## State-of-the-Art in LCA

# Theory and Practical Implementation of Life Cycle Assessment

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**Gerald Rebitzer[1]*, Annette Köhler[2], Sangwon Suh[3], Walter Klöpffer[4], Olivier Jolliet[1], Konrad Saur[5]**

[1]Swiss Federal Institute of Technology, ENAC-GECOS, CH-1015 Lausanne, Switzerland
[2] Swiss Federal Institute of Technology, ETHZ, CH-8093 Zürich, Switzerland
[3] Center of Environmental Science (CML), Leiden University, NL-2300 RA Leiden, The Netherlands
[4] C.A.U. GmbH, Daimlerstrasse 23, D-63303 Dreieich, Germany
[5] Five Winds International, D-73072 Donzdorf, Germany

*Corresponding author (Gerald.Rebitzer@epfl.ch)

This year's Annual Meeting of SETAC Europe was hosted by Hamburg, an exciting and beautiful city, also called Germany's 'Gate to the World' due to its important and impressive seaport. The life cycle assessment (LCA) related sessions attracted over 150 participants from countries all over the world. In total the program assembled over 40 platform presentations and more than 60 posters, reflecting a broad view from academia, the private, and the public sector. Presenters form 18 countries provided a wide-ranging perspective on the state of the art research and applications of LCA and life cycle management (LCM). In the following report an attempt is made to give an overview of the four sessions focusing on life cycle approaches:

- Life cycle management
- LCA and economics – input/output analysis
- Life cycle impact assessment – toxicity/risk assessment
- LCA and economics – life cycle costing.

Lively discussions in the sessions, workshops of the UNEP/SETAC Life Cycle Initiative (see Udo de Haes 2003, Int J LCA, September issue), and meetings of the SETAC Working Groups on environmental input/output analysis, life cycle costing, and electricity generation completed the scientific program.

### Session 1: Life Cycle Management (chaired by Paolo Frankl and Konrad Saur)

Life cycle management (LCM), also due to the activities within the UNEP/SETAC Life Cycle Initiative, has become a lively element of research and application within the LCA community. This development was continued with this session, featuring 13 oral presentations and 15 posters.

The session was opened by Yoshihisa Fujii with a talk on **life cycle quality considerations in PET bottle recycling systems in Japan.** He introduced a matrix model that allows for establishing correlations between the quality of used PET-plastic beverage bottles and the quality of the recycling products (fibers and sheets), the latter a determining factor for the success of the end-of-life efforts. With this model it is possible to identify links between the resulting recycling quality and bottle handling and processing. For instance, Fujii found that the process of cap separation is the most relevant for decreasing broken bottle threads and that the handling and sorting by the consumers play a crucial role. It is planned to couple this model with LCA tools, so that the environmental benefit of recycling improvements can also be quantified. Konrad Saur gave an overview on the perspectives of life cycle management with his presentation titled **Sustainable development quo vadis – A life cycle thinking paradigm is needed.** Though significant improvements in implementing sustainable development with a life cycle view have been achieved in the last years, the current mainstream business models still lack sustainability elements, specifically if return-on-investments are required to take place within periods of less than one year. The end-of-life focus of legislation is another problem, since it is missing the systems perspective and often leads to economic inefficiency and shifts of burdens. Saur concluded that it is essential to further promote life cycle thinking on all levels of society, including SMEs and in developing countries, and that the link of life cycle tools to procedural management systems has to be strengthened. Peter Müller Beilschmidt discussed the **question if ISO 14048 is a good basis for the implementation of process data exchange interfaces in LCA software.** He outlined the key elements and requirements of the ISO specification for life cycle inventory (LCI) data documentation formats. Data exchange formats such as SPINE (www.globalspine.com) or EcoSpold (www.ecoinvent.ch) already meet the requirements of ISO 14048 and are currently being implemented by LCA database and software providers. He stressed that the standard is a good basis, but that the aforementioned implementation efforts will be the critical success factors for the widespread and consistent use of LCI data. An **approach for the efficient application of LCA in industry, demonstrated with a case study on wastewater treatment,** was the topic of Gerald Rebitzer's presentation. He distinguishes between LCA as a research tool (for policy making, comparative assertions, etc.) and LCA as a management tool (company internal applications with the goal of improving the firm's products). One important characteristic for the application in management is that the actors

