available data and tools for EEE designers and manufacturers to implement eco-design. Reuse of EEE products and component is very common. It is also mixed with the recycling practices, which makes the WEEE flow pathway more complicated. There are no specific disposal facilities for the final residuals from WEEE treatment.

The eco-efficiency method and life cycle assessment tool are used to model and compare different strategies within the life span of WEEE like personal desktop computer. The results show that the informal manual collection and components-reuse strategy is higher in eco-efficiency than the formal motor powered vehicle collection and shredding strategy.

The current policy and regulation for management of WEEE in China are reviewed and hot points are discussed. The unclear definition of Extended Producer Responsibility (EPR) makes the regulations and law went slowly and the stake-holders for WEEE are just on the way of waiting.

The strategy proposals are suggested that the national resources recovered and recycling target for WEEE should be set and EPR mechanism should be implemented sooner.

SP 16 Capacity for Life Cycle Assessment and Development Assistance

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A key objective of the UNEP-SETAC Life Cycle Initiative (LCI), which was launched in 2002, is to encourage the practice of Life Cycle Assessment (LCA) in developing countries. Through workshops and other events, stakeholders are informed and trained to become aware of the LCA rationale, adopt it, and develop appropriate skills to practice LCA. However, this process meets several challenges. Stakeholders in developing countries claim that LCA methodology favours modern industry thus ignoring socio-economic concerns e.g. employment creation. Furthermore, they point out that some development projects, which upgrade the products of small farmers and fishermen thus providing them with new income generation opportunities through exports to overseas markets, fail on a life cycle assessment of the environmental impacts. The collision between environmental and socio-economic impact is explicitly expressed, when stakeholders in developing countries reject any further conditionality in their foreign trade as defined by LCA.

Some countries have adopted national LCA projects, primarily to develop life cycle inventories for processes in the most important sectors, and to conduct outreach activities to industry. There is a need to strategize programs of action for LCA in developing countries, which integrate with their level and scope of environmental management, and which effectively address capacity constraints at company level and within the enabling institutional context. The implications for development assistance need to be clarified by suggesting coherent development aid policy initiatives, which promote synergies and momentum for LCA capacity building and adjustment. How can donor aid to the environmental sector best be integrated with foreign investment incentives, and with national environmental policies to enhance capacities for adjusting to environmental standards and to effectively increase market access?

At the same time, research on social life cycle assessment (SLCA) defining and testing indicators to fully incorporate socio-economic concerns in developing countries needs to be enhanced. Also, research on simplified LCA tools, which integrate with existing environmental managements systems, and which are feasible for small producers, must be stepped up. It is proposed that development aid projects targeting small producers, who are supported to access or initiate global value chains, may serve as one testing ground for the application of LCA in developing countries. Eco-business projects 'at the bottom of the pyramid' need to adopt a three-fold sustainability approach promoting economic, social, and environmental sustainability in order to provide livelihood strategies for the small producers and to contribute to the transition towards sustainable production and consumption.

SP 17 The global life cycle of rechargeable Lithium ion batteries: what natural resource savings can be gained through recycling?

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Rechargeable Li-ion batteries are ubiquitous in our modern society with applications in consumer products like mobile phones, personal digital assistants and laptops. It is obvious that these rechargeable batteries show a better

environmental profile than primary batteries, but even a step further is to recycle rechargeable Li-ion batteries. This makes sense from several points of view, but particularly reduction of depletion of natural resources such as Cobalt and Manganese metals is a prominent driving force: it is estimated that battery applications account already for nearly 25% of worldwide cobalt demand.

Quantification of the environmental benefits induced by recycling rechargeable Li-ion batteries is not a piece of cake: the material flows have an international dimension giving rise to lack of accessibility and transparency of information; the complex nature of the processes induce allocation difficulties; and also the definition of recycling can be questioned: do we look at the overall mass of the battery or at specific exhaustible metals? In this contribution, we have established two life cycle scenarios for advanced Li-ion battery cathode materials: one scenario based on Cobalt and Nickel recovered from batteries and one based on freshly mined Cobalt and Nickel. It must be emphasized that the former scenario is not yet common practice today. It is anticipated that a much bigger portion of these end-of-life batteries will be recycled in the near future.

To analyze the two scenarios, data on practice spread internationally, including Lithium, Nickel and Cobalt mining, Manganese production, Nickel and Cobalt recycling through pyrometallurgical and hydrometallurgical processes, and battery cathode production have been studied, along with involved transport processes. Secondly, the authors approached the two cases via a resource oriented life cycle approach: exergetic life cycle analysis as described recently in the review of Dewulf et al., *Environmental Science & Technology*, 42, 2221-2232, 2008, and more specifically in Dewulf et al., *Environmental Science & Technology*, 41, 8477-8483, 2007. From the detailed study, it turns out that the recycling scenario result in a 51 % natural resource savings, not only because of decreased mineral ore dependency but also because of reduced fossil resource (45% reduction) and nuclear energy demand (57%).

SP 18 From environmental impacts to economic valuation of different waste management options: An industrial perspective of the LCA-CBA approach

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Environmental impacts related to municipal solid waste (MSW) landfilling evaluated with a Life Cycle Assessment (LCA) approach are usually expressed in various units, thus sometimes hardly understandable for non LCA-practitioners. Without weighting these environmental impacts, communication is difficult and can somehow lead to misunderstood conclusions. Expressing the environmental impacts into a well-understood unit (€) is a way to facilitate communication. Therefore, it increases the use of LCA in environmental assessment and the strength of its conclusions in a decision-making process.

This study aims at evaluating the environmental impacts of different MSW landfilling scenarios, combining successively two management decision tools: Life Cycle Assessment (LCA) and Cost-Benefit Analysis (CBA). The methodology has been conducted in three stages: from environmental impacts to the total external costs for the landfill of 1 tonne of MSW through the calculation of the external cost of each impact. 6 different scenarios have been modelled: « conventional » landfill, bioreactor, and 4 types of MBT (Mechanical and Biological Treatment). Depending on the scenarios, these MBT include or not sorting of fractions by size, shredding, incineration or landfilling of the coarse fraction. The common step concerns the biological stabilisation of waste before landfilling. For each scenario, different types of biogas recovery were compared: flare, gas engine, gas turbine and steam turbine, as well as different leachate management options.

In accordance with literature conclusions, this study shows that Global Warming and Acidification are the main contributors to the total external costs of MSW landfilling. The wide use by industries of these tools is then prevented, because of LCA and CBA methodological limitations (units used for the analysis of some impact categories, cost factors for some environmental impacts, site-specificity of some cost factors, etc.), as well as data gaps or uncertainties. Some local social impacts associated with the site implantation (disamenity, land disturbance) have also been monetarised and included in the economic valuation, even if they are usually not included in LCA.

The last stage will consist in the development of a communication strategy with the stakeholders in order to improve

the accounting of this methodology in the decision-making process strategy. This analysis may show that the relevance of an environmental project may be evaluated by comparison between real costs and expected external monetarised benefits.

The presentation will detail the methodology used and underline methodological gaps and solutions. It will be based on a real study from the waste management industry.

SP 19 Copper flow in Brazil and its comparison with other economic regions

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This quantitative study characterizes the copper cycle in Brazil (base 2005), including its process stages (production, manufacture, use and waste management), using the Substance Flow Analysis. Its result shows us that Brazil is a net importer of copper (64,000 t), but in beginning of 2010 decade, it will change due to a new producer of refined copper. In 2005, copper consumption was 1.44 kg/capita, and 0.52 kg/capita stay "in use" as stock mainly at infrastructures, buildings, electrical equipments and household appliances. Waste generation (1,411 kg/capita) is close to the European index (1,865 kg/capita), smaller than Latin American (3,000 kg/capita) and bigger than Asiatic (852 kg/capita) and African (192 kg/capita) ones.

Copper content was accounted for in the seven major residues flows (municipal solid waste - MSW, construction and demolition - C&D, waste of eletro-eletronic equipments - WEEE, end of life vehicles - ELV, solid sludge - SS, hazardous industrial waste - HIW, non hazardous and industrial waste - NH&IW). The copper content in each of these flows were calculated: 27,8% in C&D, 27,7% in WEEE, 19,7% in MSW and 13,2% in HIW. It differs from other regions where a concentration of copper in WEEE is highly apparent (83% in Latin America and 62% in Africa). WEEE and ELV have counted less than 1% (weight) but concentrate about 38% of residual copper after its use.

