

layers. Other obstacles relate to the age of process data (because of rapidly developing technologies), the availability of life cycle inventory (LCI) data for various specific chemicals used in electronic industries (generic LCI data for well know generic chemicals cannot be applied since in many cases extremely purified chemicals are needed). For end-of-life processes the fast changing legal frame makes predictions difficult and/or unreliable. In addition, there is little information available on the behavior of electronic wastes in landfills. On the side of life cycle impact assessment (LCIA) many characterization factors for the specific emissions are not yet available. On top of all these obstacles, it is important to note that any LCA for these product groups has to be performed quickly if it is to be applied to the design of products, since the development cycles are extremely short. To simplify the life cycle inventory analysis and the impact assessment, the Fraunhofer Institute has developed the screening methodology ProTox. This approach targets the problem of missing generic data for upstream processes. It is based on the mass flow and the material safety data sheets; it looks at the material content of the final product and assesses its toxicity.

TOURADJ EBRAHIMI (Swiss Federal Institute of Technology Lausanne) presented his view on the **future developments in telecommunication systems**. He presented communication between people as a means of sharing experiences, real or imaginary. He described the evolution of communication as follows: Story telling and cave drawings, books and written press, photography, telegraphing, telephoning, radio and music recording, cinema, television and video recording, internet, mobile communication. What will be next? Today, the prevailing trend is to provide new mobile features such as image, music, and video applications. Huge investments made in this area contrast with few investments made in the development of the interface between humans and machines, which could essentially be a more important factor. As an outlook for the future, Ebrahimi outlined his view on the telecommunication system of tomorrow, consisting of special glasses that permit virtual conferences, replace laptops and internet terminals. He argued that this would just be the beginning of a new era. Richer and more realistic experience could be achieved through other new features as experiences of taste, smell, and even emotion. Will that be realized? Will we be able to communicate directly with the electronic devices, without speech or display interface? What are the implications if the future provides sharing of thoughts and feelings without any limitations of language?

JENS MALMODIN (Ericsson) presented two **LCA case studies on mobile communication that were performed between 1996-1998 in collaboration with two large operators/customers from Sweden**

and the USA (Telia and AT&T). The LCAs focused on the wireless system, but fixed infrastructure and peripherals were included. On the other hand, internet was not within the scope. One conclusion was that the electricity grid (mainly hydro and nuclear based in Sweden vs. high reliance of fossil fuels in the US) has a high influence on the results. From the total electricity demand, about 0.5% is used for telecom applications. For the wireless system the use phase is the largest source of impact. Within this the radio base stations consumes the largest amount of energy. Based on these LCAs, an LCA of Ericsson's activities as a whole was performed. It was found that building operation (electricity, fuels), air and car travel of employees (kerosene, gasoline, diesel), and hardware transports (kerosene, diesel) are the main sources of energy consumption at Ericsson's sites or directly related activities. In this context the share of employee commutes to and from work had a surprisingly high share. Regarding the mobile phone itself, the main energy consumer is the manufacturing phase. The use phase is dependent on the electricity consumption of the charger and its stand-by currents when plugged in. The new line of Ericsson's chargers tackles this problem by turning off automatically when not in use (i.e. when not connected to a phone).

FILIPPO DELLA CROCE (Swiss Federal Institute of Technology Lausanne) presented a **comparison between two life cycle assessment methods, process LCA and economic input-output LCA (IO-LCA)**. This was based on the comparison of the embodied energy of a computer control unit. Data from the Atlantic consulting study (Atlantic consulting, Draft Criteria: EU Ecolabel for Personal Computers, 1998) have been used for the process LCA and LCA Netbase (Greg Norris, Sylvatica), with US data, for the IO-LCA. The result is that the embodied energy calculated with the IO-LCA is about 4.5 times higher than the value obtained by the process LCA. Explanations for this difference include:

1. Differences in energy efficiencies in Europe and in the US;
2. System boundaries: about 50% of the embodied energy calculated with the IO-LCA are caused by inputs that are only considered within the IO-LCA approach (e.g., activities indirectly related to the product such as law or insurance services, manufacturing of capital goods);
3. The employed IO-LCA data are relatively old. This could be significant for a sector that changes so rapidly.