and the spheres of influence of the targeted decision-maker are explicitly taken into account, leading to simplified and tailored product system models in regards to unit processes included and the required level of detail. Rebitzer illustrated his approach with a case study on municipal wastewater treatment, showing that LCA and life cycle costing (LCC) can be efficiently applied based on the same data inventory, and that clear recommendations for the decision-maker (here the operator of the wastewater treatment plant) can be derived. The subsequent talk of Manuel Gottschick **dealt with the life cycle management of closed-loop steel recycling.** Closed-loop steel recycling in order to achieve the same metal qualities as through primary ore is limited by impurities as copper from scrapped products, which accumulate in the steel cycle and lead to negative influences on the material properties. Generally proposed solutions for this problem are design for recycling as well as advanced disassembly and separation technologies, though not commonly applied due to different actors with different interests in the life cycle. Gottschick has developed a material flow analysis (MFA) model for the visualization and communication of the aforementioned issues across the process chain. He concluded that this model could support organizational learning that is necessary for the required cooperation of the relevant actors involved. Hirokazu Sugiyama introduced and explained a **life cycle based design methodology for the chemical industry.** He has developed a design methodology for chemical processes which includes, apart from economic, also environmental objectives with the goal of developing production integrated environmental measures in the sense of a design for environment (DfE). He showed the relevance and feasibility of his approach by comparing different design options for processes for the chemical recycling of PET bottles, for which he obtained LCI data via chemical process simulation. By introducing Sugiyama's approach it is possible to reduce the need for inefficient end-of-pipe technologies. The question of the **optimal ecological lifetime of durable goods** was in the centre of the paper by Heiko Kunst. Using the illustrative example of three generations of automobiles he explained that a premature substitution of (still) usable products might be advisable if the environmental burden of a product increased with time (by a decrease in efficiency or an increase in emissions caused by technical wear) or if new products, due to technological developments, have lower environmental burdens in the use phase. To find the optimal lifetime he has elaborated an LCA model with which a chain of substituting products can be analyzed. For household washing machines, for instance, he found that the optimal lifetime was in the range of 6–10 years, considerably lower than the average technical lifetime. Elisabeth Hochschorner explained the **application of LCA in the acquisition procedure of military defense material in Sweden.** In this country environmental aspects gain in importance in public sector purchasing, thus also in the military sector, though they cannot be a priority compared to economic and other aspects. Hochschorner showed how LCA can be used for the relevant applications to set specifications for tenders, by deriving the environmental key parameters. The use of LCA for the selection of alternative offers is limited, since environmental considerations must not be discriminatory, based on the EU procurement legislation and world trading regimes. However, the systems perspective of LCA can, in simplified forms, identify trade-offs, which might also have economic consequences. Further work is planned on integrating external effects into the life cycle costing of defense material. The very diverse and comprehensive LCM session was continued by Israel Herrera, who gave a talk on '**Elaboration of an environmental profile for industrial processes for different levels of detail and category indicators**'. For his goal of developing a framework for establishing the environmental profile of industrial activities, he explained the detailed assessment of emissions with spatial differentiation, based on mid- and end-point impact assessment indicators. He concluded with a case study of an industrial plant for iso-pentane separation from naphtha. **Life cycle assessment of remediation activities for contaminated sites (brownfields)** was the topic of Pascal Lesage. He showed how shortcomings of traditional environmental evaluation approaches like neglecting impacts and consequences caused by the clean up processes for site remediation itself can be overcome by integrating all relevant issues via the LCA methodology. He proposes to use LCA for decisions regarding the implementation of a specific remediation strategy, for comparing alternative technological options, and for policy development in the domain of contaminated site management. Lesage outlined a tailored LCA procedure that addresses all of the aforementioned decision situations. Frans Christensen discussed the **potential role of LCA in chemicals regulation in the European Union.** There is growing interest to go beyond the pure assessment of chemicals on a per kg basis and to assess their usage in products. In this context he pointed to the OMNIITOX project, to which the European chemicals bureau (ECB) has enrolled, with the goal of investigating potential applications of LCA in future EU regulation activities. Detailed results from the OMNIITOX research will be presented in future issues of this journal. Rolf Frischknecht presented results of an **LCA of the new mobile communication system UMTS** in Switzerland. This work, carried out together with an electronics manufacturer and a network provider, looked at the complete system including the complete life cycle of mobile phones, base and switching stations, as well as impacts form the administration of the network provider. Two different functional units were considered in the LCA: average use of the phone and transmission of a defined quantity of data (e.g. for Internet applications). Frischknecht found that the production of the UMTS phone is extremely relevant for the impacts of the overall system. Comparing the future UMTS system to the current GSM network, he concluded that the environmental impacts per quantity of transferred data will decrease, while the impacts per client will increase. Denis Le Boulch, with his talk on the **application of LCA within an international electricity producer,** reported on the LCA activities of ELECTRICITY DE FRANCE (EDF), an electricity provider based predominantly on nuclear power. He explained that this form of electricity production shows excellent

