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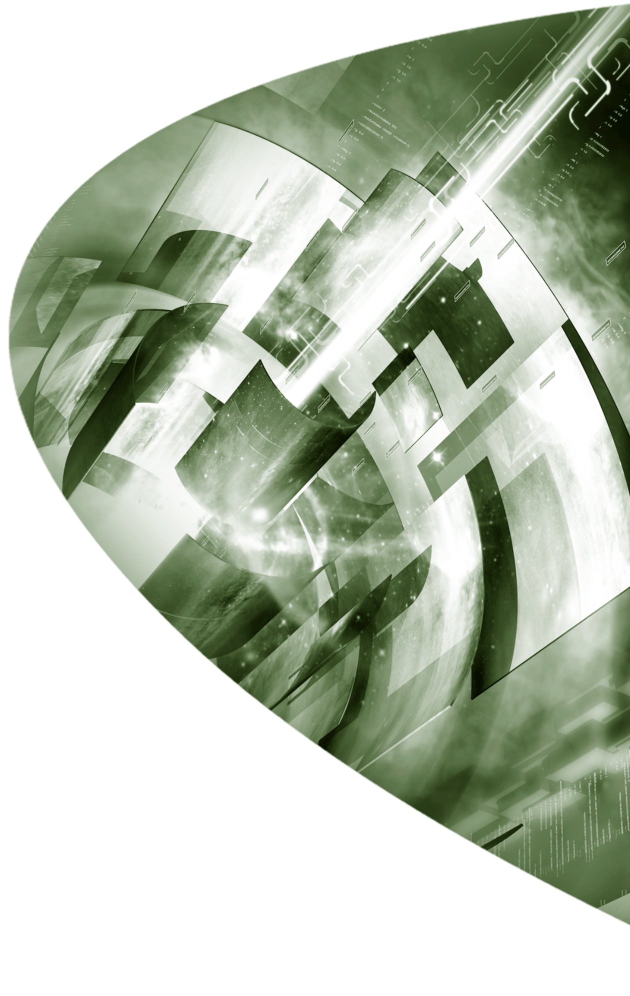

Selected papers from *In*LCA/LCM 2003: An international conference on supporting environmental decision-making with life cycle assessment

Guest Editor: Mary Ann Curran

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Guest Editor
Mary Ann Curran

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Guest editorial

About the Guest Editor *Mary Ann Curran manages the LCA Research Program in the US EPA's Office of Research and Development, Cincinnati, Ohio. Since 1990, Ms Curran has presented the Agency's LCA research activities at technical meetings worldwide, authored numerous papers on LCA, and edited a book in 1996 entitled* Environmental Life Cycle Assessment. *She received a BSc in Chemical Engineering from the University of Cincinnati (1980) and an MSc in Environmental Management and Policy from Lund University, Sweden (1996). She currently serves on the editorial board of three technical journals, participates in the UNEP/SETAC Life Cycle Initiative, serves on the SETAC-NA LCA Working Group, and acts as an advisor to the American Center for Life Cycle Assessment.*

Environmental management strategies have evolved from compliance-based end-of-pipe regulations to accounting of the environmental impacts of products and processes throughout their life cycles, i.e. from the time that resources are extracted from the earth, through production and use, until end-of-life management. With this evolution, the notion of sustainability (i.e. maintaining quality of life without causing irreparable damage to the Earth) is quickly becoming a central ethic in environmental management.

A semi-regular forum of international conferences on life cycle assessment and management has been held over the past years in order to help foster the application of the life cycle concept in all areas of environmental decision-making, including purchasing, public policy, community sustainability, product and process design and development, supply chain management, buildings, external reporting and communication, and product labels and declarations. The most recent event, dedicated to Life Cycle Assessment methodology and application was the International Life Cycle Assessment and Management (*In* LCA/LCM) conference. *In* LCAM was held in Seattle, Washington, USA, from September 22 to 25, 2003. The American Center for Life Cycle Assessment maintains a web site where the abstracts for all the 80 or so presentations that were made can be found (see www.lcacenter.org). Since the conference required only the submission of an abstract and presentation slides, select authors were chosen to prepare full papers on their presentation material.

A focus on LCA in decision-making and management was chosen for the main theme of this Special Issue. The presenters who addressed any aspect of how LCA has been applied in a case study or conducted research that resulted in advancing the used of the life cycle perspective in decision-making were invited to contribute to this issue. The result was seven papers that range from the better understanding of life cycle costing (LCC) as it relates to LCA, to exploring sustainability indicators and using the life cycle concept to direct sustainability efforts within various industrial sectors.

It is vital to provide a regular forum for all those who are interested and involved in life cycle assessment and management to have the opportunity to exchange ideas and experiences. The next international conference along the life cycle theme will be

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"LCM2005: Innovation by Life Cycle Management", to be held in Barcelona, Spain, September 5-7, 2005, at the new International Barcelona Convention Center. This venue will provide attendees the opportunity to present or obtain the newest information about applications of life cycle thinking and LCM theory and practice, meet and network with colleagues from all parts of the world, and enjoy Barcelona and its Mediterranean environment. The conference will be organized in cooperation with the SETAC-UNEP Life Cycle Initiative. Details can be found at the conference web site (see www.lcm2005.org).

Mary Ann Curran
Guest Editor

Environmental costs and benefits in life cycle costing

Bengt Steen
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Abstract

Purpose – From a methodological point of view, life cycle costing (LCC) is well developed with respect to conventional costs. However, when it comes to costs related to environmental issues, neither the items nor their estimation have been well developed. This paper aims at investigating the possibilities of using life cycle assessment (LCA) results to identify and estimate environmental costs or benefits in an LCC.

Design/methodology/approach – The paper begins by looking at the driving forces for introducing environmental costs in companies, continues by identifying external and internal environmental cost issues, and concludes with an attempt to estimate the internal costs.

Findings – Some of the items of an LCC have to do with increased/decreased sales, others with good will. Both are difficult to estimate, but LCA or LCA-like investigations may be helpful in identifying relevant issues. Future costs to the product system may also be estimated, for example, with a distance-to-target type of weighting. LCA may be helpful in roughly estimating risks, especially together with those LCA impact assessment methods that model damage. Such an item in LCC can be dealt with as an insurance fee or, if the risk is too high, as a way of including necessary preventive actions.

Research limitations/implications – The literature on the subject is limited and not sufficient to aid in estimation of environmental costs and benefits for a company. It seems reasonable to begin an improvement of the methodology by looking at future costs and benefits.

Practical implications – This paper may help in structuring the task of using LCA information for estimating environmental costs in LCC.

Originality/value – There has been increased interest recently in the integration of LCA and LCC, such as in the SETAC (Society for Ecotoxicology and Chemistry) working group on LCC. This paper contributes with new outlooks and structures for that work.

Keywords Life cycle costs, Sweden, Accidents, Risk management

Paper type General review

1. Introduction

Life cycle assessment (LCA) and life cycle costing (LCC) are both methods that emerged from the energy crisis in the mid-1970s. LCC was developed with an economic focus, LCA with focus on mass and energy balances.

LCC developed quickly as there was already a methodological framework: economics. The main problems were to find the items to include and to estimate their values. The first teaching books in LCC appeared in the early 1980s (e.g. Dell'Isola and Kirk, 1981).

LCA developed more slowly. Initially, the focus was energy balances. Then, mass balances were added, including material and waste streams. Later, environmental

This work was funded by CPM, the Centre for Environmental Assessment of Products and Material Systems. Many valuable discussions on the topic in SETAC's working group on LCC and in the EU project DANTES are gratefully acknowledged.

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assessments were made for the mass and energy balances, and the framework developed gradually.

Since the early 1990s, there has been a significant development of LCA, both in terms of methodology and applications. The development of LCA methodology has followed some lines:

- software – making the work easier and faster;
- harmonisation (various ISO standards), which improved communication; and
- databases – making the work easier and faster.

The application of LCA has developed along the following lines:

- At the company level – many companies have carried out LCA studies. Some have routines at the offset of a project that determine when LCA is required. (Is a new technique or new material involved? Are any environmentally "hot" substances involved?, etc.) Baumann (1998) found that one of the main benefits of LCA to companies is learning.
- At the national level – LCA is used to back up certification and labelling rules. Some policy decisions are based on LCA studies. Environmental product declarations based on LCA are made available in some countries (Environmental Product Declarations, 2003).
- At the international level – The EU commission has published a Green Paper on the *Contribution of Product-Related Environmental Policy to Sustainable Development – A Strategy for an Integrated Product Policy Approach in the European Union* (EU Commission, 2001).

LCC is a much older tool. The first attempts were made even before the energy crisis. It is mainly used as a decision support method for investments. It considers the costs associated with the whole life cycle of a product from development and manufacture to its use and subsequent disposal. During the 1990s discussions started to include externalities in the LCC method (e.g. cost of environmental impacts caused by the product). The "polluter pays principle" (PPP) explains some of this interest. Anyone who causes an impact on the environment shall pay for its cost. In LCC these costs could be made visible.

LCA is seldom used on a routine basis, although a few companies do have a management practice that tells them when to use LCA. (e.g. ABB and Volvo Cars). The European Environment Agency (EEA) has made an overview of the development and use of LCA (European Environment Agency, 1997, Table 1).

One consequence of the different applications of LCA and LCC is that they usually have different system borders. One weak point in the use of LCA by companies is the understanding of what the result means to their economy.

This paper aims at increasing the possibilities for interpreting LCA results in terms of economical consequences for a company. This is done from a LCC perspective in order to focus on the economically relevant information in a LCA. The ambition is modest, as very little has been done on this subject, and it may not even be possible to reach any normal precision in cost estimations. But it has still been carried out "hands on" in order to make the methodological issues more visible than in a general discussion. This paper is based on a presentation made at the LCM Conference in Seattle, September 23-25, 2003, "LCA as input to LCC".

There are at least two situations when environmental costs are of interest in LCC: one is when estimating the full life cycle cost of a project or decision, and another is when trying to increase production efficiency and focusing on cost elements related to the environment. In the first case, only downstream costs are of interest. In the second case, all costs related to environmental issues are of interest.

The report presented here is part of the efforts to integrate LCA and LCC into two networks, the EU project DANTES (DANTES, 2003) and the SETAC working group on LCC (Hunkeler and Rebitzer, 2003).

2. Driving forces

When developing any methodology, it is important to know the driving forces for the use of it. The ambition level of the method ought to be in harmony with the ambition level of its users, and it should satisfy the needs defined by it.

One basic driving force is often expressed as PPP, the "polluter pays principle", or the more updated and positive version: "Get the prices right" (EU Commission, 2001). Damage to third parties shall be paid for by whoever causes it.

There are, however, several things preventing this principle from being applied in practice:

- lack of knowledge of who caused what damages to whom;
- lack of enforcement capacity; and
- lack of global and regional consensus.

These obstacles are gradually decreasing, thanks to:

- the growth of the information society;
- increased institutionalisation; and
- globalisation.