Della Croce explained in detail the role of retail and wholesale trade in the LCA model. This distribution phase corresponds to all activities carried out to facilitate

the transfer of manufactured products from the final manufacturer to the end-user. The energy contribution of this phase is highly important. For the personal computer sector, it represents 47% of the total pre-consumer phase embodied energy. Within the subsystem from manufacturing to the selling of the computer 20% of the total energy consumption can be attributed to transportation (air and road transportation). Therefore, wholesale and retail trade, elements often neglected in process LCA, can play a significant role.

Short Presentations

ANTONIO FEDERICO (Italian National Agency for New Technology, Energy and Environment) presented a **survey to evaluate the material requirements to provide mobile telephoning services in Italy**. The study considered the Ericsson T28 mobile phone as a typical device. 75kg of ecological rucksack (i.e. total material consumption) have been identified for the telephone. The rucksack of the mobile phone service network is of the same order of magnitude and has been evaluated at 183.85 kg/user. As service as units both the minute of telephone call and the SMS message have been considered. In total this results in an estimated Material Input per Unit of Service (MIPS) of 0.207 kg/(minute of telephone call) or 0.632 kg/SMS (short messaging service). With the assumption of one SMS substituting 10 seconds of telephone call a final MIPS of 0.196 kg/minute can be obtained for the latter.

GABOR DOKA discussed **yield losses in production of electronics and their significance for LCA**. The example given was on manufacturing of modern microchips. For this product, the yield losses are between 84% and 22%, depending of the stage of the technology. The production cycles of the electronic components are becoming shorter and shorter, leading to fast changes in technologies and learning cycles. This leads to a decrease in the available time to optimize component production and minimize yield losses. Moreover, data on yields are highly confidential and therefore hard to obtain (see above). Ignoring yields in LCA for electronic products needs to be verified since it can lead to a significant underestimation of the environmental burdens.

MARTIN SCHÄFER (Siemens AG) described the **life cycle inventory of a Siemens cordless phone**. Cordless phones, similar to mobiles, but for in house use, are becoming more and more popular, replacing conventional phones. Consequently, it was important to assess the environmental impacts of this product in order to develop environmentally improved products in the future. It appeared that the use phase dominated the overall impacts.

MIREILLE FAIST (Swiss Federal Institute of Technology Zürich) highlighted the **importance of the definition of the functional unit, the system boundaries, and the scenario assumptions in the evaluation of new media technologies**. The products considered are often multifunctional, inducing allocation problems. On-line newspaper reading is one example. The assumption of considering a single article vs. the complete newspaper determines the result of a comparison with the internet as information source (see above). Telecommuting is another example. The important factor to know in this case is to what extent the telecommuters will compensate for social isolation by traveling during additional free time, resulting in a rebound effect.

GERALD REBITZER (Swiss Federal Institute of Technology Lausanne) elaborated on **opportunities and threats associated with e-commerce and their implications for LCA**. The rapid development of the world-wide-web is changing industrial business and activities around the world, one of them being e-commerce. The opportunities associated with e-commerce include dematerialization, telecommuting, improvement of information transmission, and trade benefits on a global market. On the other hand, additional transport activities, destruction of regional markets (an issue, for instance, in the discussion on mad cow disease), loss of supplier-customer relationships, and shifts in production to second and third world countries with possibly lower environmental standards are occurring. In addition, goods and services get cheaper and therefore more units are consumed per customer (rebound effect). Consequently, not only the functional unit, but also the total consumption of units should be taken into account, if LCA wants to be more than just a measure of eco-efficiency. Rebitzer proposes that such a view combined with the functional unit perspective is necessary for tackling problems and challenges of sustainable development in the true sense.