results with regard to the impact category 'climate change' (GWP), the results being reported via Internet.

A general discussion of the session in the auditorium, addressing priorities in LCM, lead to the conclusion that communication is a crucial element, which needs more attention, if LCM wants to succeed in the long-run and influence decision-makers across the board. Though this finding is commonly accepted, the methodologies and procedures, generally, still have to be improved in this regard. It was stressed by several contributions from the floor that for these communication issues in general, but specifically regarding social and economic aspects, an increased interdisciplinary exchange is needed. The LCA/environment community should try to establish stronger links with the relevant domains, as is currently already done by the activities of the SETAC working groups. No consensus was achieved on the question if an ISO standard on LCM would support this development.

#### Session 2: LCA and Economics – Input/Output Analysis (chaired by Gjalt Huppes and Gregory Norris)

This session was devoted to the topic 'LCA and input/output analysis (IOA)' for the second time within the society following the Annual Meeting in Vienna last year (see Rebitzer et al. 2002). Input/output-LCA (IO-LCA) and its combination with process-LCA, which is generally called hybrid-LCA, have been practiced since the beginning of the 1990s, but it has been discussed mainly, although not fully, outside the boundaries of SETAC until recently. It was the European Network of Environmental Input-Output Analysis (ENEIO), for which the kick-off meeting was held in Madrid in 2001, that first tried to form a platform to discuss such subjects in connection to the activities of SETAC (see Suh 2001). Last year, with the growing interests by its members including those from ENEIO, SETAC Europe launched a working group on IO-LCA to combine the efforts and to facilitate the scientific developments.