The whole process may be seen by examining IPP activities (EU Commission, 2001). In the development of an integrated product policy (IPP) in the EU, a number of instruments and actions have been identified.

As the development and integration of a methodology normally require several years, and as interest may be assumed to grow, it seems reasonable to develop a methodology the ambition level of which is somewhat higher than what is requested today.

3. Identification of environmentally-related costs to a company

3.1 Identification of external costs

Looking back at the history of LCA, it began as the energy and mass balance analysis of a product system. There was hardly any systematic discussion of which mass flows to include. When the life cycle impact assessment step was developed, the objective was normally seen as assessment of the LCI results. In the ISO 14042 standard for LCIA (ISO, 2000), it is stated: "The purpose of LCIA is to assess a product system's life cycle inventory analysis (LCI) results to better understand their environmental significance". Hopefully in reality it is the other way round, and the LCI is planned to deliver those data that are of importance for an impact assessment.

But impact assessments give different results depending on what is included. And this, in turn, depends on how trade-offs are handled between different impact types and how uncertainty is addressed.

When deciding upon what to include in the study, there are many dimensions to bear in mind. One is the *qualitative* dimension. In general terms one may think of things to include as belonging to "safeguard subjects" or "areas of protection" (e.g. human health or natural resources). In LCA, the concept of impact categories exists, which is more focused but still not a quantitative indicator. The quantitative indicators, called "category indicators" in LCA and "impact indicators" in many other methodologies, define the qualitative system borders of the "environment" we study.

Another dimension where system borders need to be set is *time*. The consequences of an emission or impact may never end, even if our possibilities of following and modelling them decrease as time elapses. The depreciation of future impacts by narrowing system borders or (as economists do), by discounting, is particularly important to recognize when dealing with global warming effects (Azar and Sterner, 1996) or depletion of natural resources. Another dimension is *space*. There are many examples of how local environmental issues have been "solved" by shifting the impact to another scale or a wider region.

The number of different impacts is enormous as emissions and resource extractions interfere with complex ecological and socio-economic systems. We therefore need to disregard some impacts and concentrate on the most important ones. Consequently we face the problem of tradeoffs and how to handle uncertainty.

In impact evaluation, as in many other types of evaluations, there are two ways of handling tradeoffs. One is to try to minimize or maximize an objective function of some sort. This may be called a "utilitarian" approach. Another is to try to achieve some type of justice, i.e. to deal with each indicator separately and try to reach an acceptable compromise.

The way of handling uncertainty depends on the study context, and also on the practitioner's general attitudes. One common way is to let the degree of uncertainty decide whether or not an issue or figure should be included in the evaluation. Another sometimes more fruitful way would be to accept uncertainty as a part of reality and try to describe its consequences. Instead of focusing on what is "correct" or not, one may ask what our present knowledge, in terms of data and models, tells us. The "precautionary principle" is often used in impact evaluation and it works well with the "justice" type of trade-off approach, but for a utilitarian approach, safety margins in one impact type tend to decrease the appreciation of other impacts.

In ISO 14042 (ISO, 2000), a minimum requirement is that impacts on human health, ecosystem health and natural resources are considered. Issues like work environment, economic impacts, impacts on cultural values and social impacts are sometimes also included as externalities (ExternE, 1995).

3.2 Identification of internal costs

The World Business Council for Sustainable Development (WBCSD) formulates the business case as follows:

> Pursuing a mission of sustainable development can make our firms more competitive, more resilient to shocks, nimbler in a fast-changing world and more likely to attract and hold

customers and the best employees. It can also make them more at ease with regulators, banks, insurers and financial markets.

WBCSD (Heemskerk *et al.*, 2003) gives an overview of the business case in the form of a "sustainable business value matrix" (see Figure 1).

Some more precisely defined costs and revenues are listed below:

(1) *Process costs*:
- control equipment;
- environmental permit;
- environmental monitoring;
- certification cost;
- labelling costs; and
- environmental management.

(2) *Sales*:
- volume; and
- price.

(3) *Accidents*.

(4) *Goodwill change*:
- impact on sales;
- impact on recruiting; and
- impact on mortgage rates.

(5) *Taxes and fees on emissions and resource consumption*.

To be used in an LCC, we need a clear definition of the cost so that everything of importance is included and no double counting occurs.

3.2.1 Process costs.

3.2.1.1 Control equipment. Process and cleaning equipment used to decrease emissions involve capital costs, operating costs and demolition costs.

3.2.1.2 Environmental permits. Costs exist for purchased services and investigations and for fees related to the permit process. Cost depends on type of industry branch and the legislation and traditions in the country where the plant is located. Local conditions can also influence the cost, like nearby areas of high nature conservation value, or extra-sensitive ecosystems.

3.2.1.3 Environmental monitoring. Permits often come with requirements on monitoring. Monitoring can be done of process conditions, emissions and/ambient conditions.

3.2.1.4 Certification costs. A number of companies have acquired certification according to ISO 14000. Costs are fairly well known, but there are also benefits in terms of increased sales.

3.2.1.5 Labelling costs. Like certification costs, labelling cost are associated with the labelling process and benefit from increased sales.

3.2.1.6 Environmental management. There are costs for an environmental management, but also benefits in terms of lower insurance costs and hopefully more efficient environmental protection.

Financial categories	Value issues / Sustainability issues	Ethics, value and principles	Accountability & transparancy	Triple bottom line commitment	Environmental process focus	Environmental product focus	Socio-economic development	Human rights	Workplace conditions	Engaging business partners	Engaging non-business partners
Financial performance	Shareholder value	+	+	+	++	+	+	+	+		
	Revenue	+		+	+	+	+	+	++	+	+
	Operational efficiency	+	+	+	++	+	-	-	++	+	
	Access to capital		+	+	++	+	+	+	+		
Financial drivers	Customer attraction	+	+	+	+	+	+	+	+		+
	Brand value and reputation	++	++	+	++	+	++	++	+	+	++
	Human & intellectual capital	+	+	+	+	+	+	+	++		+
	Risk profile	++	+	+	++	++	+	++		+	+
	Innovation		+		++	++	+	-	+	+	+
	Licence to operate	+	+	+	+		++	++		+	++
	Sustainability categories	Governance		General	Environmental		Socio-economic			Engagement	

Note: "-" means negative, no sign means no impact, "+" means weak moderate positive impact and "++" means strong positive impact (Heemskerk *et al.*, 2003)

Figure 1.
Type of evidence available for various relations betweeen sustainability and value creation

3.2.2 Sales. Sales may be influenced by company good will and also directly by product performance (e.g. such as communicated via labelling). This may be achieved either by increased volumes or by increased price.

3.2.3 Accidents. Insurance companies seldom offer environmental insurance. The main reason is that is impossible for them to make economic risk estimates. But the costs are there for the companies, such as:

- misjudgements on environmental issues;
- rare accidents like breakdown of cleaning systems and other equipment; and
- over-sizing or other extra precautions.

3.2.4 Goodwill changes.

3.2.4.1 Impact on sales. While labelling more or less instantaneously gives and removes benefits directly to and from a product, company good will has an impact on all products associated with the company and depends not only on environmental issues.

3.2.4.2 Impact on recruiting. Costs may occur directly through increased recruiting costs and indirectly through less efficient personnel.

3.2.4.3 Impact on mortgage rates. Environmental performance is one of the parameters looked at when rating companies' creditworthiness, which in turn affects mortgage rates.

3.2.5 Taxes and fees on emissions and resource consumption. Current taxes and fees are well known, but many projects last for several years and taxes and fees may change.

4. Estimation of environmentally-related costs for a company

4.1 Process costs

Statistics exist in Sweden (Statistics Sweden, 2003) for process related costs, such as process external investments, process integrated investments, company internal protection work, purchased services, taxes and fees. The relative shares of the total costs for industry is shown in Figure 2. Environmental protection costs vary between industry branches (see Figure 3).

In a LCC, environmental costs are normally included in the total costs for upstream and downstream processes, i.e. the price of delivered parts and materials and the total waste handling cost.

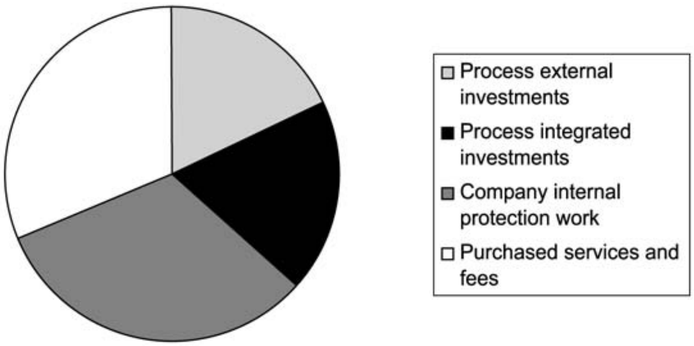

Figure 2.
Environmental protection costs in Swedish industry related to process plants

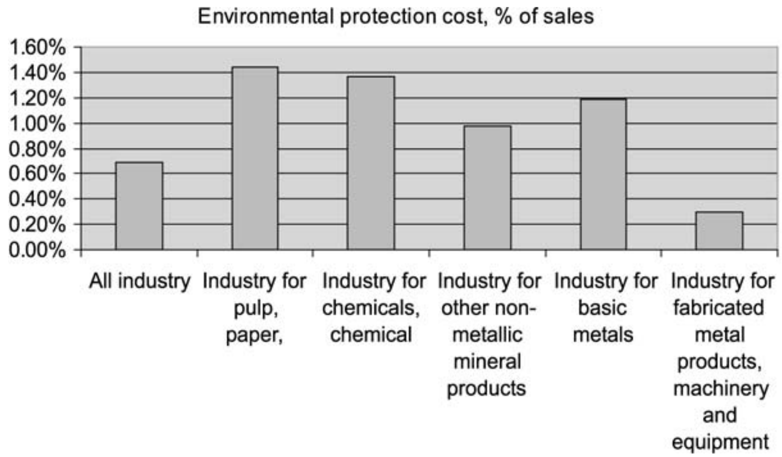

Figure 3.
Environmental protection costs for various industry branches

4.2 Sales

4.2.1 Volume. For consumer goods like washing powder, coffee filters, etc., sales statistics from producers as well as shops ought to give reasonably good information,

For capital goods like refrigerators and cars, environmental impacts are closely linked to energy consumption at use. This makes it difficult to separate environmental aspects from financial aspects, but that is not really a problem for the LCC estimation or the environment, as long as they are included. As an LCC is a steering tool for decisions, it is not very important whether you achieve an environmental improvement for financial or purely environmental reasons.

4.3 Price

An alternative to increased sales volumes is increased product prices. If there is a limited customer group that appreciates environmental qualities, the volumes may not be influenced.

For everyday consumer goods in Sweden a price increase of approximately 10 per cent has been observed.

For capital goods, the increased willingness to pay (WTP) is more difficult to determine from simple price comparisons, as there are seldom two similar products as there are for consumer goods.