MICHAEL SPIELMANN (Swiss Federal Institute of Technology Zürich) focused on the **potentials of LCA for environmental management systems (EMS) in the semiconductor industry**. LCA is essential in EMS in order to answer the following questions: Which are the most significant aspects of a company's activities and products? Which objectives, targets, and measures are necessary within an EMS to improve environmental performance? What are the most important elements of an EMS inside a logistic network for semiconductor production?

PIERRE ROSSEL (Swiss Federal Institute of Technology Lausanne) introduced the topic of **LCA for complex systems**. These are particularly difficult to perform in a robust manner. Rossel took the case of telematics used to reduce traffic congestion to illustrate this problem. In this example, successful implementation of the

technology can lead to more traffic, and possibly to congestion on a higher level in the long run, since vehicle use is made more convenient. Other issues need to be included in an overall assessment as well: the direct affects on safety, and the indirect affects on health, associated risks, noise levels, and pollution. LCA of such complex system has to focus on assessing various possible scenarios and their consequences.

OLIVIER JOLLIET (Swiss Federal Institute of Technology Lausanne) discussed the **environmental impacts of the internet network of the Swiss Federal Institute of Technology Lausanne**. Two approaches have been used, process LCA and input-output LCA (see above). With both methods the calculations of non-renewable energy show that personal computers are dominating due to electricity consumption in their use phase. In the future, the increased use of liquid crystal displays (LCD) instead of cathode tube monitors and the move from desktop computers to notebook bears significant potentials for energy savings. The analysis expanded its boundaries in order to include non-hardware input requirements. The total costs of ownership, which are the total costs associated with the PC network, were also determined. Management and maintenance of the network are dominating the expenses, causing significant environmental impacts as well.

NIKLAUS KOHLER (University of Karlsruhe) introduced the topic of **new work practices and building concepts**. New forms of telecommunication do not have the same environmental impacts patterns as current forms of work. Environmental impacts are produced by office and manufacturing technologies, buildings, and transport. The thesis that new information technologies reduce transport and building energy consumption has not been verified in practice until now. The question of the necessity of new buildings and the possible development of virtual buildings is discussed in relation to sustainable development.

TOMAS RYDBERG (Chalmers Industrieteknik Göteborg) presented an **LCA on videoconferencing and a comparison study between different modes of transportation to travel to a business meeting**. The case of a videoconference replacing a personal meeting has been investigated. The participants were supposed to travel by air or by train. In these two cases,

only fuel and electricity consumption was taken into account. The production and use phases dominated the energy consumption of the videoconference devices. The results show that the air travel scenario consumes much more energy than the rail travel and the videoconference scenarios. Videoconference and rail give similar results if the videoconference is used quite often and turned off when not in use. If it is left in standby and used not more than 5 hours a week, it requires more energy than the rail scenario (assumptions for one meeting a week). In addition, the results depend on the distances considered. Decreasing the environmental impact of a firm using videoconferencing can be achieved by substituting personal meetings frequently, initiate simple routines to turn off the video equipment and raise demand for environmentally adapted product developments.

Closing Discussion

Several **conclusions** resulted from the closing discussion:

- As new telecommunication media often offer different functionalities than classical technologies (e.g. e-mail versus conventional mail or Fax), it is rather difficult to compare these technologies on the basis of a similar function. LCA is therefore mostly suitable to identify key points and action priorities within each individual system.
- The availability of data on electronic equipment and services is still rather limited. Sharing of LCI data for electronic equipment should be a priority.
- The standby characteristics of telecommunication equipment, and consumer behavior while the
- equipment is not being used, could significantly increase energy consumption and associated emissions.
- LCA applied to information technologies are very sensitive to scenario hypotheses. Though really difficult, LCA should be expanded and complemented with social studies to evaluate the importance of rebound effects.

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