Mongelli Ignazio and his colleagues performed an **LCA study of pasta using process-LCA and IO-LCA** based on different data sources, including EIO-LCA (www.eiolca.net) and MIET 2.0 (www.leidenuniv.nl/cml/ssp/software/miet/). The study revealed dissimilarity between results of the different sources and underlying methods. A few sources of differences were analyzed including the truncation errors of the process-LCA, data ages, data sources, and aggregation errors. Erasmia Kitou **compared five options of electricity generation** in the same location by using hybrid-LCA: hydropower, solar-PV energy, wind energy, and coal and natural gas based production. Instead of only one indicator, multiple criteria were considered in evaluating these options. In terms of global warming, wind power was considered to be the most preferable option, while hydropower was the cheapest option per kWh of electricity generation. Considering the two factors hydropower seemed to be the most promising option as the upgrade of the power plant resulted in negligible emissions, but increased power supply by 39%. Randi Dalgaard presented a study carried out by a number of institutes including the Danish Institute of Agricultural Sciences and LCA 2.-0 consultants. The **agriculture study** used multiple data sources to get a representative set of data: it uses farming accounts and agronomy data; subsequently **an input-output account is employed to further adjust the data.** In addition, marginal allocation procedures were applied to deal with the multiple products of agricultural process. The results of the study and various agricultural data will be soon available (see www.lcafood.dk). Sangwon Suh **compared the uncertainties of the results from process-LCA, IO-LCA, and hybrid-LCA** of a flooring material using Monte-Carlo simulation. The distribution of the process-LCA results was characterized by a narrower peak but biased due to the truncation problem, whereas the IO-results were more widely distributed, but contained the target value within the distribution. The difference was interpreted as a problem of precision vs. accuracy, where hybrid-LCA was shown to combine the two and to successfully reduce the overall uncertainty in the results, although there were some trade-offs observed as well. Shinichiro Nakamura and Yasushi Kondo **extended their Waste Input-Output (WIO) model towards a decision analytic framework using linear programming (LP).** A number of possible alternatives were incorporated in the model including changing allocation patterns of waste, concentrating wastes for incineration with heat recovery, use of plastics as substitutes for coke in the steel industry, etc. The results showed that there were trade-offs between the alternatives, while changing the allocation patterns of waste was the most effective option in reducing environmental impacts. Finally, policy implications of the results as well as a number of issues of implementation were discussed. Kazuyo Yokoyama discussed **a dynamic extension of the WIO model, focusing on the construction industry.** The usage of landfill area was compared for three different situations: incomplete recovery and incomplete sorting (the current situation), incomplete recovery and complete sorting, and, finally, complete recovery and complete sorting. She showed that under the situation of incomplete recovery and complete sorting, the landfill area saved by the additional sorting efforts compared to the current situation would be vanished within the time period considered, while the last option would save at least 25% of the landfill area compared to the current situation for the same period. Yuki Kuwauchi presented how IOA can assist scenario-based LCA. He and his colleagues **estimated the overall effects of certain process-level changes by reflecting those changes in an IO-table.** Two cases were considered: the first case was about cascade recycling of fluoro-nitric acid for the steel industry as washing agent, and the other was about waste plastics as substitutes for coal, coke, or electricity in the steel industry. How to incorporate the **changes of coefficients due to socio-economic developments and new technology penetration in an input-output framework** was the topic of Uwe Klann's paper. Six harmonized scenarios for specific industrial activities (e.g., dwelling and construction) were developed, from which six complete IO-tables for 2020 were derived by integrating the socio-economic and techni-

cal changes in a macro-econometric model. For all scenarios considered, the analysis showed that one technology was always superior to the other in terms of $CO_2$ emissions, while the results would be different if multiple criteria were considered. In addition, he showed that the service industries would gain importance in the future in regards to both $CO_2$ emissions and the total cumulative working hours, which highlights the relevance of including services in an LCA, e.g. via hybrid approaches. The session was concluded by Helias Udo de Haes, who reported on the experience of the first year of the UNEP/SETAC Life Cycle Initiative (see Udo de Haes 2003).

Both theoretical developments and practical applications of IOA for the use in LCA were presented in the session. The application areas of these studies varied from process-level decision- to national-level policy-making. One of the notable trends was that the issue of strategic decision-making and scenario analysis had been widely explored using IOA or its combinations with process-analyses. Use of IOA and process-analysis in combination is considered to be very relevant for such studies as the changes at the process-level system lead to changes in its broader economic system and vice versa, and thus certain strategic decisions should be examined in the context of a broader interdependence between the two systems. Another visible trend was the application of the hybrid approach. The benefits of the hybrid approach have been well accepted, and the approach is now being applied to many case studies. Overall, the presentations showed that IOA is a prominent tool for applications in LCA, many of which remain to be explored.

#### Session 3: LC Impact Assessment – Toxicity/Risk Assessment (chaired by Michael Hauschild, Olivier Jolliet, Thomas McKone, and Helias Udo de Haes)

Life cycle impact assessment (LCIA), the 'historic' origin of the LCA activities of SETAC, continued to be a hot topic. New impact categories, interactions with risk assessment, and further development of the conceptual framework, to name a few issues, were heavily discussed.