In Taiwan, the government has recommended their different organizations to pay up to 10 per cent more for sustainable alternatives (Taiwan Environmental Protection Agency, 1999).

4.4 Goodwill

There are at least three types of items that have to do with good will.

One has to do with sales volumes and prices. A company that has a "clean and honest" image attracts more customers than a company without it.

Another has to do with employment. If fewer people apply for a position, the personnel quality falls, and ultimately the product and business quality will also fall. The costs for recruiting, in many companies, are about 0.1-0.3 per cent of the turnover. The consequences of not having the best person for a job are, of course, very difficult to estimate, but there is some information to be found in the variation in salaries among people doing the same job.

A third type has to do with financing. The interest rates for loans may decrease and the stock value may increase. Standard & Poor use environmental criteria in rating loans with properties as security. These criteria are mostly related to waste disposal or parts of the building (e.g. asbestos).

LCA allows for a benchmarking of companies in terms of environmental efficiency. Databases with generic (average) data may be used for comparison with type III labels. This is not yet done, but there has been a tendency of an increasing number of type III labels and easily available LCA data.

4.5 Accidents

How can the risk of accidents and unforeseen episodes be estimated? If we look at some environmental accidents from a company economics point of view, what information would an LCA give regarding the nature and size of the accident?

4.5.1 Case 1. A dam burst in Los Frailes, a Boliden-owned mining site, threatening a nature conservation area, Coto de Donana, in 1998. Claims were made by farmers for a total of about €7 million, and from the Spanish government of €45 million in fines covering sanitation costs. The company has refused to pay and the issue is not yet settled.

A normal LCA could have identified the process and would have been able to identify the danger, but would most likely not have estimated the risk. An LCA offers a good overview of the substances and processes used.

4.5.2 Case 2. Combustion Engineering and its parent company ABB were sued by 100,000 people suffering from high exposure to asbestos. CE went bankrupt and the net cost to ABB was around €1 billion. The problems relate to exposures in the 1950s and 1960s. At the end of the exposure period, the risk was known, and it certainly was when ABB bought Combustion Engineering in 1990.

According to RAND, around 6,000 other companies in the world are involved in asbestos-related legal conflicts. Up to the year 2000, their costs have been €45 billion. Another €180 billion may be outstanding. According to Lindström (2003) 100,000 people die annually from asbestos-related diseases.

If a value of €1.5 million per excess mortality case is used, the total value for excess mortality is €150,000 million per year.

In this case, externalities have become internalities of the same magnitude and could be foreseen. But the risk for companies of having to pay for externalities was probably low in the 1960s. With the growth of the information society these risks are increasing and in the asbestos case, the exact probability is not very important. The conclusions of an LCA/LCC study would undoubtedly be "unacceptable."

A normal LCA could thus have identified the cost, but there is a risk that the work environment would have been outside the system border, and that the problem would not have shown up.

4.5.3 Case 3. In Southern Sweden a train tunnel is being built through the Hallandsås ridge. The work began in February 1996. To prevent water from penetrating into the tunnel, cracks in the rock were sealed with "RhocaGil", a product containing acryl amide. Workers were overexposed and cattle harmed from drinking drainage water. The whole project was stopped on October 7 1997 and was delayed for six years. The costs to the companies building the tunnel were €45,000 as compensation to the exposed workers, (Karlsson, 1999) and probably something to the farmers, but above all six years of capital costs for the €180 million that was invested, which is about €50 million.

Would an LCA/LCC on the tunnel project have been able to foresee this? If the people handling chemicals and materials were unaware of the risk, would they have told an LCA practitioner about RhocaGil? It would have been one of numerous chemicals used and maybe only reported as "chemicals" or "sealant".

But an LCA on the RhocaGil product could have identified the danger and made an estimation of its consequences. This could, in turn, have led to improved communications with the users.

4.5.4 Case 4. In 1995, Greenpeace protested against Shell's decision to dump a disused oil platform, Brent Spar, in the North Sea. After a long debate, Shell decided to change their plans and in 1998 it was dismounted and partly re-used. No impact actually took place. There was only a postulation of impacts that could have happened if Brent Spar had been dumped.

The costs to Shell were great. In Sweden they lost market shares and their leading position was taken over by a competitor. Similar pictures may have been seen in other countries.

Could an LCA/LCC have been a support in this case? Yes and no. It might have turned the battle into a dialogue. The qualitative statements used, saying something like "heavy metals from Brent Spar will harm the bottom fauna" could be exchanged with LCA results, where emissions could be quantified and compared to others, *and* the potential destroyed area could be estimated as well as the damage cost. The alternatives could have been weighed against each other.

4.6 Future costs

If the LCC addresses a product or project with a lifetime of many years, additional costs may be added. The damage cost for an emission may be used for estimating the potential for future taxes and fees. The "polluter pays principle", used by most governments, or the modern version, "Get the prices right", indicates that external environmental costs may sooner or later turn up as internal costs. The likely timing for introduction of the taxes is uncertain, but for a specific country and products with a short lifetime, estimations may be made looking at what treaties and environmental goals have been set up. For instance, the Kyoto protocol on CO_2, with a target year of 2010, may influence the economy of many products.

5. Discussion and conclusions

In the above, it becomes obvious that there is some potential for use of LCA for identifying and estimating environmentally related cost items in an LCC, but the methodology is immature.

The forces driving the internalising of environmental costs in companies are increasing. The rates by which this results in an actual increase of costs to companies are not possible to predict, but the magnitude of the cost increases can be estimated by using the "polluter pays principle" and a cost-benefit analysis.

A starting point for the "polluter pays principle" is the identification and estimation of external environmental impacts and costs. This is not a straightforward task as there are major differences between how different people understand the borders of the system “environment”. It is comparatively easy to identify internal environmental cost issues, but it is difficult to estimate them. Still, there is a strong need for such estimates, not only from companies, for motivating environmental management, but also from authorities developing regulatory tools.

The World Business Council on Sustainable Development (WBCSD) identified two financial issues that were particularly strongly related to environment and products: innovation and risk profile. The cases reviewed above underline the relation to risk. There are examples of innovation benefits, but these may be expected to increase with the transformation to a sustainable society.

In practice, allocation of costs to the “environment” account may be tricky. Many measures taken have multiple functions, and the allocation may be arbitrary. Here the LCA debate on allocation may be helpful.

It seems reasonable to start an improvement of the methodology by looking at future costs and benefits. Costs that exist can be estimated roughly without new methodology having to be developed.

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LCC application in the Polish mining industry

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Abstract

Purpose – To provide a tool to evaluate the economic and ecological feasibility of new and existing mining projects using a combination of environmental goals expressed in life cycle assessment (LCA) results with economic goals expressed within life cycle costing (LCC).

Design/methodology/approach – Sustainability is developing into a target for an increasing number of industries and governments. As a consequence focus has shifted from the production process to the entire life cycle. LCA is a tool that can help producers make better decisions concerning environmental protection, whereas the aim of LCC analysis is to create a cost-effective model for environmental impact assessment.

Findings – Study of the influence of the environmental cost of projects should be based on long-term analysis of environmental investment. Using the life cycle net present value (LCNPV) method it is possible to compare different investment options, and this method can be treated as a tool that can help producers to make better decisions pertaining to environmental protection.

Research limitations/implications – Internalisation of external costs and valuation of environmental costs are the biggest problems for LCC calculations.

Practical implications – Mining producers can reasonably expect that implementation of LCA and LCC will lead to minimisation of environmental impact of their activities and to more effective environmental, cost and waste management. This means savings through reducing the amount of waste emissions and a decrease in fees and fines.

Originality/value – The use of the tools described in this paper will increase the efficiency of the decision-making process, demonstrating the connection between activity and devastation of the environment.

Keywords Life cycle costs, Mining, Investments, Waste management, Poland

Paper type Research paper

Introduction

Sustainability is developing into a target for an increasing number of industries and governments. As a consequence, focus has shifted from the production process to the entire life cycle. Life cycle assessment (LCA) is one of the environmental management techniques to identify and quantify the environmental impact of goods and services during their entire life cycle – the "cradle to grave" approach. However, since LCA does not consider financial aspects, the life cycle cost (LCC) technique should be implemented to encompass both environmental and economic aspects. LCA can help producers make better decisions concerning environmental protection. The additional use of LCC can create a cost-effective model for predicted environmental impact. Minimisation of environmental impact as well as more effective environmental, cost and waste management is one of the most important aims for mining producers. The mining industry globally is experiencing increasing pressure to minimise the impact of mining activity on the natural environment. In the case of underground mining in Poland, the main environmental problems concern solid wastes, salted mine waters,

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and also the issue of dusts and gases. In 1989 a new policy for the mineral industry was introduced by the Polish Government – it focused on principles of sustainable development. The introduction of high fees and fines for polluting the environment was the most important change (Goralczyk, 2003). Since these charges represent an important cost factor, many companies began to look for solutions that would decrease them. The most natural consequence was the increase of expenditure on pro-ecological investments. As a result, emissions to water and air declined substantially. Moreover – due to economic reform – energy prices increased, resulting in increased efforts to reduce the energy consumption of production processes. Some mines and processing plants began to apply for ISO 14001 certificates to prove their compliance with environmental standards. Also, environmental management techniques gained more attention and some companies began to estimate their environmental impact according to the principles of LCA and LCC. The main purpose of LCA is to identify and quantify the environmental impact of goods and services during their entire life cycle. LCC encompasses all economic implications during the whole life cycle.

LCC definition and application

The LCC concept was developed by the US Department of Defense during the 1960s and incorporated as policy by Directive 5000.1, Acquisition of Major Defense Systems, in 1971:

> The impetus for LCC had developed along with increasingly complicated and technically advanced weapons systems, which entailed much higher post-acquisition costs in areas such as training, maintenance, technical upgrade and operation. In this situation, purchasing a system on the basis of lowest bid would not be beneficial if that same system proved to be more costly to deploy and maintain over its life cycle. By taking into account the costs of ownership, the Department of Defense developed an ability to better identify the possible cost impacts over the entire life cycle, including situations where costs were transferred from one part of the system to another (Stone, 1997).

Many definitions of LCC can be found in the literature – the most common are:

- LCC is the total cost of a device or system during its full life cycle including the cost of development, acquisition, operation, conservation and maintenance, and final disposal;
- LCC is the sum of all costs incurred during the life cycle of a building, system or product. It includes the costs of the project, development, acquisition, operation, conservation and maintenance and salvage value if it exists (Glossary of Acquisition Terms by US Federal Acquisition Institute); and
- LCC is the total cost of acquisition and ownership of the system during its life cycle. It includes the costs of development, acquisition, operation, conservation and maintenance as well as final disposal (Glossary of Project Management Terms by Center for Systems Management).

LCC (the abbreviation “LCC” is also used for “life cycle costing” to describe the process of identification and performing LCC) is then defined as the sum of total costs estimated to be incurred in the design, development, production, operation, maintenance, support, and final disposal including the salvage value of a major system over its anticipated useful life span (Barringer and Weber, 1996). LCC encompasses all the economic implications during the whole life cycle, and therefore it also includes such financially measurable items as energy recovery, reduced fines for pollution, lower operation and maintenance cost.

