

Conference Reports

Life Cycle Management: Bridging the Gap between Science and Application

Report from LCM 2001 – First International Conference on Life Cycle Management

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Preamble

This conference attracted approximately 270 participants in order to define and discuss Life Cycle Management (LCM), as well as its historical basis and relationships to other systemic approaches such as industrial ecology. Applications were integrated across all subthemes of the event. Plenary lectures were held on the first and third days of the conference with three parallel sessions on the second day. Fifty-three platform presentations were complimented by forty-seven posters all of which are detailed in an extended abstracts book¹. A preview of a report on Life Cycle Management² based on the deliberations of the LCM working group of the Society of Environmental Toxicology and Chemistry (SETAC) was also included in the material provided to attendees. The conference concluded with a panel discussion and an optional tour of the Kalundborg Center for Industrial Symbiosis and preceded a one-day meeting to discuss the UNEP/SETAC Life Cycle Initiative (see [1]).

A special characteristic of LCM 2001 was that it attracted much more interest from businesses (multinational corporations as well as SMEs) than most conferences in this area, and that there was a relatively strong participation of developing countries, which seems to be a promising approach to tackle the challenges in the area of sustainable development laying ahead. The conference was perceived as very stimulating and successful by the business as well as the academic world and it was welcomed that this concept will be continued in future events³.

Plenary 1: Introductory Session – Why LCM?

KONRAD SAUR, the chairman of this session from Five Winds International, cited the shift from environmental process management in large firms (e.g. pollution prevention, waste minimization) to product-based methods, including those for SMEs. He specifically gave reference to a 1999 EC document on Integrated Product Policy (IPP) and Environment Canada's Guide to Life Cycle Management for small firms (1995).

In the opening remarks STEEN GADE, the Executive Director of the Danish EPA, noted a shift, in part due to ISO 14000, from a purely environmental focus to a product emphasis. He also referred to a Danish survey that observed three main barriers to implementing LCM: lack of knowledge, particularly in SMEs, a lack of tools and fear of information disclosure. DAVID STANNERS, a Program Manager at the European Environment Agency, noted a shift in the EC's focus from

supplying guidelines to the provision of the access to information on a continuous basis. He also referred to the Integrated Product Policy (IPP) Green Paper, which has been submitted for comments and is scheduled for finalization as a white paper by December 2001. IPP will focus on upstream policies given that a recent survey has indicated that 91% of firms polled have a poor dialog with stakeholders.

ARNE REMMEN (Aalborg University) discussed the balance of technical and social factors in IPP and LCM. He noted that, regardless of local progress in environmental issues, the global damage continues to increase. He, therefore, cited a tendency and a need to move from the polluter pays principle, to pollution prevention pays and, the latest P3 theme, Profit-People-Planet.

Plenary 2: What is LCM?

CLAUS STIG PEDERSEN (Brd. Hartmann) discussed What is New in LCM? and noted that LCM strategically links P3 concepts, though it differs from other systemic environmental assessment, or evaluation, approaches by its business focus. Specifically, Pedersen believes that LCM includes liability management, innovation, stakeholder relations, product chain optimization and a focus on cyclic material flows within a product and customer perspective.

¹ A limited number of abstract books are available by contacting: sch@dk-teknik.dk.

² The complete working group elaborations will be published as a book or comprehensive proceedings in 2002. Please contact the corresponding author of this report (David Hunkeler) for further updated information.

³ An electronic only conference (LCA/LCM 2002) will be held in May 2002 and the format of LCM 2001 will be continued at LCA/LCM 2003 in Seattle, USA, in summer 2003. Further can be obtained at www.lcacenter.org.

Drivers and entry gates for LCM in organizations was discussed by KONRAD SAUR who noted that environmental assessment, and management, differs from financial analysis, in that the latter has a single indicator, all based on the monetary unit, whereas environmental measurement lacks a common measure, hence causing a proliferation of metrics, or indicators. Saur summarized the three years of deliberations of the SETAC working group on LCM with the following definition:

"Life Cycle Management is a flexible, integrated, framework of concepts, techniques and procedures to address environmental, economic, technological and social aspects of products and organizations to achieve continuous environmental improvement from a life cycle perspective."

Drivers include government actions and legislation, global agreements, such as the Kyoto protocol, marketplace demands, NGO demands, demands from institutional investors in the provision of credit to firms, as well as incorporation into a portfolio, as is practiced by several mutual fund managers. A final driver is the expansion of the legal liability of the board of directors to include responsibility for environmental aspects of the firm. Entry gates include various divisions within the firm, including marketing via responses to consumers, production via responses to supply chain questions. Procurement can also lead to LCM by incorporating innovative solutions or suppliers. Engineering and top management can also initiate LCM via bottom-up and top-down approaches.