Copper recycling, different of other countries of Southeast Asia, is not a predominant activity in Brazil. Its index is 25%, far from North American and Asiatic (60%), European (48%), and African (34%) ones. Such a low rate has resulted in 141,000 t released to biosphere (including the landfills). Copper released per capita for Brazil is 0.75 kg, in an intermediate position together with Latin America, with Europe in the top (1.4 kg/capita) and Asia/Africa in the bottom (0.23 kg/capita). If considering contamination indicator, copper release amount by territorial extension (area), Brazil again is in intermediate level (16.3 kg/km²) with Europe (159.5 kg/km²) four times upper than Asia (37.9 kg/km²) and Africa is the last one with 6.6 kg/km².

Brazilian indicators are low comparatively to the other ones but it does not mean that nothing need to be done. To diminish the environmental pressure and optimize the secondary copper recycling, governmental policies should implement restriction mainly in WEEE and ELV flows during their final destination, incentive by economic instruments such as charging manufacturers and consumers to recover copper post-use, besides prioritize on education and awareness of unsustainable consumption and production patterns practiced nowadays.

SP 21 LCM's general appointments to design an electric vehicle to collect urban recyclable solid waste more ecofriendly

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The programs of recyclable waste management have increased on the lasted years in Brazil. If one side there is the private enterprises, on the other there are people that live collecting urban recyclable solid waste using vehicles of human propulsion. In some towns in Parana State, it has aided local governments to promote recycling of some materials, from different sorts of papers, metals such aluminum to the plastics such PET (Polyethylene terephthalate). Towards this scenario, hydroelectric of ITAIPU had started with a private industry, the design and manufacture of an electric vehicle this sort of waste, into a context of ITAIPU Renewable Energy Programme. According to it, this paper contains some general appointments about main steps to the environmental assessment

of this vehicle. Beyond of a briefly approach of the vehicles to collect waste used in Curitiba town, considers the context of the life cycle management of these vehicles. Intending to promote a decrease of environmental impacts during the life cycle, the life cycle assessment is applied as a tool for the design of an electric vehicle to collect solid waste more ecofriendly.

SP 22 Life Cycle Management of Natural Resources / The case of Aluminium

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The natural resources in their use for our daily life constitute the major ingredient for our civilization as we know it today. However, natural resources are not infinite and in many countries are not at all abundant. It is imperative today as the world is changing, the needs for natural resources increase, and the environment is polluted by our industrial activities, to manage properly the use of our resources in order to keep the high standards of living for the developed world and give a chance to the developing world to attain higher standards of living. Life cycle management of each resource is the only way to reach to attain this goal. It is important, and today it has become necessary, to take into consideration the life cycle of each material so that the proper processes are designed to reduce its environmental impact and to achieve a high level of recycling. The case of aluminium is a perfect example. Even though aluminium is one of the most polluting material produced due to the high amount of natural resources needed for processing and the high quantities of electricity used, its high recyclability could minimize the environmental impact from production and will also lead to lowering the use of natural resources. A life cycle assessment has been performed for the aluminium production in Greece and the impact of scenarios at different recycling levels calculated.

SP 23 LCA as Methodology to Evaluate Energetic and Environmental Impacts of Integrated MSW Management Systems

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This paper summarises the results of a number of life cycle evaluations of different Italian integrated municipal solid waste (MSW) management systems that we have carried out in recent years. The aim is to give an indication about the energetic and environmental impacts associated with the different sub-units that compose a MSW management system, i.e. the waste collection and transport, the recycling of the packaging materials, the treatment of the bio-waste, and the energy recovery from the residual waste. The impacts of these sub-units can therefore be combined together to calculate the impacts of a specific integrated MSW management system.

More in detail, the analysed sub-units are: the waste collection and transport, which comprehends the collection of waste in a certain place but also the transport of the collected waste to the specific treatment plant;

- the recycling of the packaging materials, i.e. the recycling of iron, aluminium, glass, wood, paper, and plastic;
- the treatment of the bio-waste (both green waste and kitchen waste), which may occur through composting or anaerobic digestion;
- the energy recovery from the residual waste, which in most of the cases is carried out in dedicated combustion plants.

In this paper, we report the life cycle assessment results of all these different sub-units, related to global warming, human toxicity, acidification and photochemical ozone creation impacts and to cumulative energy demand. The impact indicators for a specific sub-unit will not be a single value but a range, according to the different assumptions made. For example, in the recycling of paper, the results of a certain impact indicator will be affected by the different selection efficiencies of the material separated with the collection, which can be mono-material or multi-material

collection within a kerbside or a drop-off collection scheme. The results will vary according to the quality of the collected material, which determines the maximum number of recycling cycle, too.

The impacts of the different sub-units can therefore be combined together to calculate the impacts of a specific integrated MSW management system, knowing the data about how much waste is collected and then recovered in the different ways and how much is the residual waste.

SP 24 LC thinking in combination with meta-modelling technique- a useful tool for evaluating the environmental impact of recycling processes

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The modelling of recycling processes offers the potential of identifying the main influences of the processes, the main material flows and emissions – to reduce the environmental impact and improve the economics. Simulation has to be made possible for further investigations. The major problems are the uncertainties about the material composition within the material flows, and in the recycled products; especially their characteristics like size, material combination and distribution. Due to the lack of data a whole Life-Cycle Assessment is not available for most recycling processes, therefore only Life-Cycle Thinking is applicable. The processes with the main influence must be identified and evaluated within the model.

A meta-model describes the structure of a model and uses mainly the information generated from processing steps. This results in an abstract combination of the elements of the model and its linkages. Therefore, this technique allows to develop the model. Tools to build this model are the LCA software “Umberto” to define the mathematical connections between processing steps as well as the programming language “Matlab”.

Assessing the information of the processing steps for modelling purposes with the availability of data ranges and the focus on uncertainties is the focus of the research. Modelling recycling processes and the assessment of uncertainty regarding the input and process parameters are firmly connected. With modelling the recycling process the known and unknown uncertainties become important parameters to consider. Due to the fact that residues always vary in their composition and for material flows only data ranges can be used as input parameter. A simulation of recycling processes is therefore often difficult. A model relies on the quality of the process data. Uncertainty can be understood as the variation of a parameter in a model. The variation is not known and at random. For modelling purposes the acceptable level of uncertainty has to be defined through statistics.

An ideal separation of waste material components is not possible but quality standards can be met through defining separation grades as categories (high, medium, low). Therefore, the modelling is not related to specific data (numbers) but rather to data ranges (or quality issues). The modelling can help with the decision making process if the uncertainty of the model has an acceptable level. The acceptable level depends on the aim of the modeller and the model user.

The model may be simplified by focusing on significant processes. Accounting for the important sources of uncertainty should be a key objective in modelling recycling processes. However, it is not possible to characterize all the uncertainties associated with the model and data. Qualitative evaluations of uncertainty including relative ranking of the sources of uncertainty may be an acceptable approach to uncertainty evaluation, especially when objective quantitative measures are not available.

SP 25 Systemic analysis and waste management

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Nowadays, for dwellings or for all types of built spaces, in a sustainable vision, Several targets must be then taken into account, such as the waste management. The problematic of waste management in an island environment includes the management of spaces dedicated to the various of waste treatment (incineration, production of biogas, centers of recycling). The objective of this study is to propose a systemic description and analysis of all initial system producing wastes. In this work, we studied first of all the typology of space built or of infrastructure in a macroscopic scale in a given environment. We also defined the internal functional or structural typology of these elementary system, as well as the typology of incoming fluxes. A following step leads us to the physico-chemical characterization of the incoming fluxes and also the creation of database and a software of study of the behavior of consumers. We included also various modes of delivery and storage, modes of transformation and discharge. The purpose was to bring out social and human models of behavior, models of evaluation of energy and economic consumption and finally, models of evaluation of the gaseous and solid, liquid emissions of waste. The results we want to reach are:

- The estimation of the general functioning of the global system of production of wastes and the definition of strategies of collecting, sorting, recycling and final treatments.
- The foresee of volumes and physic-chemical characterization of wastes to evaluate the energy apports and the sanitation potential given by the treatments solutions.