Since LCC is based on a life cycle approach, the financial data should be collected in every stage of LCA:

- *Goal definition and scoping* – where system boundaries and functional units are defined. LCC analysis should be performed for each functional unit within the defined system boundaries. It is crucial to define the functional unit according to the product or process under analysis.
- *Life cycle inventory analysis* – This stage involves data collection and calculation procedures to quantify relevant inputs and outputs of a product system. These inputs and outputs may include the use of resources and releases to air, water and land associated with the system. To complete a financial inventory all financially measurable items, such as cost of inputs (i.e. any materials and energy coming into the functional unit), as well as cost of outputs (i.e. fee or fine for all products, wastes, and pollution generated by the functional unit) should be collected in this stage.
- *Life cycle impact assessment* – This stage "is aimed at evaluating the significance of potential environmental impacts using the results of the life cycle inventory analysis. In general this process involves associating inventory data with specific environmental impacts and attempting to understand these impacts". Regarding the aspects of LCC at this stage it is possible to establish a hierarchy of cost both for each functional unit as well as for the entire process. It is also possible to determine the largest cost contributions for each category.
- *Valuation and interpretation* – Valuation is a final step of assessment, which includes the weighting and aggregation of different environmental impact categories in order to compress multidimensional information into a decision making model (Seppala, 1999). Using the financial data collected in previous stages any decision can also be evaluated in monetary terms.

To identify and reduce all LCC, i.e. internal costs (including all those costs that, even if borne by the company, are not considered to be related to environmental protection – hidden costs, non-tangible costs, and potential future costs, as well as social costs), and external costs (cost paid by other companies for environmental damage, such as impact on climate change, on the ecosystem, on human health), analysis should be performed for each functional unit. Using the LCC method for each functional unit, only direct internal costs can be evaluated. Aggregating the costs of all functional units and adding the indirect costs gives the total internal costs of the selected process. Then, by adding external costs, LCC can be calculated. Direct costs include energy, fuel and water consumption, material and personnel. Indirect costs include existing environmental investments, fees, fines and penalties, costs of closure and reclamation, and monitoring. External costs are paid by external companies (e.g. the company which has to clean the water), states (e.g. scientific research which can be useful for the polluter), and people (e.g. disasters connected with climate changes). The budget for external costs can and should be provided by the polluter and the state (Figure 1), not in the form of a fee or fines, but in the form of environmental expenses for current work and a special environmental fund for future protection.

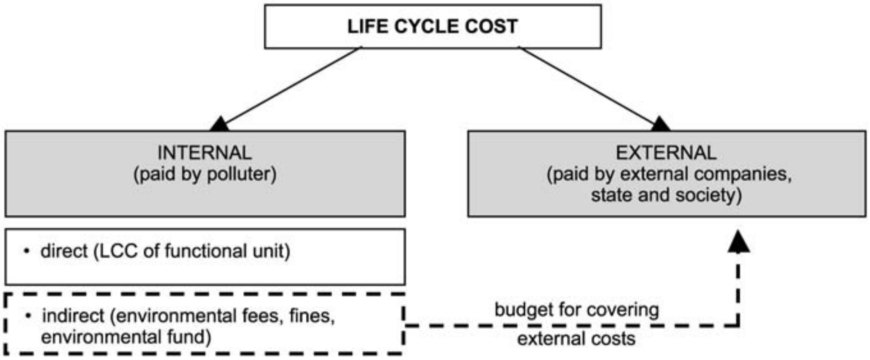

Figure 1.
LCC definition

To effectively implement a LCC analysis, many parameters have to be taken into consideration to determine the cost to the user during the system's expected operational life. It includes spare parts, maintenance, repair turnaround, training duration, skill levels, technical publications, operating cost, etc. The following formula is proposed (Hydraulic Institute, 2001):

$$LCC = C_{ic} + C_{in} + C_{e} + C_{o} + C_{m} + C_{s} + C_{env} + C_{d},$$

where C_{ic} is the initial investment cost (to compare different sized units, it can be calculated on the base of the capacity of the functional unit), C_{in} is the installation and commissioning cost, C_e is the energy cost, C_o is the operation cost (i.e. labour costs related to the operation of the system), C_m is the maintenance and repair cost, C_s is the downtime and loss of production cost (the cost of unexpected downtime and lost production is a very significant item in the total LCC and can rival the energy costs and replacement parts costs in its impact), C_{env} is the cost of contaminant disposal during the lifetime (including disposal of parts and contamination, such as used parts, the investment cost, and cost of environmental inspection), and C_d is the decommissioning/disposal cost, including restoration of the local environment.

To summarise, the LCC for the process is the sum of total direct, indirect, recurring, non-recurring and other related costs which are estimated to be incurred and includes costs associated with design, research and development, investments, operations, maintenance and support of a system over its life cycle.

Application of LCC to the mining industry

Environmental issues are having an increasing influence on the mining industry. Mining and metallurgical processes are burdensome to the environment, mainly due to the large bulk of material to be transported and processed. It is impossible to contain such extensive activities within a limited area so the spheres of influence cover considerable areas, even changing the landscape. The primary non-ferrous industries are particular examples of this, as non-ferrous ores contain only a few percent of metals. The rest of the extracted mineral has to be eliminated gradually in successive production stages. Thus, it is technology that decides the quality of the streams of separated waste and the total amount of waste. Waste from the mining industry represents a major waste stream in the EU, amounting to approximately 29 percent of the average annual waste production. In Poland and in other accession states it represents a higher value – the mining industry was extensively developed in centrally planned economies. Therefore, many accession states are now the main European producers of mining waste – in Poland, for example, 49.4 Mt of waste came from the mining industry (i.e. 36 percent of total waste produced) in 1999, and 43.7 Mt (i.e. 35 percent of total waste produced) in 2001. In Romania, out of 80 Mt of waste produced, 49.4 Mt (61 percent) came from the mining industry in 1999 (Central Statistical Office, 2002). There is a growing need to identify economically feasible and environmentally compatible solutions. The implementation of LCA in the mining industry should take into account three groups of capital investment projects (Durucan and Korre, 2000):

(1) "Greenfield sites", where provisions for minimising the impact of mining on the environment constitute an integral part of the mine's design.
(2) Redevelopment of deposits on the site of previous mining operations, where mine design is constrained by old surface and underground operations, and the options available to minimize additional environmental impact may be limited.
(3) Ongoing investments in active operations, where fundamental modifications to the existing mine design are not practical and may even be counterproductive.

In order to implement LCA and LCC in mining operations, the entire life cycle of the product/process should be analysed in terms of environmental and cost aspects. Since mining production as a whole consists of different technological processes, environmental problems should be recognised for each process. The functional unit in the mining industry can be defined as one machine, for example an underground mine drill car (Kulczycka *et al.*, 2001). The environmental aspects (primary input and output) of such a functional unit are presented in Table I, and selected costs, based on Polish conditions, are presented in Table II (Goralczyk, 2003).

To effectively implement a LCC analysis, many parameters have to be taken into consideration to determine the cost of ownership during the system's expected

Table I. Inputs and outputs for sample functional unit

Inputs		Outputs	
Fuel (kg/h)	24.56	CO (g/h)	2.80
Electric power (kWh)	50	NO_x (g/h)	8.20
Lubricants (g/h)	0.30	Lubricants used (g/h)	0.30

Table II. Estimation of functional unit costs

Cost type	Amount
Purchase (incl. freight and installation) (€)	40,000.00
Power (fuel and electricity) (€/h)	15.00
Lubricants (€/h)	0.04
Operator wages (€/h)	5.00
Maintenance labour costs (€/h)	5.00
Fines for CO emission (€/10,000 h)	0.63
Fines for NO_x emission (€/10,000 h)	6.76
Fees for used lubricant disposal (€/10,000 h)	0.0117
Cost of disposal and cost of spare parts (€)	2,500.00

operational life. Additionally it is important to consider the measures used. For example, the same process output volume should be considered and, if the two items being examined cannot give the same output volume, it may be appropriate to express the figures in cost per unit of output (e.g. US$/ton, or €/kg) (Hydraulic Institute, 2001).

Using the LCC method for each functional unit, only direct internal costs can be evaluated. Summarising the costs of all functional units and adding the indirect costs gives the total internal costs of the selected process. The identification of some environmental costs for each major mining industry process (system boundaries) are presented in Table III.

Application of LCNPV to the Polish mining industry

Using the life cycle net present value (LCNPV) method, it is possible to compare different investment options, and this method can be treated as a tool that can help producers to make better decisions pertaining to environmental protection. LCNPV is proposed to evaluate and select the best solution for new investment plans in existing mining projects, or for evaluation of the economic and ecological feasibility of new projects. Depending on the accuracy of the model, the LCC calculation can consist of the sum of costs for functional units or a sum of costs for every process. Therefore input and output are measured for each functional unit in monetary terms, for example output as contribution to the greenhouse effect is monetised in terms of charges that will have to be paid for emissions (based on Polish regulations). The model can also help in investment decisions when basic investment evaluation methods fail to give an explicit answer. This can occur when competing projects are financially similar. Even so, for every project under consideration it is essential to perform a normal investment evaluation, since – as with all decisions that involve money – the financial aspects are crucial. If the project is unsatisfactory in financial terms it cannot be implemented, even if this means rejecting solutions that are environmentally safer. One of the reasons for this is that the company's shareholders expect to earn a profit on the money they have invested. They will not accept a loss or break-even situation over the long term, and if such a situation should were to occur they would withdraw their funds from the company and invest them elsewhere. Therefore, every environmental

Process	Environmental impact/LCC
Prospecting for raw material	Land use
Extraction	Mining water discharge – also salted water, land degradation, land use
Treatment	Waste storage and disposal, dust and gas emissions, water discharge, human health
Manufacturing	Dust and gas emissions, solid waste disposal, water discharge, human health, co- and by-product recovery
Transportation	Dust and gas emissions, noise
Distribution	Dust and gas emissions
Use	–
Storage	Waste disposal (hazardous and non-hazardous)
Recycling or waste utilization	Water purification, improvement of the environment
Closure and monitoring	Improvement of the environment

Table III. Social and environmental aspects at each major mining industry process investment should be screened with the usual investment evaluation methods (Goralczyk, 2003). The proposed methods for this evaluation are LCNPV and internal rate of return (IRR). LCNPV is the value of the project expressed in the first year of the project's life. It is calculated by discounting all costs and incomes during project life using the following formula:

$$\mathrm{LCNPV} = \sum_{i=0}^{n} \frac{\mathrm{CF}_n}{(1+i)^n},$$

where CF is cash flow, i is the interest rate, and n is the number of years.