Arjan de Koning started the session with a presentation on the **assessment of the impact of toxic substances on the marine ecosystem in LCIA.** He analyzed the causes for the domination of metals in the marine environment in comparison to organic chemicals. Applying the nested multi-media model USES-LCA de Koning assumed the long environmental half-life and the lack of geochemical processes relevant for the elements as the main problems in modeling. However, the analysis revealed the main reasons for high marine impact scores of metals to be LCA specific: firstly, the time-integrated PEC/PNEC ratio is used as the ecotoxicity potential without considering thresholds and background concentrations. Secondly, for normalization there is a severe lack of emission data into the marine environment. Moreover, it was concluded that the uncertainties for the calculated distribution of metals between seawater and soil might be significantly overestimating the element concentration in the marine system for some metals, notably Ba, Co and Ni. Philipp Preiss introduced the **Impact-Pathway-Approach as a general methodology for the LCIA of innovative industrial technologies.** This bottom-up approach enables the weighting of impacts on environment and human health according to the society's preferences by using contingent valuation as the concept of willingness to pay. Within this method, the environmental and health costs are estimated by tracking the pollutants' pathway and approximating the physical impacts by applying dose-response-functions which are attributed to monetary values representing the external costs. Preiss illustrated the proposed methodology with a case study of different car painting technologies. He advocates the Impact-Pathway-Approach as the state of the art methodology for quantifying external costs and stressed that the approach is applicable and capable of assessing environmental benefits of industrial technologies. A general methodological **comparison of multi-media models representing the state of the art in LCIA** was presented by Manuele Margni. With the special focus on characterization factors for human health and aquatic ecotoxicity, differences between USES-LCA, CalTOX 4.0, IMPACT 2002, and EDIP were examined on the basis of three release scenarios and a selected data set of organic chemicals. Margni analyzed discrepancies of toxicity characterization factors by separately analyzing the fate, exposure, and effect factors. For human health he identified a fairly good correlation between the factors of IMPACT 2002, CalTOX, and USES-LCA. In contrast, for ecotoxicity no correlation could be established between IMPACT 2002 and USES-LCA. In addition, a novel framework based on source-to-intake modeling for an in-depth comparison of fate and exposure factors was introduced allowing the identification of significant model differences without reviewing the model algorithm. The following presentation of Thomas McKone focused on the **comparison of results from probabilistic and statistical exposure models for LCIA.** Investigating the uncertainties in source-to-dose relationships for human health assessment, probability distributions to characterize the intake fraction for food-chain exposure to air emissions of dioxin compounds and polycyclic aromatic hydrocarbons (PAHs) were developed. Both probabilistic multimedia exposure models as CalTOX and empirical statistical models directly derived from measurements were applied. McKone came to the conclusion that the comparison between the simple statistical models and the probabilistic multimedia models is feasible, useful for identifying gaps in the understanding of modeling results, and can raise important questions for further investigations. Moreover, he stressed the potential of confidence building for both assessments, whereas the problem of data quality and quantity remains. Rana Pant continued with the **comparison of four LCIA methods for ecotoxicity based on a detergent case study from the OMNITOX project.** In order to identify methodological differences between EDIP, USES-LCA, and IMPACT 2002, the same consistent data set on effect and physio-chemical data for three detergent