SP 26 Life Cycle Assessment of Aluminium Metal Production in Western Australia

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The aluminium industry contributes significantly to the Australian Economy and is the world's largest producer of bauxite. While aluminium is the most distributed and used metal in the world with increasing global demand, there are also significant environmental impacts associated with each stage of aluminium production, from extraction to processing. The challenge facing the industry is to reduce the environmental impact of aluminium production, in particular greenhouse gas emissions, such as perflourcarbons and carbon dioxide. The Australian aluminium industry is committed to achieve major reductions in environmental impacts. The importance of life cycle approaches in managing environmental sustainability issues of the industry has already been recognised.

This paper offers a new Life Cycle Assessment (LCA) study considering the particularities of the aluminium production in Australia and taking local base data into account. In this LCA the functional unit is defined as one tonne of aluminium produced. The presented analysis consists for four stages: mining of bauxite, conversion of bauxite to alumina, the processing of alumina to aluminium and the final cast product. This LCA research will identify 'hot spots' or stages causing the most significant environmental impacts. Finally, an improvement scenario that applies cleaner production strategies for restructuring and reengineering the production process and supply chain will be developed to reduce the life cycle environmental impacts.

SP 27 LCM in Designing Towards Innovation

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Generation, exploitation and diffusion of knowledge are fundamental to economic growth of nations. Central to this is the need for better understanding of the role of innovations. They can occur in any sector of the economy, but this most important is bussiness enterprise sector. Through the main orientations of innovation there are also, as a leading now, proenvironment oriented innovations. It is growing need for creating environmentally compatible solutions, which are also economically and technically feasible. The right tool for measuring the innovative solutions seems to be LCA. Using LCA, it is necessary to look at the product in a holistic way. Product life cycle has to be

considered by all stakeholders as a core and it is obvious that in the design stage all important decisions, considering its environmental impacts during entire life cycle, have to be taken. Experiences of the leading enterprises show that working systematically with environmental aspects during product development can have beneficial side effects in the form of process, organisational and marketing innovations.

In this paper the role of LCA in design stage of the products has to be considered. The use of this tool in support of the strategies for fulfilling environmental requirements, focused on different aspects, as: product life extension, material life extension, material selection, process management, efficient distribution and improved management practices, with the emphasis on searching more innovative solutions, have been reviewed. Typical tendencies assigned to different environmentally oriented decisions made during design process have been analysed, with special attention on choice of materials. Practical examples of above mentioned activities, coming from the different enterprises, have been reviewed. One of them is in detail shown in this paper. The environmental analysis is done on the wrapping machine for butter, with the special focus on its transmission gear. Using LCA, environmental profiles and environmental indices for different constructions of gear wheels are produced. The combination of materials for elements of transmission gear: shaft, gear wheels and body, has been investigated, using supported computer programme. The results of numerical simulation give many interesting observations, important for machine designers and manufacturers, and for further development of innovative construction. The evaluation of LCA as a method shows that the field of its application becomes broader and broader.

It is still lack of information in Poland on how to make the technical objects more environment friendly. Designers, in general, begin to understand the relationship between a product and an environment. The product designing is therefore aiming at reducing the total material content, preferring the materials, which can be recycled, minimizing in this way the use of energy-intensive materials and decreasing the energy consumption in use phase. The some conclusions for machine designers, and more general for innovation development process, are drawn at the end of the paper.

SP 28 Life Cycle Assessment and Geographic Informatic System Integration for Bioenergy Projects

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A methodology capable to analyse the energy crops biomass potential production and consumption and its environmental performance integrating environmental tools as Geographic Information Systems and Life Cycle Assessment is presented in this paper. The case study area is Pallars Jussà in Catalonia (north-eastern of Spain). Environmental assessment is focused in CO₂ eq. balance considering the avoided impact of substituting non-renewable energies as Gas Natural but also the generated and avoided CO₂ eq. emissions of other land uses that compete for energy crops area proposed. The energy crops system will be compared with the followed reference systems: 1) an equivalent quantity of non-renewable fossil fuel as natural gas to demonstrate that biomass can help to reduce environmental impacts as Global Warming. 2) A theoretical Mediterranean forest system that could grow in the areas where is proposed to implement energy crops. 3) Urban area and 4) Cereal importation from East European.

SP 29 Environmental Profile and Sustainability of Hydrogen Production Technologies; PHISICO2 Program

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Regarding climate change mitigation, safety in energy supply and energy independence of regions, hydrogen has been anticipated as a good alternative for the current fuels system. Hydrogen is an energy carrier. Therefore, it has to be produced from primary energy. The conventional –and the cheapest –way to obtain it is from natural gas through steam reforming, but this technique produce a huge amount of carbon dioxide per volume of hydrogen. The so-called PHISICO2 Programme, a Community of Madrid regional activities program, studies several

'clean' techniques to produce hydrogen: methane decomposition, solar two-step thermochemical cycles and photodecomposition of water. In this context, Life Cycle Assessment tools have been employed to evaluate the environmental profile of those technologies and to compare them to conventional or alternative hydrogen sources: steam reforming with carbon capture and storage system and electrolysis with different electricity origins (grid, photovoltaic and wind). The assessments have been focused on the greenhouse gases emissions, the renewable character of the produced hydrogen, calculated through the consumption of energy resources in the life cycle, and exergy efficiency. The last one has been calculated to realize if process is consuming or producing usable work from nature. As well, total impact score has been calculated through IMPACT2002+ assessment method. Results indicate that water photodecomposition shows the best environmental performance, it produces less carbon dioxide emissions, the hydrogen obtained is completely renewable and its exergy efficiency is higher than 1 (it produces net work). Unfortunately, its behavior is highly dependent from its efficiency, which currently is quite low and variable. Processes with fossil resources as raw materials (steam reforming and methane decomposition) also show a good environmental behavior. In fact, methane decomposition produces, apart from hydrogen, high quality carbon, which is, a great advantage from the environmental point of view, if allocation in other sectors is considered in the assessment. On the other hand, solar thermochemical cycles are quite sensitive to process yield and materials lifetime, and wind-electrolysis has also a high degree of sustainability, while solar and grid-electrolysis performance is worse than expected.

SP 30 Environmental impacts of meat producing farms in Switzerland

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Agriculture often has an important share in the environmental impacts of the food chain. The high variability of the environmental impacts of farms with the same main production submitted to the same legislation (e.g. Gaillard & Rossier (2004) observed up to four times higher energy demand per kg milk for dairy farms) indicates that the farmer is a key-player, making farm LCM a central issue of an efficient environmental farm management. This hypothesis is now analysed more deeply.

We assess 35 meat producing farms using the SALCA (Swiss Agricultural Life Cycle Assessment) methodology developed at Agroscope Reckenholz-Taenikon Research Station ART. The analyses are carried out on the farm level and the meat production branch level, i.e. beef and pork. Results are expressed for the functional units ha utilised agricultural area, MJ digestible energy, Swiss francs gross profit and kg meat production. After the calculation of the LCAs every participating farmer receives a feedback with the farm results allowing him to draw conclusions for the management of his farm.

The high variability of the environmental impacts between the different farms is confirmed, with e.g. for energy demand a factor of over 15 between the farm with the highest and the one with the lowest energy demand per ha utilised agricultural area. Even between farms of the same farm type there is still a factor of 3 to 5. This suggests that there is a considerable management effect. Furthermore it indicates that there is a potential for optimisation.

For each environmental impact different inputs are relevant. The important factors also vary according to the type of farm and between the farms of the same type. The main input groups for energy demand are the purchase of feedstuffs, the purchase of animals and the energy carriers used on farm, though also the infrastructure (buildings and machines) can have an important share. For eutrophication, the important input groups are the fertilisation/nutrients, the purchase of feedstuffs and animals, as well as the animal husbandry/ handling of manure.

The present variability of results between the farms underlines the necessity of a sufficient number of sampled farms for making general conclusions. Furthermore, the sample design must take the farm type into consideration. While parts of the results are linked to the farm type others are due to the farm management. Hence, identifying management options, e.g. for energy carriers, feedstuff or animal purchase, are important to lessen the environmental burden of meat producing farms

SP 32 Application of Product Quality-Based Eco-Efficiency

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Eco-efficiency is an effective method for measuring the sustainability of a product, and is expressed as the ratio of the product value of a system to its environmental influence. When calculating eco-efficiency, it is generally accepted that the environmental influence of the whole life cycle is measured by using Life Cycle Assessment (LCA). But, there still remains considerable confusion and controversy about what product value is and how it should be quantified.