A positive present value indicates that, by this criterion, the project is profitable. Another criterion, the IRR, is a rate of return that would make the LCNPV equal to zero, which indicates the minimum rate of return that can be accepted in order to achieve a profit. If the producer decides – due to environmental reasons – to purchase new equipment (functional unit) the whole life cost can be determined using the formula for annual costs (Stermole and Stermole, 2000):

$$\text{Annual cost} = C\left[\frac{i(1+i)^n}{(1+i)^n - 1}\right] - L\left[\frac{i}{(1+i)^n - 1}\right],$$

where C is the initial cost, L is the salvage value, i is the interest rate, and n is the number of years.

The calculated annual cost can be used in the model for further calculations. The calculation of annual costs is very important, because project costs and revenues must be known in order to calculate the LCNPV and IRR. It is also important to include in the project plan the costs and savings that pertain to environmental protection. Apart from the initial investment, these costs should cover technology (usually more expensive, but better for the environment), pollution monitoring, rehabilitation costs, final disposal costs, and energy and maintenance costs, which are often neglected. The cost of performing LCA should also be taken into account. As for savings, these include not only financially measurable items, such as reduced (or even eliminated) fines for pollution, and lower operation and maintenance costs, but also non-measurable effects, such as improved company image and increased competitiveness.

For companies already in business, the most common difficult decision involves the choice between existing and new technology. It is quite difficult to assess the exact amount of income produced by a capital improvement that provides a service. Incremental analysis is thus required in order to evaluate service-producing investment alternatives that involve initial costs. This analysis is based on subtracting the investment that would require less capital from the alternative that would place a larger demand on funds. As a result, a cash flow diagram is created with an initial investment that will produce savings and/or revenues in the future (Stermole and Stermole, 2000). If the incremental LCNPV of the project is greater than 0, revenues can be expected from the investment.

At the end of the life cycle of an item of technology, the issue arises as to whether it is more economical to use or dispose of obsolete equipment. The issue of when to upgrade obsolete equipment must be taken into account when budgeting, as it will impact the cost of the technology in the long term. When a decision has been taken to dispose of obsolete equipment, it may be possible to achieve some return on the investment made on that equipment by selling it.

A basic analysis of the life cycle inventory for Polish non-ferrous copper producer KGHM Polska Miedz SA (by comparing the inputs – i.e. energy and materials – and the outputs – i.e. wastes and pollution) shows that the largest amounts of waste and pollution (and also the highest fees) are generated at the mining and processing stages. Solid waste (flotation tailings, slag from the smelting furnace, waste from the desulphurisation plant and also dust and slugs from the disposal of gas cleaning systems) management is now the largest environmental problem for KGHM (Table IV). It is possible to dispose of the solid waste in the existing tailing pond as its capacity may be sufficient for future production (the mine's life expectancy, based on the reserves available for extraction, has been calculated as 25 years). But the environmental hazards and the costs of reclamation and monitoring (in compliance with Polish law) will continue to be incurred for 30 years after closure.

Using LCC, it is possible to calculate the maximum budget available for any technology investments that reduce the amount of solid waste. For such a calculation it is proposed to use the net present value (NPV) method. Adding LCC assumptions, LCNPV analysis can be created. The first step in such analysis is to establish the project design life (in this case 55 years), then to establish the current cost of waste management. The next step is to evaluate the possible cost reduction during the whole life of the project and the environmental gains. In order to solve the problem of solid waste, research has been conducted on the possibility of utilising post-flotation waste in underground mining techniques to backfill exploited areas and fill abandoned works. In all likelihood, after implementation of LCA, such a solution (now considered too expensive) will be found to be the correct one. At the same time, it will also minimise the dumping of solid waste, which is the most hazardous. Finally, this reduces the amount of fees and fines that KGHM must pay for generating waste, and enables the company to avoid some of the costs of tailing dump reclamation and monitoring after closure of the mines.

KGHM's aim is to minimise the amount of waste produced, to maximise the disposal of unavoidable waste, to control the impact on the environment and to reduce dumping costs and environmental charges. The analysis can be done not for each functional unit but for all the mining process stages, including waste storage and closure and monitoring. To answer the question of how much money it is feasible to invest to reduce the internal cost of solid waste management by 50 percent, incremental analysis

Table IV.
Volume of inputs (materials, energy) and outputs (pollutants) at Polish copper producers

	1997	1998	1999	2000
Production of copper (t)	440,640	447,000	470,494	486,000
Material consumption (ore/t Cu)	56.1	58.4	57.4	
Environmental fee ($/t Cu)	53.94	38.78	32.79	27.62
Fuel and energy consumption (MJ/t Cu)	10,391	9,343	9,295	NA
Of which electricity (kWh/t Cu)	1,163	1,219	988	NA
Salted water released (m^3/day)	72,378	59,342	42,989	43,514
Dust and gas emission (t/year)	1,691	958	977.4	915.8
Solid waste (×1,000 t)	24,447	26,202	26,973	27,080
Of which utilized (× 1,000 t)	12,816	18,099	19,887	20,706

was performed. Currently, the cost of waste management equals €20,510,000, and includes direct costs of waste management, environmental fees, fund for closure and reclamation, and monitoring. The production time is 25 years, but the life span of the project (including reclamation and monitoring after closure) is 55 years. The calculation of LCNPV is done for 25 years, as it was assumed that the money for the reclamation and monitoring after closure should be generated now and saved as a special fund for closure and reclamation. The discount rate of 7 percent has been chosen for the calculation of LCNPV for new investments. The evaluation of capital expenditure will be calculated for the year 2003, since LCNPV is calculated for a certain moment in time. The value of LCNPV amounted to €512,750,000 for the current situation and €119,507,495 for a 50 percent cut in expenses. The LCNPV value of €119,507,495 can be treated as the maximum economically feasible value which can be invested now to reduce the environmental hazard. Of course there is a question whether the company has such an amount of money available for investment, but that method of investment evaluation can be applied to clarify the decision whether to improve existing technology or introduce a new system. The choice between these two alternatives is constrained by limited funds, resources, and other factors, such as environmental issues. LCNPV could be useful to decide which alternative is economically feasible.

Conclusions

The structure created by a LCA study enables a clear perception and estimation of the environmental impact of a product, process or service during its entire life. It creates the basis for an assessment of the impact of analysed factors (classified in the impact categories) on the environment and an indication of which process phase carries the biggest environmental load. The wide scope of LCA study supports improved results in environmental management, as the analysed process and its phases are presented from a global perspective, regardless of whether it concerns a single machine, a group of them or all equipment used in the production process. In a time of increasing interest in ecology, LCA is a valuable tool for effective environmental protection. Since it is based on the analysis of actual input and output data of the industrial process reviewed, it makes possible the evaluation of the real threat to the environment and effective negative impact reduction. For some companies LCA is the first step in introduction of clean production and – at the same time – enables acquisition of a competitive ecological position on the international market. The concept of environmental management lacks a consideration of indirect environmental aspects – that gap can be filled by LCA. If LCA is going to be developed as a tool for the quantification of indirect and direct environmental aspects together with potential impacts during the whole life cycle, there is a need for systematic data collection. The availability of data and its scope, which can be analysed in LCA is growing, so LCA can be applied to new products or areas. Both methodologies and data will in time be better and more precisely documented, and hence future use of LCA will intensify. Also with the increased availability of data, LCA analysis will be performed more precisely.

The increased significance of LCA in Poland can be foreseen in relation to the following regulations:

- ISO Standard 14040-14049 – companies holding certificates will be granted larger social confidence, as well as having facilitated access to international markets because nobody will accuse them of ecological dumping;
- the Directive of the European Parliament and Advice from 20 December 1994, in the matter of new and used packaging (94/62/WE) in article 10 affirms: "[T]he committee will particularly support the study of European norms relating, among others to criterions and methods of analysis of cycle life of packaging"; and
- Article 143 of the Polish Environmental Protection Law dated 27 April 2001 states that the installation of new, or significantly altered technology should take into consideration – among others – the Life Cycle Assessment approach.

In the same legal Act there are regulations concerning reporting of the environmental impact of a project as well as gathering of data pertaining to this environmental impact. The scope and detail level of the data correspond to the LCA/LCC quality requirements. These legal regulations clearly indicate the growing importance of LCA/LCC methodology in Polish environmental protection.

However, only in a few cases could LCA be used as a single decision factor. A natural supplement for LCA is LCC analysis which aims at creating a cost effective model solution with respect to the estimated environmental impact of the particular product, process or service. Depending on the model detail level, the LCC calculation can consist of the sum of costs for functional units or a sum of costs for every process. LCC includes all costs (acquisition, use, maintenance and final disposal) that are important for the decision-making process. The potential area of future development is the integration of LCA and LCC as well as other environmental management tools that support this decision making process. Combination of environmental goals expressed in LCA results with economic goals expressed within LCC should allow for the evaluation and introduction of ecologically and economically optimal solutions. Thanks to such a combination, decision-making will become more effective, with the emphasis on the relationship between investment activities and environmental effects. The LCNPV method proposed in the paper is a useful tool in evaluating investment decisions and alternatives, both for functional units and processes. In LCNPV analysis, the most important factors are correct definition of functional units, system boundaries, input and output analysis as well as calculation of the cost range (external and internal, including direct and indirect costs). Decision-makers can reasonably expect that implementation of LCA and LCC will lead not only to minimisation of environmental impact of their activities, but also to more effective environmental, cost and waste management. This means savings through reducing the amount of waste emissions and a decrease in fees and fines as a consequence. As a result of the tools described in this paper, the decision making process will become more efficient, demonstrating the connection between the activity and devastation of the environment. Another benefit that cannot be omitted is the improvement of the image of producers in the world market.

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Integrating LCIA and LCM

Evaluating environmental performances for supply chain management in South Africa

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Abstract

Purpose – Evaluations of environmental performances are of increasing importance for environmental management systems. In the automotive sector of South Africa, suppliers of components lack the ability to provide customers in the value chain with the necessary information to assess and compare environmental performances. Original equipment manufacturers (OEMs) in South Africa have systematically commenced to obtain limited process information from first-tier suppliers. However, the information is not an accurate reflection of the true environmental burdens associated with the supplied components. Based on the available process information, this paper introduces a performance evaluation methodology that is applicable for South Africa.

Design/methodology/approach – The LCA methodology, as stipulated by ISO 14040, has been applied to obtain quantified environmental performance resource impact indicators (EPRIIs) associated with limited process parameters in the South African context. Three first-tier suppliers of an OEM are used as a case study to demonstrate the application of the indicator methodology.

Findings – The EPRII procedure considers the spatially differentiated ambient environmental state of the South African natural environment for normalisation factors of typical LCIA categories. The procedure further incorporates costs in order to compare supplied components (and companies) equally.

Originality/value – The EPRII procedure provides the means for OEMs to obtain a first approximate of environmental concerns in the supply chain, based on three basic process parameters. Thereby, tiers can be prioritised to determine where assistance is required to improve environmental performances.