JACQUELINE ALOISI DE LARDEREL, the Assistant Executive Director of the United Nations Environmental Program (UNEP), discussed the untapped potentials in sustainable consumption. She mentioned the UNEP/SETAC Life Cycle Initiative (see [1]), which will provide a platform for representatives from large and small firms, north-south dialog, governmental, non-governmental and academic institutions. The initiative attempts to define and develop pragmatic approaches, share successes and define appropriate tools. It will include external sponsors, an International Life Cycle Panel and Scientific Executive Committee as well as working groups and task forces, with external peer review. Deliverables should include easy-to-access information, sectoral guidelines and training modules.

Plenary 3: LCM in Practice

KEVIN BRADY (Five Winds Int.) discussed case studies in corporate benchmarking in regards to sustainable development. He focused on a survey of approximately twenty CEOs of multinationals to take a ten year historical look at the firm's drivers, strategies, programs and tools related to 'sustainable development'. This includes companies such as Compaq, DaimlerChrysler, Noranda, Shell and Suncor. He also mentioned results from a Round Table, whose members include Boeing and Rio Tinto. These activities have identified cost reduction, reputation, employee retention, innovation opportunity, revenue generation, the maintenance of the 'social license' to operate, transparent communication, and a shift of environmental and social responsibility to direct costs as drivers. In summary, leading firms in environmental management have a vision, indicators, hopefully validated, and effective communication. Indicators include general global measures, such as global warming potential, product or client-specific metrics and internal metrics, which, for some firms, can be quite extensive. Industry's strategy for implementing sustain-

able development includes design for environment, dematerialization and stakeholder dialogue.

BILL FRANKLIN and BEV SAUER (Franklin Assoc.) outlined the application of LCA and LCM in the support of informed business decisions. In 1994, Chrysler defined LCM as a cost difference technique, though the author admitted that the scope had broadened. LCM, Franklin believes, occurs at the post-production part of the downstream supply chain. He also presented a case study for brake disc coating to stabilize the product in overseas transport, examining costs in infrastructure, transport, as well as sludge and water treatment expenditures. LCIA was also carried out with primary energy, GWP, acidification potential and eutrophication potential as impact categories. In this example, the option which had the lowest cost also had the lowest overall environmental burden. However, the ranking of the other alternatives was not the same between LCC and LCA.

JEAN-PAUL FRÉTIÈRE discussed practical aspects of LCM at 3M. 3M have 50,000 products using 10,000 different raw materials, operating in 60 countries with 15 core technologies. Thirty-five percent of sales come from products introduced in the last four years. For 3M, LCM involves a screening of the advantages, risks and opportunities of various design options throughout the life cycle. After a preliminary LCM screening, a series of systematic questions are asked for each element in an impact-life cycle stage matrix. 3M has run the LCM process over thirty times, varying from adhesives, which is a minimal study, to some medical products such as asthma aerosol inhalers. LCM has generally been carried out to improve business growth, save materials or reduce the level of hazardous substances used. 3M-LCM will be included in a corporate sustainability report. 3M may also be the first firm to have an LCM director.

Selected Summaries from the Parallel Session

In the following selected papers selectively presented in the three parallel sessions, which comprised the second day of the conference, are summarized.

In the session on Sustainable Development, BRUCE VIGON of the Life Cycle Management Group at Battelle discussed several areas where LCA could be considered for the analysis of Sustainable Development (SD). Elements essential to understanding the potential role of LCA in SD include:

- Continual change – the sustainable system is highly dynamic and adaptable, not static. The lack of an explicit dynamic framework limits LCA utility.
- Uncertainty and ignorance – the time frames involved and the complexity of the interactions indicate analysis within the context of adaptive, evolutionary models may be appropriate.
- Interdependencies – interactions between the human elements (anthroposphere) and the biosphere are critical to creating the changes necessary to develop and maintain a dynamically stable and resilient system. A more resolved impact component is required.

He concluded that inappropriate use of LCA in SD analysis is potentially damaging to the credibility of the methodology.

In the Supply Chain session BARBARA LIPPIAT (NIST) presented a systematic methodology for selecting cost-effective green build-

ing products – the BEES model (Building for Environmental and Economic Sustainability). The goal of this model is to achieve the most appropriate balance between environmental and economic performance based on the decision-maker's value judgment. BEES was supported by US EPA and by the White House-sponsored Partnership for Advancing Technology in Housing Program and is now implemented in free publicly available decision-support software complete with actual environmental and economic performance data for 65 building products (see www.bfrl.nist.gov/oae/bees.html).