We proposed here a quantification method for eco-efficiency derives the ratio of product quality to whole environmental impact, which is in line with the conventional eco-efficiency. The applicability of the proposed method to actual products were also evaluated using case studies on home electronics and vehicle. Three steps are applied to quantify the product quality as one value. These are: normalization based on a value function, determination of subjective weighting factors of attributes, and summation of the quality of the chosen products. The ranges and units of attributes are different, and these differences are resolved by normalization based on a non-linear value function, which reflects the market situation. To calculate the value functions of each attribute, one should investigate the attributes' values for all products that have been sold in the market and calculate the minimum, average, and maximum values for each attribute. Minimum, average, and maximum value means minimum acceptable value, middle value point, and maximum desirable value, and corresponds to the normalized scores 0, 0.5, and 1 respectively. A value function can be drawn by using these three coordinates. Finally, actual values for each attribute are normalized by applying the calculated value functions of each attribute. The second step is to determine the weighting factors of the attributes. The preferences for each of the selected attributes are different and these differences are considered by weighting factors. Here, the weighting factors of attributes are determined by the consumer's questionnaire because consumers are the main actors in purchasing, using, and evaluating products. It is possible to sum the quality of chosen products using normalized values and subjective weighting factors of the attributes.

The final outputs are the relative quality values of chosen products. On the other hand, environmental impacts are calculated by following both Life Cycle Inventory (LCI) analysis and the Life-cycle Impact assessment Method based on Endpoint (LIME) modeling, which was developed by our institute in Japan. The quantification method for eco-efficiency derives the ratio of product quality to whole environmental impact based on LIME was calculated. The major advantages of the proposed method are that it applies a non-linear value function that reflects the market situation, and that it is possible to identify the quality level of chosen products by considering all products that have same functions in the market.

SP 33 Product End-of-Life in the Motorcycle Industry: an Integrated Management Perspective

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Moving from the principle of "extended producer responsibility" (Directive 2000/53CE), a project has been recently started in collaboration with a number of companies from the motorcycle industry located in Italy. This project aims at studying the possibility of recovering and recycling components and materials resulting from the end-of-life collection of assembled products, esp. in the motorcycle industry.

The main objective is to identify opportunities to improve the functional, economic and environmental performance of products and production systems, along the supply chain, by integrating into existing or alternative processes the flows of materials and components resulting from the disassembly of end-of-life products.

The theoretical framework is based on the principles of Eco-efficiency and Industrial ecology. For the design and management issues Eco-design and Reverse Logistics tools will be used. The options of improvement will be assessed by means of Life Cycle Oriented tools to identify those scenarios that would feature the lowest overall environmental impact, and, consistently with that, an improved operational and economic performance of the

industrial network in which they will be implemented.

The project mainly focuses on the following issues:

- materials choice, product structure, production processes, recovering/recycling processes;
- disassembly, identification tools and traceability of components and materials; packaging, handling systems, logistics organisation;
- management accounting and costs accounting.

Project outcomes are expected to provide significant insights on: i) the potential reduction of the overall environmental impacts generated by the systems under analysis, esp. related to the end-of-life product management, as well as the use of resources as an input to production processes: ii) the potential competitiveness increase of the manufacturing system, as a result of reducing waste and maximising the recovery of materials and components, with a subsequent enhancement of their economic lives.

In this paper the overall project is outlined and results of preliminary analyses are presented: this phase includes all the activities aimed at recognizing the current state of products (materials and components), processes and production systems; data collected will be used to formulate hypotheses and identify alternative recycling scenarios.

SP 35 Visualization of Environmental Impacts of Electrical and Electronic Products using Multidimensional Scaling

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The growing amounts of waste electrical and electronic equipment (WEEE) may cause serious damage to the environment and have adverse effects on human health. This paper illustrates the wide-ranging applicability of the concept of environmental performance applied to a variety of household appliances, using Multidimensional Scaling (MDS) to compare them and visualize their positioning. LCA environmental impact assessment is measured using Eco-indicator 99. The results indicate the existence of significant differences as regards the environmental performance of appliances. Moreover, the assessed environmental performance of products changes when their relative economic value is taken into account. The results are intended to show the potential use of MDS as a method to analyse environmental impact data, providing consumers and producers with a synthetic description of the environmental impacts of appliances as well as information on the relative positioning of products in terms of their environmental performance.

SP 36 Life Cycle Assessment of renewable energies – Aspects of cumulated energy

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Beside water and biomass wind energy and photovoltaic are the most favourable renewable energy technologies worldwide. There is an enforced market introduction from on shore and also off shore wind facilities worldwide. The construction of wind parks as well as photovoltaic devices is material-intensively, it needs a big amount of conventional energy as fossils to produce it. With the energy consumption connected are emissions of green house gases. Is the use of wind energy and photovoltaic sustainable under the aspect of cumulated energy? That is the problem the presentation is dealing with. To give an answer to the question the methodological approach of Life Cycle Assessment will be used. Life Cycle Assessment is an instrument to quantify all impacts of the entire energy supply chain. In this presentation only the cumulated energy as indicator for depleting of resources and cumulated carbon dioxide emissions will be considered. To obtain the cumulated energy demand for production, for instance, of a power plant, the whole facility has to be split up into components, sub-components and their respective materials. Using this material balance with specific data for material, energy resources and emissions it is possible to calculate the cumulated energy demand. For final evaluation of the energy systems Energy Yield Ratio as relationship of produced energy (valued as primary energy) and total Cumulated Energy Demand has been used to

decide if market introduction of wind energy is sustainable enough or not.

This paper will present and discuss the results of wind energy converters and photovoltaic stations with different nominal power output. For calculating the yearly energy output two locations of wind converters have been selected: near coastal and offshore. A wind energy converter of 1.5 MW with 67 m hub height and 66 m rotor-blade diameter, as produced in Germany, has been chosen to be considered in this presentation. Beside that a park of multi megawatt wind turbines in the ocean, 30 miles far away from the coast is considered. For calculating the energy balances of photovoltaic devices three types of plates are selected: mono-, multi-, and amorphous silicon. The results of this study show e. g. that -surveying the life cycle of a modern wind turbine-, much more primary energy can be harvested during the operational phase, than it is actually needed in the constructing phase and that the energy balances of photovoltaic devices are not so good as in case of wind energy. To advise politics in term of market introduction of renewable energies it is absolutely necessary to do such kind of life cycle management investigations.

SP 38 Energy and Environmental analysis of retrofit actions for a single-family house in the Mediterranean area

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An appropriate planning for building energy saving should need rational criteria of energy assessment to quantify energy consumption at all stages of life cycle, and suitable strategies to increase building energy performance, such as the growth of renewable sources, and the energy-efficient conversion. Buildings are characterized by a useful life of many decades, by a slow replacement rate of the building stock (about 1% per year) and by a much lower rate for building demolition (about 20 times less than new constructions). Consequently, retrofit actions on existing buildings involve immediate effects on climate change, energy consumption, indoor air quality, and other issues of sustainability as safety and accessibility. Due to the complexities of the involved actions, Life Cycle Assessment (LCA) represents a comprehensive methodology to estimate energy and environmental performance of a building at all stages of life cycle, and to identify suitable strategies of impact reduction.

In this paper, starting from an experimental investigation performed on a Mediterranean single-family house the authors highlight the significant weight of the building management step in the global energy requirement (GER) and, consequently, in the greenhouses emissions (GHG). Further, some retrofit actions are engaged and a LCA study is performed to assess the environmental impacts arisen from the selected actions, focusing on the highest impact components and tracing a balance of environmental benefits and drawbacks concerning the retrofit actions. In this step the above assessment is referred to the equipments construction and fitting. Hence a thermal simulation is carried out to estimate the primary energy saving related to the chosen retrofit actions during the building operation. The presented research is part of the Italian "Genius Loci" project on the contribution of buildings in the climate change.

SP 39 Traditional versus new buildings constructions concepts in Madagascar, evaluated from life cycle analysis point of view

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This paper deals about the study of life cycle analysis of the whole construction of traditional buildings in Madagascar. Nowadays, new construction products and new methods are integrated in Madagascar. So the study propose a computed tool to evaluate the differences between the different modes. This study includes the steps of the life cycle inventory exposed in the European normalisation (ISO 14040) It is based on the mass and energy balances. The factors depend on chemical and above all on the energy sources used in the local construction. We have also included the effect of buildings construction wastes treatment. We will also deal about a sensitivity analysis of our results.