Keywords Life cycle costs, Supply chain management, Environmental management, Automotive industry, South Africa

Paper type Research paper

Introduction

The automotive industry, which operates as multinational companies, is increasingly pressurised to incorporate economic, environmental and social performances in its policies, culture and decision-making processes (Brent *et al.*, 2002). These performance objectives are manifest in three operational focal points that are fundamental to the manufacturing industry (Brent and Visser, 2005):

(1) *Projects*, which drive change in internal operational practices. The concept of sustainable development must be integrated in the planning and management over the life cycle of projects.

(2) *Assets*, which are required in the manufacturing process. The life cycle of assets must be optimised in terms of sustainable development performance objectives of the manufacturing facility.

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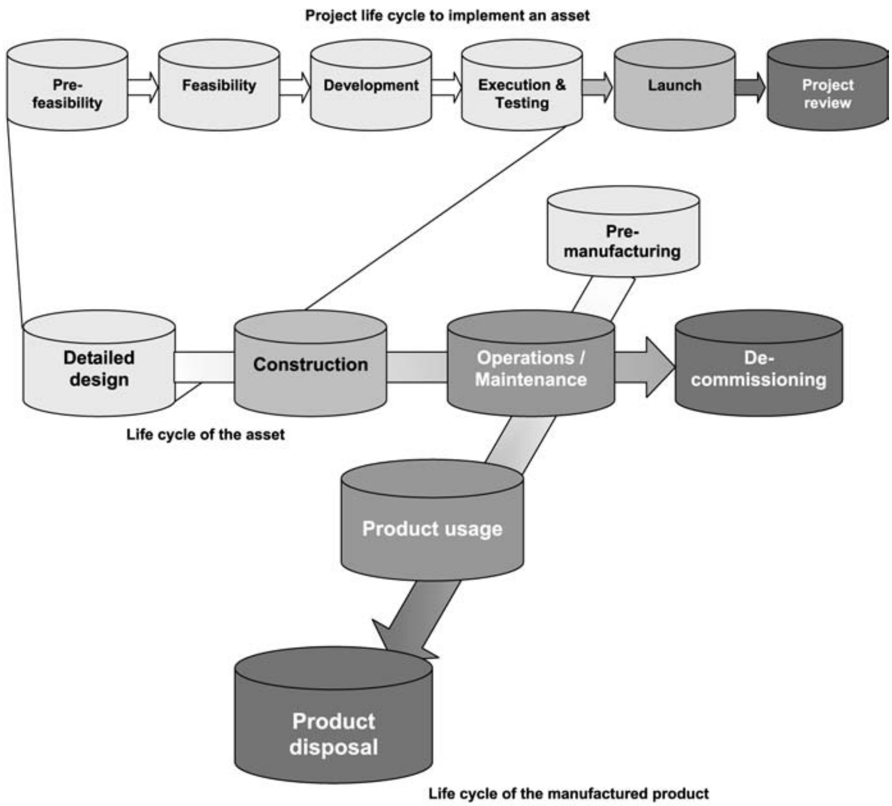
(3) *Products*, which determine the economic value of manufacturing operations. The influence of products on economies, environments and society as a whole must be considered, i.e. the concept of product stewardship (United States Environmental Protection Agency, 2003).

A comprehensive life cycle management (LCM) approach is subsequently required, which assures that the operational processes are consistent and that there is effective sharing and coordination of resources, information and technologies (ISO, 2002; Brent and Visser, 2005). Such a holistic LCM approach would require an effective integration of the three life cycles within an original equipment manufacturer (OEM) in the automotive sector (see Figure 1) (Brent and Labuschagne, 2003a). Management practices must adhere to sustainability performances in all three of these life cycles.

Project life cycle

Various project life cycle approaches have been defined, e.g. control-oriented models, quality-oriented models, risk-oriented models, a fractal approach to the project life cycle, as well as some company-specific project life cycles (Bonnal *et al.*, 2002). The



Source: Brent and Visser (2005)

Figure 1.
Integration of project, asset and product life cycles in the manufacturing industry

number of phases within each of these approaches differs as well as the names used to describe the phases. Due to the complex nature and diversity of projects, industries, or even companies within the same industry sector, cannot reach agreement about the life cycle phases of a project (Kerzner, 2001). A generic project life cycle has been defined (Buttrick, 2000), which has been used as basis for Figure 1 (Labuschagne and Brent, 2005).

Asset life cycle

The project life cycle and asset life cycle are often viewed as one life cycle due to the fact that the two life cycles contribute to the same value chain (Labuschagne and Brent, 2005). Nevertheless, there is a definite difference between a project and an operational activity (or asset) (Kliem *et al.*, 1997). A typical asset life cycle also consists of six phases, namely two design phases, a construction phase, a start-up/commissioning phase, operation/maintenance phase, and then a decommissioning phase (Labuschagne, 2003).

The asset life cycle can be simplified to four phases (as shown in Figure 1) if all design phases are treated as one phase and start-up and commissioning are treated as part of the operational phase. The design phase of an asset can be the selection phase of manufacturing equipment if the asset is purchased and is not an in-house design.

Since the project is the vehicle to design (if applicable) and implement the asset the two life cycles still interact (see Figure 1) (Labuschagne and Brent, 2005). The project normally ends after the asset commences stable operations in accordance with performance requirements (Dingle, 1997). Therefore, the design, construction, and a small part of the operational phase are completed during the project's life cycle. A post-implementation review will take place when the asset is in its operational phase.

Product life cycle

The main goal with the implementation of a new asset is to manufacture a product or to improve the manufacturing of a product that can meet the needs of a customer (Labuschagne and Brent, 2005). The operational phase of the asset life cycle is thus the manufacturing or production phase of the product. Product life cycles have played an important role in the field of life cycle assessment (LCA), which has been used to evaluate the environmental performances of products. A product life cycle consisting of five phases has been proposed from the perspective of LCA (Graedel, 1998). These phases are: pre-manufacturing, product manufacturing, product delivery, product use and refurbishment, and recycling and disposal. Another approach is to apply the generic systems life cycle to products (Blanchard and Fabrycky, 1998). The difference between these two life cycles is that the first uses a supply chain perspective and excludes the design phase of a product, while the second starts the life cycle of a product with the need identification, and considers supply chain activities as part of the production phase. A simplified supply-chain focused product life cycle is used to describe the interaction between the product and asset life cycles in Figure 1 (Brent and Labuschagne, 2003a).

Sustainable supply chain management in the automotive sector

Sustainable product life cycle management (LCM), or product stewardship (United States Environmental Protection Agency, 2003), implies the incorporation of the principles of supply chain management, whereby the manufacturer of a product assumes responsibility for the economic, environmental and societal consequences of supplied components, materials and energy inputs (Brent and Labuschagne, 2003b). However, little attention is given to the actual societal influences of suppliers. Rather, the current focus is to increase the environmental performance of the supply chain (*Engineering News*, 2002), which originates from the integration of supply chain management and environmental pressures (Hall, 2000; Brent and Visser, 2005):

- it is recognised that systematic approaches to environmental concerns in buyer-supplier systems are necessary;
- buyer-supplier relations play an increasingly important role in industrial systems and the strategies of companies; and
- external environmental pressures have implications on the internal behaviour of companies in supply chain systems.

Although large manufacturing facilities or customers are exerting pressure on suppliers, the responses from within the supply chain vary. Supplying companies are often hesitant to invest in environmental innovations, as there is no clear correlation with financial performance. In particular, smaller, lower profile suppliers, who are integral parts of any manufacturing system, lack incentives to improve environmental performance, whereas larger, higher profile suppliers respond positively to considerable pressures from customers (Hall, 2000; Brent and Visser, 2005).

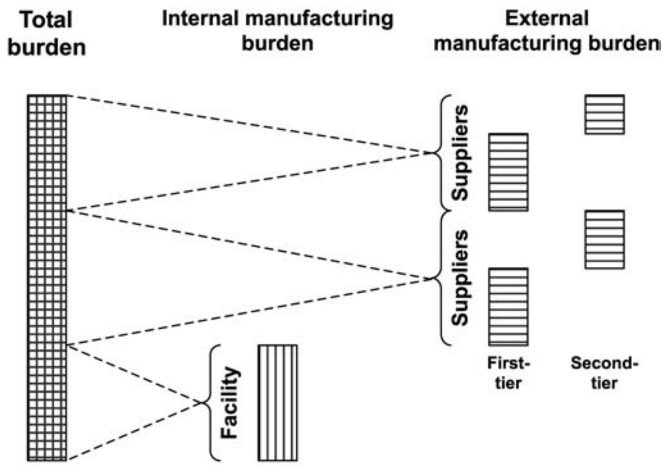
The environmental pressures that are exerted by larger manufacturing facilities are often the result of the performance requirements of these facilities in terms of environmental management systems (EMSs) that have been introduced, e.g. ISO 14000. Purchasing is one of the key processes assessed by ISO 14000 and the procurement process is progressively being more recognised to significantly affect corporate performance along environmental dimensions (Handfield *et al.*, 2002; Brent and Visser, 2005) in two ways:

(1) *Directly*, i.e. products acquired from the supply chain increase waste during the storage, transportation, processing, use or disposal of these purchased items.
(2) *Indirectly*, i.e. procured items do not consist solely of a direct monetary cost, but also of an environmental burden associated with producing or manufacturing these items.

For a complex product, e.g. the automobile, the total burden associated with the product is therefore dependent on accumulated internal and external burdens. These burdens can translate to a total cost (purchasing and manufacturing burdens) of the final product or a total environmental impact (or pressure) associated with the product (see Figure 2) (Brent and Labuschagne, 2003b; Brent and Visser, 2005).

Environmental burdens associated with the South African automotive supply chain

The South African automotive manufacturing supply chain contributes to the national environmental concerns, primarily through (Department of Environmental Affairs and Tourism, 2002; Brent and Labuschagne, 2003b):



Source: Brent and Visser (2005)

Figure 2.
Accumulated burdens (economic and environmental) of a manufactured product

- over-abstraction from surface and ground water resources;
- salinisation of surface water due to the discharge of saline effluent from manufacturing and processing industries, irrigation, the discharge of underground water pumped from mines (which also leads to acid mine drainage), and the discharge of treated sewerage effluents;
- destruction of riparian and in-stream habitat;
- discharge of toxic substances at point and diffuse sources;
- health and environmental impacts on groundwater resources due to diffuse pollution;
- production of solid waste;
- emissions of greenhouse gases and other air pollutants;
- loss of biodiversity and valuable land, for example the degradation of wetlands in mining areas, invasion of riparian zones by invasive plants due to bad management practices, etc.; and
- localised pollution through spillages and accidental leakages that may cause health problems and damage to ecosystems in the immediate vicinity.