The session on **Environmental Product Declarations** was opened by EVA SCHMINCKE (Office for Ecological Studies), who discussed **communicating LCA for green marketing**. A main finding was that most labels recognized the environmental assessment, or features of the product, though few quoted the LCA, with the information highly dependent on the target audience.

PIOTR CIECHANOWSKI (ABB) presented the practical implementation of ISO 14025 in Poland, which covers environmental product declarations (EPDs). ABB uses the Swedish EPD system, which was the first one available and emphasizes product-specific requirements. These include product definition, specification of the functional unit and system boundaries as well as the inclusion of LCIA results. The 10% limit rule restricts the amount of generic data used in the underlying analysis to 10%. No end-of-life scenarios are included. Specific case studies were presented for disconnecters and power transformers.

JOEP MEIJER (Intron) elaborated on LCM as a link between LCA, EMAS and EPD with a particular focus on experiences of Dutch firms. Producers, such as the Dutch Association of Suppliers to the Building Industry, are attempting to coordinate data in regard to energy, material and waste flows as well as transport. Meijer noted that, although EMAS, in practice, is often gate-to-gate, it can benefit from links to LCA and EPD. This includes unification in conversion, unification in sources and checks of completeness. The three speakers in this session, in response to a question from the chair, stressed that the principal advantages of EPDs are in product image and marketing as well as product improvement itself. The session concluded with a reference to a new NIMBUS report⁴ detailing a coordinating system for EPDs.

Life Cycle Economy the topic of another session, which was opened by DAVID HUNKELER (Swiss Federal Institute of Technology). In his talk **Return on Environment – Addressing the Need for Normalization and Validation in Ecometrics** he discussed the various subjectivities involved in LCAs and hypothesized that, if based on the same inventory, life cycle costing and impact assessment could be used to cross-validate each other. In a series of cases including light bulbs, furniture and auto parts, Hunkeler demonstrated that the ratio of a scaled life cycle cost, normalized by the selling price, to a validated non-weighted impact assessment indicator, such as GWP or ODP, clustered around a mean value. This ratio, called Return on Environment, was shown to reduce the variance in either LCC or LCA, and have typical values in the 2–20% range. It was advocated as a validation tool, as well as a means of carrying out preliminary cost estimation, or impact assessment.

⁴ Ole Jorgen Hansen, Heidi K. Stranddorf et al., *Nordic Co-ordinating System for EPD (Type III)*, Report for the NIMBUS Project, ISBN 82-7520-425-9, Fredrikstad, July, 2001.

GERALD REBITZER (Swiss Federal Institute of Technology) further elaborated on the aforementioned Return on Environment concept by presenting studies, which focused on merging economic and environmental information in LCM. These included a fresh-water tank for a passenger aircraft, as well as an ongoing study on water treatment, as a service. He noted that the combination of LCC and LCA could lead to the establishment of industry-specific benchmarks and that the joint application of these economic and environmental methodologies produces exploitable synergies.

NORIHIRO ITSUBO (AIST) discussed **total cost accounting and the assessment of external costs in the product life cycle**. Itsubo began with a presentation of the various LCM tools presented to the SETAC LCM working group. Interestingly, while the various tools were flexible, and multidimensional, none could span the six pillars of LCM including the inclusion of a product LCA, costing, design information, environmental management, labeling and supply chain management. Therefore, multiple tools, or indicators, will be required. In his study, conjoint analysis was used to connect environmental endpoints to a monetary value for external costs. In a case study on refrigerators with and without CFCs, the DALY calculated was approximately 2.5 times that estimated by Ecoindicator'99, likely due to the fact that the Japanese method includes cataracts in addition to the skin cancer assessed by Ecoindicator'99. Itsubo's total cost accounting included corporate costs, consumer costs and social costs. Relative to the Swedish EPS system, the costs were underestimated, although the cost and impact rankings were always constant between methods.

In the **LCA/LCM session** BO WEIDEMA (2.-0 LCA Consultants) gave a talk on **LCM – A Synthesis of Modern Management Systems**. He identified four key elements of modern management tools: bottleneck identification, friction removal, shrinking to size and adjustment to demand. Carried out stepwise, these elements would lead to reduced costs and/or environmental impacts. Weidema stated that LCM as a management paradigm has the potential to provide a synthesis of the modern management theories and practices due to its global throughput-thinking approach and its integration of concepts such as life cycle costing, re-engineering, product benchmarking, supply chain management, quality function deployment, etc.