SP 41 Evaluation for CO₂ Emission from a Golf Tournament and Scenarios for CO₂ Reduction

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Life Cycle Management (LCM) is an important concept and method for organization, groups, and society to build the sustainable society, aiming to proceed management from the sight of LCA. In recent years while global warming spreads so rapidly that the reduction effort are getting advances for those events such as international conferences, sports tournaments, music festivals, etc. To estimate the GHG emissions from those various events, following items are demanded; (1) quick disclosure of the results, (2) comprehensiveness of the scope surveyed, (3) proper evaluation for various services and articles lasting for the large numbers of items.

This time, for the purpose of promoting a golf tournament which emits less GHG from the view point of Life Cycle Management, CO₂ emission concerning a golf tournament was estimated in following way; More than twelve hundred items for activities, foods and drinks, articles, temporary constructions, equipments, distribution materials, etc. were investigated so that the CO₂ emissions from them could be calculated on the bases of input-output method. For the movement of participants including players, galleries, staffs, volunteers, and the disposal of waste, CO₂ emissions were calculated using the process LCA method. The reduction effects of the CO₂ emission were estimated using process LCA method about environment-conscious activities, including enforcement the use of public transportation, bus tour from Tokyo, use of locally produced food and drink to avoid oversea-import, forest management through the thinning by donation, etc.

As a result, about 1,000 ton of CO₂ emission was estimated totally from the golf tournament, in which championship enforcement held 70%, and movement held 27%. A CO₂ fixing effect by the forest management through the thinning was evaluated so high, that it could reduce about 66% of the total CO₂ emission through the environment-conscious activities. From these results, some indications were obtained for CO₂ reduction in managing a golf tournament. The results of inspection and evaluation of these methods and future tasks will be discussed from the viewpoint of Life Cycle Management.

SP 42 CO₂ Emission of Different Building Materials for Walls. Case: Housing in Mexico.

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Since many years, the construction of serial housing has been governed only by the economic factors, leaving the environmental aspects in a second place. At this moment, the energy consumption during the post-occupation period of buildings begins to receive attention. But the energy consumption during the buildings operation is not the only cause that contributes to the global warming. All the processes of their life cycle are also responsible for energy consumptions and consequently of Greenhouse Gases.

Therefore, researching on the features of building materials is necessary in order to have reliable data related to their environmental performance. To achieve this objective, the Life Cycle Assessment (LCA) represents a powerful aid. In this research, an analysis about CO₂ emissions produced during the phases of primary material-extraction, transport to the production site, manufacturing, transport to the construction place, building, occupation, demolition and transport to the trash site of the main building materials used in walls of economical-housing is presented. A case study in Colima, in the Pacific coast of Mexico, has been considered. Particularly, this research is looking for the wall material that is the minor contributor on global warming. The materials analyzed are: traditional brick of burned clay, hollow block of concrete and monolithic brick of cement.

The traditional brick of burned clay is a low entropy material. Since the burning process is the only energy consumption during it's manufacturing, so a low environmental impact is expected, especially because a coconut waste and wood mixture is used as a fuel. Since the wood doesn't come from sustainable plantations, the CO₂ net global balance can't be considered as null, but in the case of the coconut waste combustion, a CO₂ positive effect can be expected since it's a by-product that does not imply the cutting and pruning of the palm trees. On the

other hand, the hollow block and the monolithic brick are made of cement. So, they possess a high-energy content, which was consumed during their productive processes.

However, the cement is necessary for the three building materials (at least in the construction phase) and this one has a highly impact on the global warming during the clinker production. As well the manufacturing of steel, which is used for the three systems too.

In the other hand, the occupation phase is the most contributor to the global warming for the three cases, due to the electrical energy necessary to maintain the indoor climate houses under 28°C, during 50 years. The majority of this electrical energy came from the fossil fuel combustion, which generate a huge impact on the global warming.

Finally, to make a comparison between the building materials during the phases of their cycle life, a simulation method has been used. The method applied was Life Cycle Assessment, ruled by the ISO 14040 series and the SimaPro v. 7.0, as well as the database Ecoinvent license (v1+2).

This project has been granted support from CONAVI and CONACYT (Mexican institutions), as well the FRABA Found of the University of Colima.

SP 43 Life Cycle Comparative Analysis of Railway Sleepers Made of Wood and of Recycled Plastic: German Case Study

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The aim of this study is to compare the Life Cycle Assessment of the railway sleepers made of wood and of recycled plastic in Germany. The two environmental aspect considered in this study were deforestation and plastic waste management. In the past, deforestation has been changing the global geography, with developed countries having destroyed almost all their forest cover. However, in the middle of the 20th century, some countries began to revert this scenario, like Germany. The global population growth in the last decades has been increasing the material and natural resources consumptions and, consequently, the solid waste generation, impacting negatively the environment.

One alternative to reuse waste materials and, at the same time, preserve the existing forests could be the increase of mechanical plastic recycling industries that produce plastic lumber. This synthetic material, made from plastic waste, is very resistant and has large durability. Also, it could replace wood (which is a natural resource and needs preservative products, such as creosote, which is a dangerous substance) as raw material to produce railway sleepers. In addition, plastic lumber is expected to increase the railway sleeper lifetime in comparison of wood, which contributes to reduce the annual costs of replacing railway sleepers and the operation cost.

Since waste impregnated wood and recycled plastic are ultimately burned in incinerators to produce electricity, the greenhouse gases emissions savings from coal, nuclear and natural gas replacement by them in the power grid should be taken into account. The Life Cycle Assessment tool was applied to calculate the total emission of both raw materials. Therefore, considering the annual replacement of 3 million sleepers in the German railway network, the emissions avoided by replacing wood with recycled plastic in the production of railway sleepers when the lifetime is taken into account could be of almost 200 GgCO_{2e} per year. When comparing the German, the Organization for Economic Co-operation and Development, the North America, the Brazilian, the African and the world annual per capita emissions, it can be seen that these savings in greenhouse gases emissions represent the annual per capita emission of almost 3 million Africans and 20 thousand Germans. Also, a mixed forest area as large as the Stuttgart city area could absorb these annual emissions. Considering again the annual wood sleeper replacement and the production of 2 sleepers per tree, if all the wood sleepers were replaced by plastic sleepers, the annual cutting of 1.5 million trees could be avoided. This represents a forest of 37,5 km², or the size of 586 Allianz Arena - Bayern München. Furthermore, each railway sleeper produced from wood would emits between 374 and 417 kgCO_{2e} and from recycled plastic emits 78 kgCO_{2e} or even could saves 2 kgCO_{2e}. Therefore, this alternative raw material could contribute to reduce greenhouse gases emissions and avoid a part of the deforestation in managed forests as well, which may also be good for the environment. This procedure adds value to waste materials contributing to income generating activities towards sustainable solid waste management.

SP 45 Decomposition Analysis for Household Life Cycle CO₂ Emissions in Japan

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The conventional measures to prevent global warming had been led by producers' side by diffusing new energy technologies or energy saving products. It is true that the diffusion effect of these kinds of technologies or products had played an important role to control the growth of CO₂ emissions. However, the quantitative and qualitative needs of consumers' have been growing and the industrial structure itself has been changed to meet the consumers' needs according to the market demand. It is said that the effect of implementing the conventional measures from the producers' side had been offset by the growth of consumers' needs and therefore the importance of the measures from consumers' side to reduce CO₂ emissions in our lifestyle have been paid attention to as one of the effective ways to ensure further emissions reduction. In terms of CO₂ emissions from our lifestyle, they can be classified into "direct" and "indirect" CO₂ emissions. Direct CO₂ emissions are mainly attributed to the energy use of each household. According to the national GHG inventory report of Japan, the amount of direct CO₂ emissions from Japanese household in 2006 is 2.08t-CO₂ per capita, which only account for 20.9% of the total CO₂ emissions (9.97 t-CO₂ per capita). From the life cycle point of view, however, it can be said that the rest of the CO₂ emissions can be attributed to household, for every activities of our daily living "indirectly" induces these emissions by production, purchase, possession and consumption of goods and services.