types (regular powder, compact powder, compact liquid) was used for calculating the aquatic ecotoxicity impact scores. USES-LCA (freshwater toxicity) and EDIP (acute and chronic toxicity) both lead to the same product ranking (compact powder being the most preferable) and recognized surfactants as the most contributing ingredients. With IMPACT 2002 and USES-LCA (marine water toxicity) the inorganic ingredients dominated the LCIA results and compact liquid detergent was identified the preferable product alternative. Thus, Pant emphasized the urgent need within OMNIITOX to determine a common approach for effect data and the residence time in water for fate and exposure modeling which were identified to be the main reasons for the deviating results. Elaborating on **Life Cycle Impact Categories** Walter Klöpffer discussed the **problem of new categories and biological impacts.** Giving a historical overview on the development of impact categories, Klöpffer stated that only the categories resource depletion and effects due to chemical emissions are well developed, whereas more work is needed on the effects due to physical emissions. For the impact category dealing with biological emissions (invasive species, genetically modified organisms, pathogenic organisms) the main problem was identified as the finding and modeling of suitable indicators. Therefore, Klöpffer promotes the application of the precautionary principle as a 'proxy' as the effects and risks of biological emissions are not yet fully understood. Barbara Nebel presented the results of a study on the **global warming reduction potential of biomass-based products** examining the case of wood products. Nebel discussed the feasibility of combining the carbon storage function of wood products and the classical global warming assessment (GWP100). Using the variable 'kg of stored carbon' expressed as $CO_2$ equivalents and time, she demonstrated the $CO_2$ storage effect over different periods and emphasized the significance of the time aspect. Thus, data validity on the useful life of the wood products was identified crucial to the approach. Norihiro Itsubo elaborated on an endpoint approach for **biodiversity damage assessment by applying the theory of biology in LCIA.** He presented a damage indicator for biodiversity that estimates the expected increase in the number of extinct species (EINES) by statistically modeling the extinction risk based on studies from the field of conservation biology. Also, a procedure to calculate additional indicators for the impact categories land use, waste, resource consumption, and ecotoxicity was discussed. With a case study on office buildings Itsubo demonstrated that the methodology enables to compare the contributions of the impact categories listed above and illustrated the differences to other existing damage indicators as e.g. Eco-indicator 99. Main differences were identified within the scope of the category endpoints and as being related to the locations assessed. The **integration of biodiversity as a life cycle impact category in agriculture** was the topic of the presentation by Daniel Baumgartner. He recommends a scoring method based on the category indicators species richness, species composition and occurrence of specialist species. In the characterization step the indicator organisms' reaction with regard to agricultural practice is estimated. The approach allows forecasting impacts of changing agricultural activities on biodiversity and the aggregation of category scores to an overall biodiversity score. Advantages compared to other methods with biotope characterization are the detailed description of effects of a specific agricultural element or activity on the species diversity. However, a plausibility study with data from farming still has to be conducted. Ruedi Müller-Wenk proposed a concept of **putting a monetary value on DALYs** illustrated with the **case of road noise related health impairment in Switzerland.** Five approaches to estimate the monetary value of a DALY were introduced: (1) the hedonic pricing in the housing market, (2) a contingent valuation based on the willingness to pay (WTP) for better health, (3) a wage-risk analysis correlating the workers' wage with the health risks of jobs, (4) market prices for health improvements, and (5) cost-effectiveness thresholds used in regulated health markets. Müller-Wenk found that currently available monetization studies are not a reliable and consistent source for attributing costs to human health damages. He also stated that a general conversion factor from DALY to money cannot be established due to the assumptions of monetization methods being incompatible with the principles of LCA health metrics. Nevertheless, he advocates the use of monetization methods under restricted conditions if an additional expression of health damages in monetary units is needed. **'Of peas, pigs, and proteins'** was the title of Martine Helms' presentation dealing with a method for the assessment of the environmental sustainability of protein production chains. Comparing the conventional pork production system with the production of novel protein food (NPF) based on peas, four major fields of impacts were chosen due to the very limited data on the production of NPF. These are landscape, hydrological cycle, nitrogen cycle, and phosphorous cycle with the corresponding indicators land use, water use, N-load, and P-load.

Wolfram Krewitt's talk titled **'When does a square meter equal a square meter'** focused on the assessment of **land use impacts in LCIA** by applying **the case of wind turbines.** It was shown that for wind energy site-specific impacts play an important role being in conflict with the current LCA methodology due to the limitation of site-specific data availability. Krewitt suggests the application of detailed GIS- (geographic information systems) modeling for land use impact assessment and promotes the usage of complementary tools with defined interfaces to LCA in order not to overload the LCA methodology. In his opinion GIS-based tools provide excellent features to analyze and communicate issues related to local scale impacts on land use, biodiversity, and life support functions. The **U.S. EPA's history of developing TRACI and a discussion of its potential applications** was presented by Jane Bare. TRACI (Tool for the Reduction and Assess-

ment of Chemicals and other Environmental Impacts) is comprised of a modular set of LCIA methods developed for the United States providing the most up-to-date impact assessment techniques for the characterization of stressors. Issues as the appropriate level of simulation sophistication, the cause-effect point for modeling specific impact categories, and the minimization of assumptions and value choices in modeling were elaborated. Bare noted that mostly midpoints are used and modularity is considered very important within TRACI.