JIM PETRIE (University of Cape Town) continued the session with a presentation on **decision making for design of cleaner processes**. He detailed the development of a decision support framework in regards to sustainability objectives and the necessary trade-offs between techno-economic, environmental and social considerations. He stressed that in this context one has to distinguish between operational, tactical and strategic management due to the different stakeholders involved.

The **CHAINET Toolbox and Network** was the focus of two sessions. The combined use of analytical tools: experiences from the CHAINET programme was the title of the presentation of HELIAS UDO DE HAES (CML, Leiden University). CHAINET was a concerted action financed by EU-DGXII for the work period 1998–2000. Historically, its aim was to broaden the scope of the preceding LCANET program, which just focused on LCA. More specifically, the aim was to link demand and supply of environmental information in the field of LCM. A structured approach was used, meaning that both demand and supply of environmental information were char-

acterized according to a number of characteristics, after which the two were linked together. The focus has been on analytical tools. Eleven analytical tools have been systematically described, including LCA, MIPS, ERA, MFA, SFA, CERA, IOA, LCC, TCA and CBA. Demand and supply have been linked, starting from question types, indicating which types of tools are particularly suited for which type of question. For instance, it became clear that LCA is particularly useful for operational questions, but less so for more strategic questions. Other aspects concerned the distinction between a broad overview and a detailed analysis, and the cultural context of the decision. Thus, it appeared that without agreement on the criteria to be used, quantitative analytical tools such as LCA, ERA or CBA may not be very helpful as support for decision-making. Rather more robust quantitative, or even qualitative tools may then be used instead. Further points which received attention were the combination of tools (rather than developing a supertool), and the customization of tools (with the need of periodic validation against a more detailed analysis). The project was concluded with three cases, one on electronic goods, one on the car, and one on clothes washing. The results will be made public in a book to be published by Kluwer.

GUIDO SONNEMANN (University Rovira i Virgili) presented a methodology for specific LCM applications that allows estimating environmental damages for industrial process chains, stepping out of the LCA framework and integrating other environmental tools according to the CHAINET idea. The basis for the general strategy is based on an algorithmic framework including a procedure that allows determining the distribution of the environmental load along the various life cycle stages. Relevant processes and pollutants are identified and used to elaborate an eco-technology matrix to be assessed by fate & exposure analysis at different levels for a compromise between practicality and accuracy. Results are then used as input for the damage assigning matrices carried out by simple impact parameters in a multi-variable analysis or by the aggregation to a reduced number of widely accepted indicators as e.g. DALYs. The methodology has been applied in a case study on a process chain related to waste incineration.

MANUELE MARGNI (Swiss Federal Institute of Technology) presented a methodological framework for life cycle evaluation of companies aiming to covering the gaps of facility focused environmental management. Qualitative in-house methods mainly consider on-site emissions without looking at life cycle burdens, causing evaluation errors that may reduce the effectiveness of the EMS and induce an inefficient use of economic resources. The proposed screening methodology is based on a synergy between LCA and Ecodesign approaches and combined with a life cycle costing analysis. The methodology was applied on two case studies: a service company and a mechanical industry, which clearly showed that reductions of environmental impacts have to be considered outside the classical company boundaries. The approach, which identifies the relevant aspects in an environmental-financial interface, showed the opportunity given to the decision-makers to take the right decision with an efficient use of economic resources.

GREG NORRIS (Silvatica/Harvard) illustrated a framework for estimating the value of LCAs as a function of their uncertainty and scope, the characteristics of the decision and other parameters. He began by describing public (societal) and private (com-

pany internal or client) perspectives on LCA value. He suggests that the application of the societal perspective in valuing the LCA might be preferable, because the private perspective already includes LCA-relevant influences without actually incorporating LCA results. Based on this motivation, Norris then explored a model of LCA value from the societal perspective and illustrated the development of a first-order estimate of the potential value to society comparing alternative sandwich packaging, or 'clamshells', in support of a product selection decision by a major worldwide fast food restaurant chain.

In the session **Environmental Performance** TOM SWARR (United Technologies) focused on the question if substance bans promote life cycle thinking. United Technologies (UTC) has adopted goals to accelerate the substitution of high-risk materials of concern - heavy metals lead, cadmium, mercury and hexavalent chromium and chlorinated solvents. These materials will be eliminated from all new products introduced to the market after January 1, 2007 and legacy products by January 1, 2012. A simple hazardous materials index (HMI) was developed to help designers track progress. Each material in the bill-of-material and ancillary materials used in the manufacturing process is scored using the Pollution Prevention Progress Measurement Method (3P2M) algorithm developed at Purdue University. Composite scores for a complete product are defined by simple weighting based on number of parts. This metric allows designers to quickly compare alternative design concepts. Selected pilot life cycle studies are being conducted to assess the concern that materials ban force designers to substitute less well characterized materials that simply shift impacts to other life stages or other media. Preliminary results show that greater than 90% of total life cycle impact of the long-life products typical for UTC occurs during the use phase. Thus, a small number of product attributes, such as energy efficiency or product noise (e.g. for aircraft engines), can be used to quickly assess life cycle trade offs.