If we are to discuss measures to mitigate CO₂ emissions in our lifestyle, it is necessary to figure out both the direct and indirect CO₂ emissions from our everyday life. One of the ways to estimate both direct and indirect CO₂ emissions from our everyday life is to combine household expenditure survey data with CO₂ emission factor of each kind of energy and input-output tables, which has been also applied to other related studies. By evaluating the estimated emissions, we can grasp the CO₂ emissions structure and estimate what kinds of every activities of our daily living have large potentials to reduce the emissions. In addition to those kinds of estimates at a specific year or point, the factors affected to the transition of CO₂ emissions will become clear by analysing the time series estimates for household CO₂ emissions, such as changes in industrial structure, composition of household attributes, household expenditure, and so on. In this study, decomposition analysis of life cycle CO₂ emissions from Japanese household will be carried out using the time series estimates calculated mainly from expenditure survey data, CO₂ emission factor of each kind of energy and input-output tables. Contributions of the factors that would affect to CO₂ emissions from household will be analysed and to what extent both direct and indirect CO₂ emissions reductions can be expected by implementing concrete actions that will lead to changes in our lifestyle will be discussed from the results.

SP 46 Home and household as a functions' network

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Recent European researches revealed that, during the last 15 years, the industrial production in the field of home appliances, has been dedicating special attention and investments to the reduction of consumption, conscious use of materials and performance improvement. Unfortunately, these initiatives allowed a limited improvement of the environmental fallout: in fact, the continuous technological evolutions cannot ensure anymore an effective reduction in the consumption and in the emissions that commodities produce, therefore the need of reconsider new production scenarios is rising.

The methodological approach of the Design by components, appears as one of the possible open paths to successfully face the on-going change; thanks to this approach, that critically analyses all the parts of a current industrial product, we can redesign new typology of products/production chains as well as the system they are introduced in. New products created thanks to this mental path represent the execution of relations and functions of the appliances.

This intervention strategy would require not only revising the planning approach to the product, but also rethinking about the whole production, retail and end-of-life cycle processes. This would inevitably generate a remarkable

industrial metamorphosis, starting with the redefinition of the concept of components.

Reinterpreting objects according to a component logic, it is possible to create families of products diversified on the base of the user's needs and according to household transformations in the last years. Operating in this way, home appliances won't be only simple products, standardized inside of the plant, but also objects managed during their use phase (maintenance included), in close collaboration with the buyer that will buy the necessary components in order to create its own functional system.

A machine designed with this vision, in fact, opens the way for a totally innovative vision of the concept of household. This can lead to the creation of component families (macrocomponents) performing the same functions but with different features, and of a machine that is designed not so much as a unitary functional system, but as a product defined by individual specialized parts to perform different function (i.e. dishwasher, washing machine and sink). Taking into consideration this new logic, the research led to the creation of an integrable based system with some macrocomponents that can, eventually, perform the different functions (i.e. dish washing, laundry and grooming).

This kind of approach and new functional system, further than generate operative advantages, brings relevant environmental positive effects: components reduction (only the needed ones are produced, shared by different appliances), flexibility of the structure (by changing one of the macrocomponents you can change the general functions of the system) and technological updating easiness with the consequent life extension of the product (only one of the macrocomponents become old, not the entire product). If we consider this latter instance we can see how maintenance would be favoured by quickly replacing the parts. Besides, if we apply this logic of the macrocomponents, we can open the track to new industrial policies for the production of home integrated systems, respecting environmental sustainability.

SP 47 The SuFiQuaD project - Sustainability, Financial and Quality evaluation of Dwelling types

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The four-year project SuFiQuaD has started in 2007 to develop a methodology that can be applied to optimize the Belgian dwelling stock. SuFiQuaD stands for **S**ustainability, **F**inancial and **Q**uality evaluation of **D**wellings. The aim of the project is to optimize buildings considering their environmental impact, their financial cost and the quality they offer over the whole life cycle, from the production of primary raw materials to the final demolition and end-of-life treatment. In the first phase of the project the optimization methodology is developed: environmental impacts are analyzed by means of a life cycle assessment (LCA). The environmental impacts are then translated into environmental costs using a monetary valuation of the environmental impacts; financial costs are calculated based on life cycle cost (LCC) analyses; and the quality evaluation is based on multi-criteria analyses. The optimization of the three aspects (environmental costs, financial costs and qualities) is based on a Cost Benefit Analysis (CBA). By means of the CBA it is possible to identify the highest marginal quality improvement for the lowest additional financial and environmental costs. The developed methodology is translated into a tool and applied in this first phase of the project to a limited selection of dwelling types. In the second phase of the project, the methodology and tool will be applied to a series of representative dwelling types for the Belgian dwelling stock. The presentation at the LCM2009 will elaborate on the developed methodology and the results of the first implementation with some selected dwelling types..

SP 48 Chain Value Agility For Achieving World-Class Man

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The range of techniques associated with competitive manufacturing has expanded rapidly since the inception of MRP in the early 1960s. These techniques integrated into the generic term Globalization. However, the range and sophistication of these techniques places dynamic Globalization status beyond the aspirations and competence of many companies. Companies progress by stages toward the desired goal of global competitiveness manufactures will have to achieve globalization status to compete effectively in global markets society. Schonberger (1986) coined the term world class manufacturing(wcm) to cover the many techniques and technologies designed to enable a company to match its best competitors. Within the various professional manufacturing attention is being paid to reliability, dependent on the stage of professionalisation, there are all kind of facilities for increasing the system design of globalization. WCM is now becoming more an area for explicit attention for all kind of manufacturing. The new concept of designing global products for global markets society has emerged in the 21 century. An agile manufacturing is a fast moving, adaptable and robust business. It is capable of rapid adaptation in response to unexpeted and unpredicted changes and events, market opportunities, and customer requirements. Such a business is founded on processes and structures that facilitate speed, adaptation and robustness and that deliver a coordinated enterprise that is capable of achieving competitive performance in a highly dynamic. On the other hand WCM is a management philosophy that emphasises the need to meet external and internal customers needs and expectations and the importance of doing things right for world market society. WCM offers a consistent and rigorous problem-solving framework for identifying the scope of the problem eliciting participant views about problem causes and system connections and identifying policy levers. Reliability, quality and cost are linked, higher quality being associated with higher reliability. The reliability of items, products and facilities is an important consideration of design by world-class Production techniques. techniques have an important role to play in dynamic world market society. WCM techniques are a competitive strategy involving continuous improvement of products, processes and services to improve quality, reduce costs, increase productivity and increase total customer satisfaction.

The paper is based on an ongoing research programme designed of to identify how the concept of agile can be made more relevant to achieve world class production. The question in this paper is which problems the management of manufacturing may encounter when it wants to organise the globalization management of the professional manufacturing more systematically for world class production. These problems such as, determining norms, developing a dynamic world-class management methodology for world market society, the demonstrability of agile in the professional manufacturing. The paper uses a case study to illustrate its findings based on company experiencing both rapid growth and increasing international competition.

SP 49 Practical Guide for Weighting Across Environmental Impacts

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LCA is a tool for decision making and/or for communication to stakeholders. Valuating environmental damages is often unavoidable in LCA, which raises the need for a procedure to develop a reliable weighting set. A study on panel weighting was performed to define the requirements for the application and/or development of weighting sets, which are compatible with the new impact assessment method Recipe . This paper focuses on the development of a LCA-users guide on how to use the different weighting alternatives. The focus is on the practical implementation for stakeholder groups that want to set their own weights. The study builds on earlier work by Thomas Mettier, Patrick Hofstetter, Roger Tourangeau, and B. Fischhoff among others. Panel weighting is especially seen as a solution for weighting endpoints. This alternative is suitable when the preferences of the population, affected by a decision, are to be accounted for. Panel weighting sets are measurements of peoples' values. In the analysis of these measurements conceptual models are applied to deal with the cognitive process of setting up values and expressing a preference based on those values. As in any other model and measurement, panel weighting sets are subject to uncertainties. The realibility and credibility of a panel weighting set can be assessed in

order to evaluate the correctness of the conclusions drawn from it.