#### Session 4: LCA and Economics – Life Cycle Costing (chaired by Kim Christiansen and Gerald Rebitzer)

The links and synergies of LCA with economics is becoming increasingly relevant (see also Session 2 – input/output analysis) in order to expand the application of the life cycle approach and to enhance the attractiveness of practical applications, but also to contribute to the sustainability debate by introducing the life cycle approach to the second of the three pillars of this encompassing concept. Therefore, it is just logical to launch a new session on life cycle costing, which is receiving more and more attention within SETAC and related communities.

The discussions on this topic, which concluded the scientific part of the LCA sessions of the conference, was opened by Kerstin Lichtenvort, who focused on the **application of life cycle costing (LCC) for the electronics industry.** After outlining the challenges the electronics industry is facing due to new European legislation regarding the end-of-life (EOL) of electric and electronic products (WEEE and RoHS directives), she outlined the goals of the European grEENn project (Cost Management System for Greening Electrical and Electronic Equipment), which aims at minimizing end-of-life costs by modeling the cost relations between all phases of the life cycle. She demonstrated the approach with a case study of an electronic automotive component, comparing the consequences of different design options for the EOL phase. The final product of the project will be an LCC tool for this industrial sector, which should support the identification of cost efficient improvements in regards to environmental impacts and regulatory requirements. Gjalt Huppes continued by looking at fundamental methodology related questions of **LCA and LCC modeling for eco-efficient based decision-making.** His presentation was motivated by the goal of linking economic cost and environmental consequences of decisions in order to find eco-efficient solutions. He stressed that for such a concept the monetizing of external effects is not necessary. Following a brief overview on the roots of LCC in the US Department of Defense, he discussed the compatibility of LCA and LCC models. Huppes concluded that it is well feasible to link the steady-state/static equilibrium model of LCA with the quasi-dynamic model of LCC if the functional unit is adapted to refer to yearly flows and the cost is expressed as an annuity. **The role of system boundaries in LCC** was discussed by Andreas Möller. He explained the material flow network approach, which consists of two steps: firstly, the modeling of the complete material and energy flow system and secondly, the evaluation of the flows, including cost allocation of single processes. He illustrated how such a detailed model can be established, creating the basis for LCA and LCC. **How to use and implement life cycle costing in the design for environment of automotive components** was the focus of Wulf-Peter Schmidt's paper. He outlined different business cases for environmental improvements and explained that LCC enables improved design decisions by taking trade-offs or win-win situations between environmental targets and overall affordability into account. By taking discounted use, if occurring over a relevant period of time, and EOL costs into consideration, the optimum can be found and/or the most cost efficient improvements can be identified. However, he also stressed the challenges of estimating future use and recycling costs, where discounting rates and other uncertainties can significantly influence the overall results.

The session was concluded with an **overview of the background and the current activities of the new SETAC Working Group on life cycle costing.** The Chairman of this working group, David Hunkeler, explained the driving forces behind the growing interest in this topic, based on the findings of the previous SETAC Working Group on LCM. He elaborated on the scope and the goals of this new activity and gave insight into the expected results which will comprise findings on the current state of the art, case studies, an LCC data format compatible to LCI formats, as well as a guideline/code of practice on LCC methodology. Additional information on the activities of the working group can be found in an overview by Rebitzer and Seuring (2003).

#### References

Rebitzer G, Seuring S (2003): Methodology and Application of Life Cycle Costing. Int J LCA 8 (2) 110–111

Rebitzer G, Windsperger A, Pennington D, Jolliet O (2002): Science and Application of Life Cycle Assessment. Int J LCA 7 (4) 251–252

Suh S (ed) (2001): Proceedings of European Network of Environmental Input-Output Analysis Meeting, Madrid, Spain (www.leidenuniv.nl/cml/ssp/projects/envioa)

Udo de Haes HA (2003, forthcoming): The UNEP/SETAC Life Cycle Initiative – A Personal View of the Results after One Year. Int J LCA 8 (5) September issue

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