In the session on **Stakeholder Values**, THOMAS EKVALL (Chalmers University) discussed the ethical implications in the choice of marginal or average data. He presented a categorization, noting that the marginal concept deals with consequences and is hence part of teleological ethics, where the consequences ('good' or 'bad') are the central issue. The use of average data, however, is based on rule ethics, meaning that specific conditions are not taken into account for the individual decision. Ekvall used the case study of aluminum production in Norway, which supplies hydroelectric energy to Denmark, to demonstrate that the consequences of choices are not easily neglected, nor is the ultimate decision. Ethical interpretations make us aware of these limitations.

MARCELO COSTA ALMEIDA (University of Sao Paulo) studied the role of the automobile tire life cycle in the context of global climate change, focusing on carbon dioxide and methane. It was assumed that an 8-kg tire has 17.5% natural rubber and 30% synthetic rubber, with its rolling resistance contributing to 1.25% of the fuel consumption of the automobile. The complex interplay in the carbon cycle was discussed, with Costa Almeida noting that a rubber tree sequesters 120 kg of carbon per year. Retreading resulting in reuse of tires also dramatically reduces life cycle energy (95% hydro and 5% thermal) as well as CO₂ emissions.

WULF-PETER SCHMIDT discussed **environmental life chain management** at Ford Motor Company. He stressed that Ford believes that the global situation is very severe. Quoting Bill Ford, the firm's chairman, he began his talk by noting that Ford had "once provided the world with mobility by making it affordable; in the 21st century they want to continue providing the world with mobility by making it sustainable". Schmidt addressed the incorporation of up and down-stream stakeholders in decision-making. Interactions between stakeholders, which include trade organizations, NGOs (e.g. Friends of the Earth) and consumers, and sharing of responsibilities are key elements. A specific case presented included Ford's cross-functional teams with suppliers. A second example is the current EC LIRECAR project, which also includes DaimlerChrysler, Opel, Renault, Volvo and VW. This involves the evaluation of a standard 950-kg vehicle to evaluate the life cycle benefits of recycling versus weight reduction. A voluntary reduction of CO₂ emissions from the current 170 g/km to 120 g/km, has been adopted by 2008. The transition of the automobile to a service is also evidenced by the industry's tendency to rent vehicles and supply motorized bikes. According to Schmidt, providing mobility has to go beyond selling automobiles.

The session on **Data Management** included MARIA WALENIUS HENRIKSSON (IFP Research), who presented a study on the life cycle of a vibration damper for a car, comparing different rubbers and observing, not surprisingly, that the use phase dominated. Natural rubber was preferred to styrene butadiene, with the additives having a minimal effect on the consumption of energy. The environmental impact can be reduced by decreasing material weight, substituting fuels and improving engine efficiency.

ANGELINE DE BEAUFORT (FEFCO-GO-KI) provided an update on the deliberations of the **SETAC working group on data availability and quality**. Based on extensive interviews, with questionnaires developed by CHAINET, the drivers for data collection were assessed. In industry, these included supply chain requests, product and process optimization and marketing. From an institutional perspective, the creation of awareness, public data availability, eco-improvement and transparency were drivers. Barriers for data exchange, amongst corporations, included confidentiality, a lack of expertise, the need for methodology development, as well as the high cost and time requirements. For public institutes, a lack of data and funding were important barriers. Recommendations to overcome barriers are the use of case studies and awareness promotion. They also believe that the initial level of complexity should be simple, expanding with need. The SETAC working group called for international standards. The complete work of this group will be published as a 'Code of Life Cycle Inventory Practice' by SETAC in 2001. De Beaufort concluded by presenting the European Database for Corrugated Board.

Plenary 4: Poster Session Summary and Awards

In this session, the posters were given special attention. Divided into four topics, the main contents and highlights of the forty-seven posters were presented. TOMAS EKVAL (Chalmers University) summarized the eleven contributions related to **Design for Environment**, which included case studies, methodology, indicators and decision-support systems, including stand alone and web-based software. Applications included

the DfE of automobile and electronic components. Specifically noted were the contributions from ANN MARIE CHALKLEY et al. (Brunel University), who examined the optimal lifespan for refrigerators. EAGAN ET AL. (University of Wisconsin-Madison) discussed customer perception of environmental attributes. They recommend that key customers, with preferences for environmental features, are identified and target marketed. The poster prize in this section was awarded to PEDER FITCH (University of Washington), who developed a decision-support framework for innovative product development and emerging technologies. His first step includes the environmental attributes, specifically in the product attributes. Material process trees are then used to accommodate the uncertainty in the early design stage to extrapolate life cycle costs and impacts from a probabilistic perspective.