In this study the analysis of reliability is done using existing research in the fields of LCA, contingent valuation in environmental economics and cognitive psychology. As a result a practical guideline is proposed, which contains recommendations on how to assess the reliability of existing panel weighting panels; on how to design and develop a panel weighting study; and even how to find your own personal weighting set. The study concludes that:

- Given the amount of information handled, it is necessary that the panel used in the development of weighting sets undergoes some sort of preparation phase to get acquainted with concepts, terminology, and knowledge of the actual status of the environment.
- It is inevitable for panellists to have biases for a certain impact category, a result of their knowledge, proximity to the impact categories and cognitive limitations.
- Due to cognitive limitations panel weighting at midpoint level is not appropriate.
- A panel weighting study should consider some sort of feedback on the response of the panellist, providing extra information if necessary and giving the opportunity to change the response if needed. Only in this way the panel weighting results can be later validated.
- Panel weighting studies should include information regarding the validity issues reported in this document.

SP 50 Life Cycle Sustainability Dashboard

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In recent years several efforts have been made to design different methods and tools for assessing and addressing sustainable development. This is now considered as a main target of both national and international administrations as well as private organisations. As a starting point, Life Cycle Assessment (LCA), an assessment procedure for evaluating the environmental performance of products and processes, can be used to address the environmental dimension of sustainability. But the concept of sustainability does not focus on the environmental impacts only; the two other aspects of sustainability, the economical and social ones, have to be considered and analysed as well. For this purpose the method of Life Cycle Sustainability Assessment was proposed, in which the life cycle approach is applied for all sustainability dimensions (environmental, economic and social) in order to achieve more reliable and robust results. This method includes Life Cycle Assessment to evaluate the environmental impacts, Life Cycle Costing to consider economic and environmental factors and Social Life Cycle Assessment to analyse the social impacts.

An important tool for assessing the sustainability in other contexts such as strategic environmental assessment, ecological footprint, multi-criteria analysis is the Dashboard of Sustainability. An outstanding characteristic of this tool is the understandability and communicability of the results by means of a graphical representation (a cartogram), characterized by a suitable chromatic scale. This makes the method very suitable for the application within a concerted decision-making process where non-technical subjects and decision makers are also involved.

In this paper the integration of the two aforementioned methodologies into a so-called "Life Cycle Sustainability Dashboard" is developed and presented. The aim is to improve the applicability of sustainability assessment by a communication tool for both experts and non-expert stakeholders and citizens. The involvement of the different stakeholders in the Life Cycle Sustainability Assessment plays a strategic and relevant role in the consideration of the social aspects. Moreover the power to present the results in readable and comprehensible way could be crucial for spreading the Life Cycle Sustainability Assessment, its indicators and tools through the different decision makers and levels of decision-making.

One challenge for the Life Cycle Sustainability Dashboard is the selection of suitable indicators. In fact the selected indicators should be able to represent the most meaningful factors that affect the life cycle of the considered product. For defining indicator sets two different approaches can be used: top-down and bottom-up. The top-down approach defines parameters by the identification of what is valuable to society so all impacts which are relevant

from a societal point of view are considered. In contrast, the definition of indicators in a bottom-up approach starts from the available data and tries to transfer them into consistent indicators. The Life Cycle Sustainability Dashboard can be used for both approaches. In this paper, an indicator set based on a top down approach will be presented and applied in a case study to assess hard floor covering products based on Italian data. The case study shows the applicability, practicability and still inherent limitations of the procedure proposed here.

SP 51 Multivariate analysis of similarities between environmental profiles of crops

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With the increasing use of LCA for life cycle management in the food sector, there is a strong demand for specific data on agricultural products from various regions. As the food chains are global and complex, there is a large need for specific inventories for agricultural products. Creating specific and detailed inventories requires a large amount of specific data, which are not easily available. Furthermore it is very time consuming to collect them. To fill data gaps, we therefore need easier and faster methods that enable a first assessment of environmental impacts for various products. The goal is to extrapolate products, regions or production modes based on existing well founded LCIs.

A new approach to detect and visualise similarities and differences of environmental profiles was developed as a first step. Multivariate statistical analysis, previously used to detect similarities and relationships between environmental impact indicators is used here to show similarities between environmental profiles of crops. Principal component analysis is applied to two databases with datasets for Swiss arable crops and arable crops worldwide. Midpoint LCIA indicators for energy demand, global warming potential, ozone formation, acidification, eutrophication, aquatic and terrestrial ecotoxicity as well as human toxicity were analysed. Between 76 and 80% of the variability could be explained by the first two principal components. The first component was largely related to the crop or crop group, while the second principal component mainly represents the production intensity or the farming system (conventional, integrated, extensive, organic).

By applying the method to the ecoinvent datasets we could clearly distinguish the crops grown on previously cleared land (from forest or shrub land), which confirms that such cases have to be treated separately. The method can also help to find proxy data for missing inventories. The analysis of the cereal datasets (wheat and barley) in different countries shows that there exist considerable differences between the countries, while wheat and barley are relatively close together within a given country. As a proxy for French barley, it is therefore preferable to choose French wheat than to use German barley data. The variability of environmental impacts is in general larger per product unit than per area unit. A correlation was found between environmental impacts and the inverse of yield, which can be applied to make rough estimates based on existing datasets.

SP 52 The influence of impact assessment value choices on the human health damage assessment in LCA

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When performing Life Cycle Assessment (LCA), the practitioner is confronted with several types of uncertainties. Uncertainties related to assumptions in reference flows, inventory data or the life cycle inventory model can be handled by applying methods such as Monte Carlo analysis and/or sensitivity analysis. Uncertainties in impact assessment are not easy to deal with as practitioner, and can be large. Uncertainty in impact assessment methods is, among others, related to decisions such as time frames and the type of effects to include. Many of these decisions can be seen as value choices. Particularly, impact categories that deal with environmental consequences in the far future due to an emission today rely on several assumptions.

The Eco-indicator 99 and ReCiPe impact assessment methods handle methodological uncertainties by applying a set of modeling choices according to the vision of three different perspectives, namely the egalitarian, the hierarchist and individualist perspective. Each perspective reflects a type of people with a specific vision in life and on society.

This is called the Cultural Perspective Theory. This presentation outlines the consequences of value choices within impact assessment, by using the Cultural Perspective Theory. For a range of ecoinvent processes, covering the most important product groups, the human health damage score is calculated using the three different perspectives of the ReCiPe 2008 method. Differences in results due to value choices are shown for the Human Health damage score. First, changes in relative contribution of the human health impacts due to climate change, ozone depletion, human toxicity, respiratory inorganics, respiratory organics and ionizing radiation to the overall human damage score for every perspective are presented.

The results indicate that the relative contribution of the human health impact categories changes when using a different perspective. For example, the damage score for building materials is mostly dominated by the impact of human toxicity when applying the hierarchist perspective, while for the egalitarian perspective the human damage score is dominated by the impacts of climate change and for the individualistic perspective the damage score is dominated by the damage of respiratory inorganics. Second, it is analysed whether changes in perspective also changes product ranking for human health damage. A high rank correlation between perspectives imply low changes in product ranking. We found that the ranking correlation between the three perspectives is product group specific and for the building materials the highest (0.96) between the hierarchist and individualist perspective. We outline and explain which value choices are the main drivers in result changes, when applying a different perspective and present guidelines and recommendations on how to deal with this.

SP 53 Stochastic Assessment by Monte Carlo Simulation for LCI applied to steel process chain: The ArcelorMittal Steel Poland S.A. in Krakow, Poland case study

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The aim of the paper is stochastic approach for LCA/LCI probabilistic conception with uncorrelated input/output data in steel process chain with six processes (including Coke Plant, Iron Blast Furnace, Sintering Plant, BOF, Continuous Steel Casting and Hot Rolling Mill) applied to ArcelorMittal Steel Poland (AMSP) S.A. in Krakow, Poland case study. Uncertainty assessment in LCI is based on a Monte Carlo simulation with the Excel spreadsheet and CrystalBall® software was used to develop scenarios for uncertainty inputs. The economic and social criteria and indicators will not further be discussed in this paper. The framework of the study was originally carried out for 2005 data because important statistics are available for this year and also because it represents the data, which are the foundation for the Environmental Impact Report of the AMSP, annually collected (2005) and evaluated.

The study comprises the inventory corresponding to the all process stages including the Coke Plant, Iron Blast Furnace, Sintering Plant, BOF, Continuous Steel Casting and Hot Rolling Mill. The complete inventory was integrated by main environmental loads (inputs, outputs): energy and raw materials consumed, wastes produced, and emissions to air, water and soil.