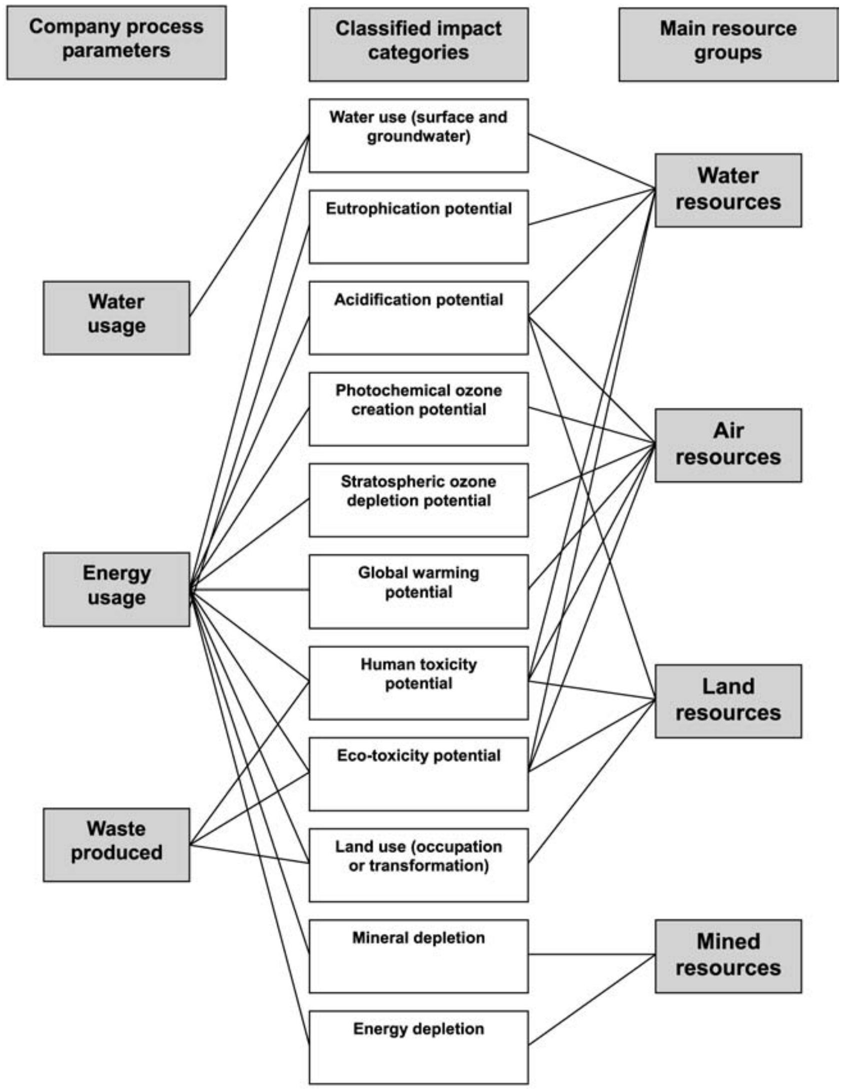
The manufacturing sector of South Africa is further resource intensive in terms of mineral and fossil fuel usage (Brent, 2002a). The environmental impacts associated with the industry sector of South Africa have subsequently been grouped into the four main categories of air, water, land and mined abiotic resources (Labuschagne *et al.*, 2005). Environmental pressures with respect to air and mined resources may be similar to other parts of the world. However, impacts on water and land resources differ to some extent, not only from regions external to South Africa, but also within the national borders (Brent, 2002a).

When evaluating the specific impacts associated with the supply chain of the South African automotive sector, special attention must therefore be given to water- and land-use and transformation, minimizing the effects of loss of habitat and of prime agricultural land, as well as water and land pollution and degradation in its broadest sense. In order to improve the accuracy of an industrial activity evaluation, four regions (termed SALCA Regions) have been identified within the national borders that are characteristic of the diversity found with the South African natural environment (Brent, 2003; Brent and Visser, 2005).

The lack of environmental data to determine the precise environmental impacts of supplying companies in industry is common in South Africa (Brent and Visser, 2005). In particular, smaller supplying companies in the manufacturing value chain of the South African automotive sector have only limited process information. Automobile original equipment manufacturers (OEMs) in South Africa are obtaining limited information, specifically water usage, energy usage, and waste produced per manufactured item (Brent, 2002b). These three process parameters do not directly show the overall burden of a supplying company on the four environmental resource groups within the South African context. This paper introduces an environmental performance resource impact indicator (RII) procedure for OEMs, whereby the environmental performances of the different South African suppliers can be evaluated and compared, and improvement possibilities identified, based on the limited process information. The EPRII procedure applies the LCIA methodology of ISO 14042 (Standards South Africa, 2003), but considers the lack of background environmental data that is available to calculate precise environmental impacts in South Africa. The EPRII procedure further incorporates the economic costs of supplied components (to an OEM) in order to compare the environmental performance of first-tier suppliers equally.

The environmental performance resource impact indicator (EPRII) calculation procedure

A life cycle impact assessment (LCIA) framework has been introduced to assess life cycle systems in South Africa (see Figure 3) (Brent, 2003; Brent and Visser, 2005). The framework assesses the impacts associated with a system on four environmental resource groups as areas of protection (AoP): water, air, land, and mined abiotic resources. Protection of the resource groups (except mined abiotic resources) ensures that the ambient environment is adequate to sustain human health and ecosystem quality without adverse effects. Based on a distance-to-target approach, the current and target ambient state levels define the importance of conventional LCIA midpoint categories that contribute to the total impact of a system on the resource groups. The current and target state levels are defined for the four South African Life Cycle Assessment (SALCA) Regions, and for South Africa as a whole. The precautionary principle is followed to determine a maximum resource impact indicator (RII) for a system for each resource group (Brent, 2004). Thereby, the impact pathway of a life cycle inventory (LCI) constituent of a system that contributes to a RII value for any of the resource groups to which it contributes, is taken into account. Furthermore, the summation of all the LCI contributions for a resource group is assigned as the RII for that resource group. The RII values for each LCI constituent are calculated according to the following general equation (Brent 2003, 2004):



Source: Adapted from Brent and Visser (2005)

Figure 3.
Framework to calculate the RII values of obtainable process parameters of companies in the South African automotive supply chain

$$\mathrm{RII_G} = \sum_C \sum_X Q_X \cdot C_C \cdot N_C \cdot S_C, \qquad (1)$$

where $\mathrm{RII_G}$ is the resource impact indicator calculated for a main resource group through the summation of all the impact pathways of the LCI constituents, Q_X is the quantity release to or abstraction from a resource of life cycle constituent X of a LCI system in an impact category C, C_C is the characterisation factor for an impact category (of constituent X) within the pathway (Brent, 2003; Brent and Visser, 2005; Guinée *et al.*, 2001), N_C is the normalisation factor for the impact category based on the ambient environmental quantity and quality objectives (i.e. the inverse of the target state of the impact category), and $S_C = C_S/T_S$ is the significance (or relative importance) of the impact category in a resource group based on the distance-to-target method, i.e. current ambient state (C_S) divided by the target ambient state (T_S). These current and target ambient state values for the SALCA Regions of South Africa are summarised elsewhere (Brent, 2003; Brent and Visser, 2005).

Figure 3 illustrates the possible impact pathways of the three process parameters that are obtained from suppliers to automotive OEMs in South Africa (Brent and Visser, 2005). Through the framework of Figure 3 and the calculation procedure of Equation (1) an overall environmental burden indicator of a company (or manufacturing process) can be determined for each of the four resource groups. In order to apply the framework and RII calculation procedure, detailed LCIs were compiled for energy usage, i.e. electricity, steam and liquid fuel, and waste produced in South Africa. For the latter it was assumed that a medium-sized South African landfill for low-level hazardous material would be required as an average. Water usage is assumed as direct extraction from surface or groundwater reserves. Similarly, the use of raw energy materials (e.g. natural gas and coal) are taken as directly extracted from available reserves. The use of liquid fuel and raw energy materials is not region-specific, and South African normalisation values are used. The majority of electricity in South Africa is generated in SALCA Region 3 (Eskom, 2002), and the RII per generated MJ is calculated with the normalisation values for this region. RIIs for the other process parameters are calculated using the normalisation values for the SALCA Regions where a company is located. Table I summarises the calculated RII values for selected process parameters if South Africa is considered as one region. By applying these calculated RII values (for the separate process parameters), the overall RII values of a supplied component can be determined through normal summation.

In order to compare the environmental performances of supplied components (to an OEM) equally, a further normalisation step is introduced to determine overall environmental performance resource impact indicators (EPRIIs). Thereby, the calculated RII values are divided by the economic cost of the supplied components (see Figure 4). The EPRII values therefore depict the RII values per economic burden for an OEM that evaluates and compares environmental performances in the supply chain.

Applying the EPRII approach in the South African automotive supply chain

The environmental performances of three first-tier suppliers to an automotive OEM in South Africa have been evaluated and compared with the EPRII procedure as a case study

(Brent and Visser, 2005). The OEM is situated in the city of Pretoria (in SALCA Region 3) and the companies supply the OEM with fuel tanks, windscreens and tyres for a standard sedan vehicle. The limited process parameters have been obtained from the companies per manufactured component (see Table II). The table also indicates the economic value (or cost) of the supplied components to the OEM in South African rands (ZAR).

All of the first-tier suppliers are located in SALCA Region 3 in the close vicinity of the OEM's manufacturing facility. The calculated RII values for the each company per supplied component (from the obtained process parameters) are summarised in Table III. Figure 5 compares the (economic) normalised RII values, or EPRII values, for the three components.

Conclusions from the case study

The RII calculation procedure shows that electricity usage is the most important process parameter (see Table III). This parameter has an impact on all of the midpoint categories. However, the burdens on water resources (in the South African context) are the highest. The other process parameters obtained are of minor importance.

Table I.
RII values for selected process parameter (where South Africa is considered as one region)

Process parameter[a]	Water resources	Air resources	Land resources	Mined abiotic resources
Waste produced (1 kg)	4.719×10^{-8}	1.506×10^{-12}	2.730×10^{-8}	0
Electricity used (1 MJ)	4.523×10^{-3}	1.026×10^{-4}	9.650×10^{-7}	5.057×10^{-7}
Liquid fuel used (1 kg)	8.756×10^{-3}	1.104×10^{-4}	1.043×10^{-6}	1.683×10^{-5}
Natural gas used (1 kg)	0	0	0	4.955×10^{-6}
Coal used (1 kg)	0	0	0	3.599×10^{-6}
Steam used (1 kg)	7.324×10^{-5}	7.061×10^{-7}	1.242×10^{-8}	4.283×10^{-7}
Water used (1 kg)	4.896×10^{-5}	0	0	0

Note: [a]The correlations between the process parameters and related RII values are linear
Source: Brent and Visser (2005)

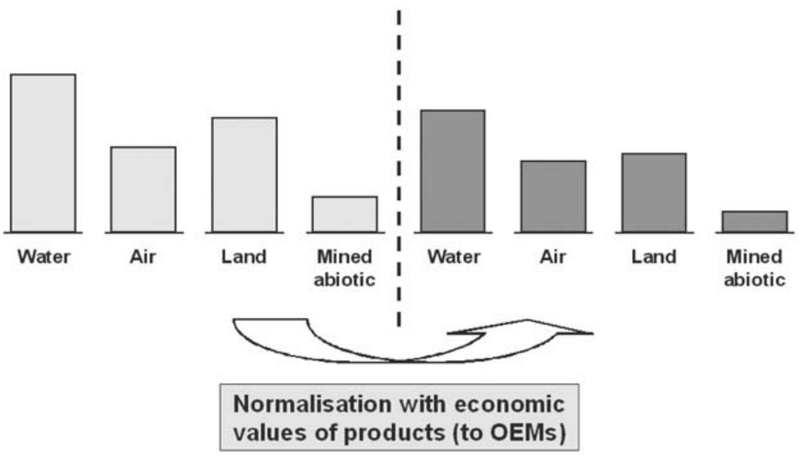


Figure 4.
Normalisation of RII values in order to compare environmental burdens equally as EPRII values

Per economic value, the EPRII procedure prioritises the suppliers of tyres to receive attention in terms of improving environmental performances, followed by the fuel tank. The supplied tyre has an EPRII value in the order of a factor of 10 compared to the fuel tank and windscreen. However, a supplied tyre has an economic value of half to a third compared with the fuel tank and windscreen. Therefore, the ratio difference between environmental burdens associated with the complete components would be smaller. Conversely, five tyres are supplied per manufactured automobile, which would increase the environmental burdens (and total cost to the supplier) by a factor of five for the specific sedan evaluated. The interpretation of the EPRII results is therefore dependent on the specific life cycle that is managed (see Figure 1), i.e. environmental performances of suppliers based on the total operational expenditure in the asset life cycle, or per manufactured product.