WALTER KLÖPFER (CAU) summarized the twelve posters on **LCA Case Studies and Methodology**. Four presentations discussed LCI and data issues, including life cycle inventories from Brazil and Thailand. One poster discussed resource conservation from a thermodynamic perspective. There were also four posters in management and policy. This included the use of LCA in a Malaysian policy approach to solid waste management. Solid waste options in Catalonia were evaluated environmentally. The management of lubricating oil in South Africa using life cycle approaches was also discussed. There were two papers dealing with comparative LCAs and one assessing the cleanliness of biotechnology. The poster award in this section went to BIRGIT BRUNKLAUS and HENRIKKE BAUMANN (Chalmers University) for a paper on the environmental assessment of housing management using time series. Their specific question was to evaluate, if different management styles (frequent vs. less frequent maintenance cycles) for apartments provide different environmental performances. Given that LCA is static, the integration of the LCA as a function of time was used to identify schedules for renovation and maintenance and their affect on environmental burden, with case studies now under way.

HELGE BRATTEBØ (NTNU) summarized the twelve papers in the **Life Cycle Management** section. One set of posters discussed the integration of environmental and financial data, including cost-benefit analysis, life cycle costing and net present value (NPV). Cases included energy networks, the building industry and the use of animal wastes in cutting fluids. A second group dealt with modeling, specifically artificial intelligence planning of industrial robots. A set of studies also discussed the organization of LCM services, with one showing that modern EMS can have a short payback time. Two similar cases, presented by Unilever and Proctor and Gamble also discussed systemic approaches to streamline LCA work across global business units. A final group of posters focused on dissemination and dialogue. This included a Danish case on the new 'Handbook of Product Oriented Environmental Work', as well as a plea to increase product chain communication, in part via internal awareness building. The poster by MAGORZATA GÓRALCZYK and JOANNA KULCZYCKA (Polish Academy of Sciences) on the financial aspects of LCA in the Polish mining industry, was selected for the award. The main point of their presentation, which evaluated an underground mine drill car, was to combine investment and environmental metrics.

FRANCESC CASTELLÓ (University Rovira i Virgili) summarized the poster session on **Sustainability and Decision Making**, which

was comprised of twelve presentations as well. He noted that virtually all contributors demand the integration of human, social, economic and environmental aspects in decision-making along product chains. Three themes dominated the posters: indicators, case studies and plans for environmental management integration. In regard to the global aluminum flow, local, regional and global indicators were presented. The twenty points of the Emmitsburg plan fostering the rational integration of human and environmental considerations into decision-making, was also summarized. A case summarizing the interaction in the management of chemicals was presented which combined a laundry service of a chemical manufacturer as well as a hotel chain. The case studies included a Malaysian case on sustainable land management, alternatives for biomass valorization and the use of the palm oil crop as an alternative renewable energy. The three cases also discussed CO₂ mitigation. The poster by CHAN JINHOOI and KS LOW (University Malaya) on the potential of palm oil and palm biomass as an alternative green energy source was selected for the poster award. Palm oil was justified given its energy density (3.6 to 5 tons per hectare annually) and its long replanting cycle (25 years). JinHooi studied the material (e.g. chemical) inputs as well as energy flow for one palm tree. Byproducts to the palm and kernel oil, include fruit fiber, the kernel shell, empty fruit bunches and mill effluent, which generate energy and biogas. A preliminary LCA concluded that the energy input for a palm is 6.7 GJ with an output of 85 GJ over the 25-year cycle. Based on these calculations, it would be possible to replace all fossil fuels by palm oil in Malaysia with the land area currently used for this crop.

There was a strong consensus that all posters were of a high quality, and the poster summaries were an important part of the conference's deliverables. Due to this the posters got more attention than is common at similar conferences. The Chairman delivered four additional poster prizes to HARRO VON BLOTTNITZ (University of Cape Town), GIL DA SILVA (Technical University of Sao Paolo), PONGVIRA LOHSOMBOON (Thailand Environmental Institute), and SUMIANI YUSOFF (University Malaya).