The functional unit in this study, central concept in LCA, is defined as "steel process chain includes all activities linked with steel production from Coke Plant and Sinter Plant to Hot Rolling Mill in 2005".

In this study only the following substances: hard coal, blast furnace gas, coke oven gas, natural gas, lubricant oil and the atmospheric emission of sulfur (S), cadmium (Cd), carbon monoxide (CO), carbon dioxide (CO₂), nitrogen dioxide (NO₂), chloridric acid (HCL), chromium (Cr) nickel (Ni), sulfur dioxide (SO₂), manganese (Mn), cooper (Cu), lead (Pb) have been taken in account.

LCI/LCI data are full of uncertain numbers. The benefits of Monte Carlo simulation are saving in time and resources. CrystalBall® eliminates the need to run, test, and present multiple spreadsheets.

Simulation models are generally easier to understand than many analytical approaches. Usually the overall uncertainty of an LCI is dominated by a few major uncertainties. The use of stochastic model helps to characterize the uncertainties better, rather than pure analytical mathematical approach. Monte Carlo analysis generates a mean value and upper and lower boundary value for each LCI exchange. The created inventories using the probabilistic approach facilitate the environmental damage estimations for industrial process chains with complex number

of industrial processes (e.g. steel production). Consequently, Monte Carlo analysis is a powerful method for quantifying parameter uncertainty in LCA studies.

SP 54 Exergy and ACV

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Traditional LCA methodologies (like the CML Method or EI'99), do not use an exergetic criterion to evaluate resource depletion. The Cumulative Exergy Demand (CExD) method uses exergy measurements to generate indicators of the resource quality demand. However, it is possible to measure the efficiency of the use of natural resources in a macrosystem, if the effect of exergy losses (destruction and waste) in the product systems which compose it is known. Identifying inefficient systems and implementing appropriate improvements can contribute to sustainability.

This paper proposes an integrative approach to assess the energy efficiency of a product system, by means of the application of exergy analysis and LCA. The destruction of exergy in a product as a whole was evaluated, not just in terms of the resources used, but also depending on the operation of the product system itself. A new benchmark that could determine both the potential of wasted useful work (materials, energy and information) and the environmental and economic consequences. This, together with thermodynamic data of systems product, could be a new way of interpreting LCA results, thus introducing holistic approaches of system efficiency.

SP 55 Land Use Impact Assessment of Forestry Processes in LCA

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Life Cycle Assessment is today a well-established tool to quantify environmental impacts of products and technical systems. Land use as an environmental issue has been greatly discussed in the last years, yet no consistent and comprehensive approach (that is able to aggregate over process chains) has been around to include land use impacts into LCA. Yet, the pressure to describe and quantify land use impacts of the life cycle of e.g. food, energy-crops or forestry products constantly increases, especially fostered by the increasing competition for land around the world. Currently established LCA indicators and impact assessment methods do not appropriately cover environmental impacts that stem from land use. Different approaches exist, using single indicators for land use impacts. Currently, a project of the UNEP-SETAC Life Cycle Initiative (LCI) works on the harmonization of existing approaches. This project, intended to provide operational characterization factors does not focus on the life cycle based discussion of different management practice. In order to improve the environmental performance of systems, it is, however, necessary to discuss different principles of management. Consequently, a project to meet this demand for validating and adopting current life cycle based land use impact assessment approaches to forestry management principles has been launched. SCA Corporate, the largest private forest owner in Europe, TetraPak, one of the largest fiber-based packaging suppliers and the University of Stuttgart, Dept. Life Cycle Engineering, working on land use impact assessment, cooperate to reach significant advances in this field.

The core method used to conduct land use impact assessment is based on the assessment of land quality (Baitz 2002), as agreed on in the UNEP-SETAC LCI (Milà i Canals et al. 2006). Land use impacts are caused by a reduction or increase of the ability of the land to provide different services described as "Ecosystem Services" by the Millennium Ecosystem Assessment. For the purpose of this approach, land use aspects that are derived from Ecosystem Services are erosion resistance, groundwater replenishment, water purification and biotic production. Effects on these are calculated with the use of site-specific or regional data on several properties of the land and the soil. These effects are then characterized with regard to the services provided. In addition to this assessment, other indicators that are given within the above mentioned UNEP-SETAC project will be evaluated with regard to the practical applicability to forestry land use impact assessment. As the method so far has only been used to assess impacts of mining, it will be

refined and adapted to forestry processes in the course of the project. Primary data will be gathered, representing forestry in Sweden and its impacts will be assessed accordingly. Special focus will lie on the coverage of land use aspects and whether or not the indicators given sufficiently represent all relevant aspects of land use in the forestry sector. The presentation will outline the described project, lay out the underlying approach to assess land use effects and will thus contribute to the current discussion on land use impact assessment.

SP 59 Identifying Key Parameters for the Optimisation of Aerobic Microbial Bioprocesses in terms of Environmental Burden Minimisation

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This paper gives insight into the overall approach to environmental burden minimisation in aerobic microbial bioprocesses. The authors developed a model to provide full material and energy balance estimates for microbial bioprocesses, based on a minimal set of inputs. These can be used in decision making and further analyses, including Life Cycle Assessments (LCAs).

It was seen, in case studies using this model, that increased Life Cycle Assessment (LCA) scores often result from the increased energy requirements associated with increased volume. Large volumes resulted from poor downstream separation efficiencies and low biomass or product concentrations or yields. Key contributors to the energy consumption included aeration, sterilisation and agitation, provided through a combination of natural gas, steam and electricity usage. Other factors influencing the LCA impacts in microbial bioprocesses were the raw materials used, especially those sourced as purpose-produced agricultural products. These generic areas targetted for their contribution to environmental burden were identified and tested more rigorously. Key input variables to the material and energy model were identified through a sensitivity analysis conducted within the penicillin case study. Further, the impact of optimising production compared with that of optimising downstream processing was investigated.

Changing single variables in an industrial setup may have significant impacts on the performance of the process. In an example shown for the production of penicillin V, increases in the product to biomass ratio, yield coefficients, product fractions retained in downstream processing units and percentage limiting reagent converted resulted in decreasing electrical requirement, bioreactor volume and LCA single score. Increases in oxygen flowrate and compression pressure resulted in increasing electrical requirement, bioreactor volume and LCA single score values. Changes in the final biomass concentration, waste fraction removed in downstream processing units and use of additives in a unit showed as critical points and should be investigated more thoroughly to enhance understanding and subsequent optimization.

The effect of increasing production through the final biomass concentration, product to biomass ratio or yield coefficients (Y_p/s and Y_x/s) resulted in a decreased single score LCA value. Similarly, a more effective product fraction recovery resulted in a decreased single score LCA value. To determine whether increasing the product formation or optimising downstream processing has a greater effect on environmental burden, several theoretical scenarios were investigated. In the cases considered, it was shown that both improvements in production and downstream processing decreased the LCA impacts. These were more pronounced for an improved production setup.

SP 60 Sustainability Impact Assessment of a Majorcan Tourist Using LCA, LCC and Social Life Cycle Assessment

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Tourism has grown considerably in the last decades with the ever-increasing mobility of the global population. The inclusion of sustainability in the tourism sector is of paramount importance given it is one of the two largest sectors of the Spanish economy. The tourism sector has seldom been the subject of life cycle assessment studies even though it can directly or indirectly cause the movement of natural resources and a large quantity of emissions to

all environmental compartments. The Balearic Islands received close to 13 million visitors in 2007. Majorca is the largest of the islands and the most widely frequented by tourists from countries such as Germany and England. Furthermore, it is one of the most popular vacation destinations in the world, where its local airport received more than 23 million passengers in 2007. Given the concern for the Island's natural, social and economic environments, the Government commissioned an assessment of the sustainability effects of an average tourist with the aim of incorporating a life cycle management perspective for its associated policies. Travel to and from, along with lodging, food, activities, waste generation and intra-island transport are included in the assessment to provide an overall picture of the sustainability of visitors to the island destination. Life cycle assessment, social LCA and life cycle costing methods are used to evaluate the sustainability of six tourist types: sun and beach; conference; residential; sailing; cruise ship; and golf. Intra-island transportation and lodging are expected to have the greatest impacts over the course of the life cycle of the tourist types studied. The golf tourist type is expected to have the largest relative impacts.