Plenary Session 5: Integration and Implementation

BRADEN ALLENBY (AT&T) discussed the *Use and Abuse of Life Cycle Methodologies in a Service Economy* and raised many questions. He noted that the future development of the environment requires new technology and the consideration of social aspects. The interplay of the aforementioned have, at least, four dimensions: governance, market⁵, culture and the anthropological earth. Other issues, which are usually overlooked, are complexity⁶ and cognitive⁷ processes. From an environmental perspective, three revolutionary technologies, which may change the world, have not been studied in depth: information technology, nanotechnology and biotechnology. Allenby also questioned to what extent tools such as LCA need to consider the consequences of new products, and lifestyle options. As an example, the interplay of longer life, more disposable income in retirement in developed countries and advanced, affordable, aircraft technology imply that the burden

⁵ Allenby questioned if the Kyoto protocol was not a commoditization of the atmosphere.

⁶ A modern automobile, for instance, has more computational power than was used on the first moon landing.

⁷ Genetic algorithms now create chips that, while functioning, are so complex that they are not understood by the designers.

of travel reaches virtually all regions of the globe. Do such considerations need to be considered in an analytical tool?

ROLAND CLIFT (University of Surrey) discussed *decision support modeling for material recovery, recycling and cascaded use*. He noted that the timing of this conference was very good due to two new drivers for LCM: the EC's initiatives for Integrated Product Policy as well as take back initiatives. LCM addresses the organization of materials and energy flows in the human economy. Clift then turned to a large case study, CHAMP, involving the material flow between six plastic firms at various stages in the supply chain, including polymer producers, part manufactures, end-product suppliers and material-recovery enterprises. He also noted that some materials, such as glass, have an ecology of reuse, where the value added, and technical requirements, decrease as the material moves through its life cycle. For polymers, this loop might include reuse, mechanical recycling, depolymerization, chemical recycling and pyrolysis, as well as energy recovery. The logistics of collection after use often dominate. For example, reverse-logistics require the recovery of segregated and relatively pure materials. Clift turned to work in the late 1970s on operation's research involving decision-making in multi-objective and multi-stakeholder scenarios. Ultimately, Clift proposed using this approach as a general means to examine material flows, and losses, in the human economy.

HAN BREZET (University of Delft) focused on the use of LCM in the design of service systems. Ecodesign (a.k.a. Design for Environment) has been adopted by approximately one-quarter of The Netherland's 4000 firms engaged in design. However, beyond early adopters, there was insufficient integration within the regular business practices of these organizations. Brezet is carrying out long-term reflective practice experiments with some of their business partners, particularly in regard to households, offices, tourism and recreation, and mobility. The latter includes car sharing, fuel-cell assessment and the luxury bike concept. The luxury bike is intended as a solution for some of the islands, to provide a 20-km alternative to cars. Brezet concluded that the formation of a green business coalition was difficult. Furthermore, business is the driver, not the environment, and the creation of user value is essential. He also noted that he did not see a difference between product and service.

Plenary Session 6: Decision Making and Implementation

SUSANNE STORMER'S topic was the *management of stakeholder relations* in Novo A/S, a multinational company in the businesses of diabetes care and enzymes for industrial use. Their business agenda deals with issues such as globalization, child labor, diversity, bribery, equality, animal welfare and ethics. Confounding factors include North-South differences and the digital divide. The types of dialogues used include 6–8 person dialogues, 15-person focused workshops and 2-day site visits. Other types of partnerships include a Chinese biodiversity fund in cooperation with WWF, learning programs with patients, and meetings with consumers, legislators and academics. According to Stormer the triple bottom line does make good business sense, as evidenced by the stock-price over-performance of the Dow Jones Sustainability Index relative to the DJIA, by approximately 40%.

JIM FAVA (Five Winds Int.) presented a paper on *Building Knowledge to Implement a Sustainable Strategy*. According to Fava, the five elements of sustainable management include human

and environmental safety, regulatory compliance, customer requirements, resource conservation and the proactive addressing of social consequences. Fava used Rio Tinto Borax as an example who followed a process of Goal-Metric-Target definition. Other examples include B&Q, the British hardware marketer, who has decided to act up its supply chain by ranking suppliers' environmental performance.

LONE JOHNSEN, former chairman of EEB, discussed the **Rio+10 industrial challenges**. The 'New Global Deal' for the Johannesburg conference includes the decoupling of environmental degradation from economic growth within ten years. The decoupling emphasis includes eco-efficiency, Factor 4/10, and LCM. Johannesburg should also address new forms of global governance, including corporate governance. Some problems of globalization include the insufficient capital flow from developed to developing countries, which was \$227 billion in 1997. In comparison, OECD countries gave about \$353 billion in subsidies to their farmers, also questioning the validity of the price mechanism. Perhaps most alarming is the fact that the 50 least developed countries account for 0.4% of world trade, while multinationals control 97% of intellectual property. The top 500 of these firms account for two-thirds of world trade, with the top-10 having the purchasing power of the smallest one hundred countries. Interestingly, a survey of 20,000 citizens, in 20 countries, showed that they had more trust in the NGOs barricaded outside of the Seattle summit, relative to those inside. The lack of choice of civil society, in face of the concentrated power of multinationals, is a concern. Johnsen noted that the emergence of the World Wide Web has lead to a new type of anti-corporate, and anti-government, activism. She concluded by noting that civil society requires resources for, among other reasons, their dialog with multinationals.

Closing Session:

Future Developments and Cooperation on LCM

MARY ANN CURRAN (US EPA) introduced the life cycle initiatives at the US EPA. These include policy development support for the LCA-based screening of fuel additives and federal procurement of environmentally preferable products. The EPA has an effort on data availability and with LCAccess, a web-based portal (www.epa.gov/ORD/NRMRL/lcaccess). Their research efforts focus on impact modeling via TRACI (tool for the reduction and assessment of chemicals and other environmental impacts). The tool, in beta testing, will carry out impact modeling at the midpoint level based on a life cycle inventory. The EPA also sees itself as having a role in the coordination of conferences. In the year 2000, a successful LCA conference, InLCA, was organized. An Electricity Production Workshop will be held October 22-25, 2001 in Cincinnati. The American Center for LCA, based in Seattle, was also introduced (www.LCAcenter.org). In conjunction with this Center, the US EPA is also involved in the organization of the next Life Cycle Management conference, LCM 2003 to be held in Seattle.

RON WILLIAMS (General Motors) presented the past, present and future environmental activities of the Society of Automotive Engineers (SAE). From November 12-14, 2001, SAE will host a conference and exposition on environmental sustainability on land, air and sea mobility in Graz, Austria.

PATRICK EAGAN (University of Wisconsin) presented the IEEE's (Institute of Electrical and Electronics Engineers) view on envi-

ronmental considerations in the electronics industry in the United States. He noted the extreme fragility of the ecosystem, which is often best viewed in isolated regions, such as the arctic. The envirosphere and business world therefore need to communicate, though there are difficulties in these regards. He believes that initiatives will come from progressive states. He mentioned that the drivers in the electronics industry come mostly from Europe and Japan (e.g. in IPP and the issue of lead-free solders). On May 6-8, 2002 there will be an IEEE meeting in San Francisco related to sustainability.

HELGE BRATTEBØ (NTNU) gave an overview of the scope and activities of the new International Society of Industrial Ecology (ISIE). Industrial ecology studies the material and energy flows and the influence of economic, political, regulatory and social factors on these flows (i.e. an industrial metabolism approach). Tools to date have included material flow analysis, energy analysis, LCA and DfE. ISIE, which is based at Yale University, organizes conferences and publishes journals, with plans for a handbook for industrial ecology in work. Information on ISIE can be obtained from www.yale.edu/is4ie.

LEO ALTING (Technical University of Denmark) summarized the activities of the Life Cycle Group in the International Institution for Product Engineering Research (CIRP). Life cycle engineering is the primary focus of the scientific technical committees of this predominantly academic organization. Anne Solgaard (UNEP) discussed the new SETAC-UNEP life cycle initiative and the role of UNEP herein. They are interested in developing and disseminating tools to foster sustainable development, as well as involving SMEs and NGOs in developed and developing countries. In terms of LCA, they will focus on best available impact assessment methods, LCI databases, and rules for system boundaries and allocation. For LCM, they are interested in a framework for life cycle thinking, the development of indicators for benchmarking and in communication strategies. Designated scientific directors include Helias Udo de Haes, Greg Norris and Olivier Jolliet. Input is possible and asked for via www.unep/ie.org/sustain/lca/lca.htm.

The European Roundtable for Cleaner Production, which has been running for seven years and has annual meetings, was introduced by KIM CHRISTIANSEN (Berendsen). Multi-stakeholder dialogue and responsibility are important to the members, which include corporate managers, government officials, representatives from NGOs, financial leaders and environmental journalists. Christiansen emphasized that LCM is not a tool, maybe a system, but is mostly a toolbox.

RITA SCHENCK (IERE) announced the LCA/LCM 2003 conference, which will be held in Seattle in August or September 2003. There will also be an Internet conference in May 2002 (LCA/LCM 2002, for both see www.LCAcenter.org).

In this closing session it was stressed by many speakers and by the audience that the several organizations organizing conferences and other activities in this field should coordinate meeting activities and cooperate more closely in order to push forward the goals strived for by LCM and sustainable development.

References

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