It must be noted that only the manufacturing processes of first-tier suppliers were investigated and compared for supply chain management purposes. Environmental performances of the second and subsequent tiers are also required for an overall product evaluation and comparison.

Conclusions

An environmental performance resource impact indicator (EPRII) procedure has been introduced for OEMs, whereby the environmental performances of the different

Energy usage	Fuel tank[a]	Windscreen[a]	Tyre[a]
Electricity (MJ)	63.7	60.5	234.1
Liquid fuel (diesel) (kg)	0.0	0	0
Steam (kg)	0.0	0	20.4
Raw energy materials (kg)	0.0	2.0[b]	0
Water usage (kg)	4.6	176.8	20.5
Waste produced (kg)	0.1	32.0	1.0[c]
Economic value[d] (R)	1,000.00	1,460.00	500.00

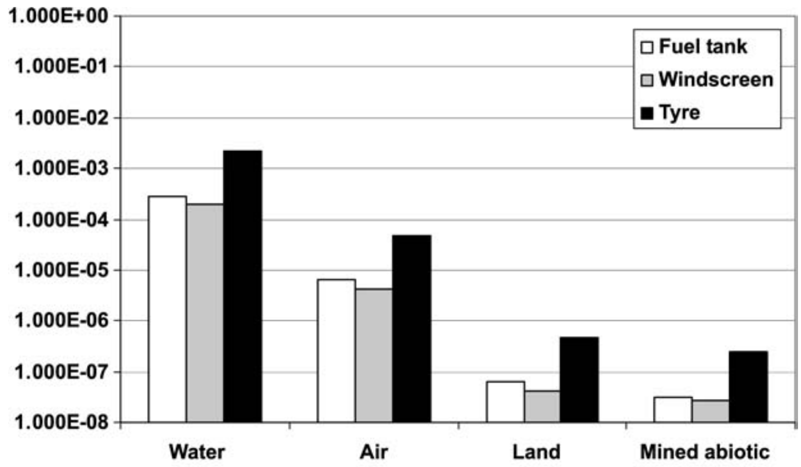
Notes: [a]Process parameters are shown per supplied component; [b]natural gas for furnace operation; [c]10 per cent assumed losses; [d]seven South African rand are equal to approximately US$1
Source: Brent and Visser (2005)

Table II. Process parameters (and economic costs) obtained from an OEM's first-tier suppliers in South Africa

	Fuel tank[a]	Windscreen[b]	Tyre[c]
Water resources	2.882×10^{-1}	2.779×10^{-1}	1.067×10^{0}
Air resources	6.535×10^{-3}	6.206×10^{-3}	2.406×10^{-2}
Land resources	6.148×10^{-5}	6.113×10^{-5}	2.271×10^{-4}
Mined abiotic resources	3.222×10^{-5}	4.051×10^{-5}	1.271×10^{-4}

Notes: [a]Electricity usage per manufactured fuel tank contributes more than 99 per cent to all of the calculated RIIs; [b]electricity usage per manufactured windscreen contributes more than 98 per cent to all of the calculated RIIs; [c]electricity usage per manufactured tyre contributes more than 99 per cent to all of the calculated RIIs
Source: Brent and Visser (2005)

Table III. RII values calculated for the manufactured components



Source: Brent and Visser (2005)

Figure 5.
EPRII values (per South African rand) for the three supplied components

suppliers can be evaluated and compared for supply chain management purposes. The procedure is based on limited process information that is obtainable from suppliers in developing countries such as South Africa, i.e. water and energy usage, and waste produced.

The EPRII procedure considers the spatially differentiated ambient environmental state of the South African natural environment for normalisation factors of typical LCIA categories. The procedure further incorporates costs in order to compare supplied components (and companies) equally. Although not highly accurate, the EPRII procedure does provide the means for OEMs to obtain a first approximate of environmental concerns in the supply chain, based on three basic process parameters. Thereby, tiers can be prioritised to determine where assistance is required to improve environmental performances. Research has subsequently commenced to adapt current management systems, especially for small and medium-sized enterprises, to incrementally enhance environmental performances of automotive suppliers in the developing country context.

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DANTES: a demonstration project for sustainable development

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Abstract

Purpose – To present the EU project DANTES (Demonstrate and Assess New Tools for Environmental Sustainability), conducted by Akzo Nobel Surface Chemistry AB, ABB, Stora Enso and Chalmers University of Technology. One of the project's goals is to assess and demonstrate tools such as life cycle assessment (LCA), environmental risk assessment (ERA) and life cycle costing (LCC).

Design/methodology/approach – Different strategies for eco-efficiency evaluation based on existing tools as well as case study results are demonstrated through the project's web site (see www.dantes.info) and through several information campaigns during the project period. The paper presents an overview of environmental assessment tools and strategies for using these tools and methods.

Findings – Provides information on the use of sustainability tools and methods, indicating the problems that can be addressed by the application of the tool as well as how and who can use the tool. The results from the project were translated into strategies for eco-efficiency evaluation based on existing tools.

Practical implications – Implementation of the strategies demonstrated in the project reduces costs by increasing the performance of products, processes and services, as well as the drive and awareness of companies' personnel in environmental issues. It also promotes good practices.

Originality/value – This paper describes the DANTES project, which is aimed at educating industries on how to use sustainability tools to address environmental problems. It offers practical help to different departments within companies.

Keywords Sustainable development, Life cycle costs, Environmental management, Risk assessment

Paper type General review

1. Introduction

In the past, environmental management practices were mainly focused on addressing emissions and waste discharges to the environment from production processes. During recent decades, attention has shifted to products' life cycles and their environmental impact (European Commission, 1998). Thus, attempts are being made to optimize every step of products' life cycles, from extraction of raw materials through processing, manufacturing and transportation to reuse, recycling and final disposal, in order to decrease the consumption of raw materials and energy, reduce costs and make processes environmentally benign. Also, companies have started to view environmental performance as an important marketing aspect of a product, and communicate it to their customers and other stakeholders. Life cycle assessment (LCA), life cycle cost analysis (LCC), environmental risk assessment (ERA), environmental performance indicators (EPI) and environmental product declarations (EPD) were

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therefore introduced to support industries in environmental management practices. However, there is still a gap in how to use the appropriate tools to tackle the complex and versatile environmental problems facing industries today.

The project DANTES (*D*emonstrate and *A*ssess *N*ew *T*ools for *E*nvironmental *S*ustainability), supported by the EU Life-Environment Program[1], is aimed at turning these challenges into opportunities for industry by demonstrating and evaluating already available tools for environmental assessment and communication, and applying them to decision-making within different parts of the company (e.g. research and development, marketing, supply chain, production and environmental support).

The project was started in 2002 by four partners – Akzo Nobel Surface Chemistry AB, ABB, Stora Enso and Chalmers University of Technology – and will be conducted for three years. Tools, case study results and other findings from the project are continuously disseminated through the project's web site (see www.dantes.info) and through several information campaigns during the project period.

2. View of the problem from different perspectives

Environmental assessment tools such as LCA, LCC, and ERA are effectively applied by industries and research institutions to identify, analyze and evaluate the environmental effects of a product, or an activity, throughout its life cycle. Environmental assessment also allows effective integration of environmental considerations and public concerns into decision-making. Thus, one of the goals of the DANTES project is to assess and demonstrate how these tools can be used in an effective way by industries in different decision-making situations.

LCA, a tool to assess the potential environmental impacts of a product or service throughout its life cycle, and LCC, a tool to calculate the economic costs that arise during the life cycle of a product or service, seem to be very similar from their definitions. However, there are differences in the methodologies, since the tools are designed for different purposes. The purpose of LCA is to find specific stages in the life cycle of a product that contribute significantly to the product's environmental burden and/or to compare the environmental performance of alternative products that have the same function. The purpose of LCC is to compare the cost-effectiveness of alternative investments or business decisions from the perspective of a manufacturing company or a consumer (Norris, 2001). Another assessment tool – ERA – is aimed at identifying and evaluating the adverse effects on ecosystems, animals and people resulting from technology (Fairman *et al.*, 1999).

Despite the active use of environmental assessment tools, they are usually applied in isolation from each other, mainly due to their relative complexity. However, the idea within the DANTES project is to conduct parallel LCA, LCC and ERA studies on the same products. This will provide a more holistic view of the product since environmental, economical and risk aspects are considered.

2.1 LCA and ERA study

One LCA and ERA study on the same product has already been performed within the DANTES project. The aim of the study was to carry out a parallel LCA and ERA on a product produced by Akzo Nobel Surface Chemistry AB. The product – an adhesion promoter used in hot mix for asphalt pavement – is a surface-active substance that extends the life of the asphalt pavement.

The purpose of the LCA study was to determine the quantity of the substance needed to extend the life of the asphalt pavement and at the same time reduce its environmental impact (Ries, 2001). The LCA considered energy use and emissions associated with the extraction of raw materials, production, transportation, and use of the product.

The ERA study was intended to assess the environmental risks posed by the production, formulation, processing, use and disposal of the product. In the study the focus was on the active substance in the product, on the predicted releases into the environment and on possible effects that the substance can cause in different environmental compartments (Berggren, 2002).

The result of the study gave a comprehensive picture of the environmental impacts and risks caused by the adhesion promoter during its life cycle. In the LCA study, the main contributor to the environmental impact was the production of one of the raw materials (see Figure 1). However, ERA showed no risks during production and formulation, but a potential risk during the usage and disposal stages due to abrasion of the asphalt and leaching of the substance to the surroundings of the road (Widheden and Sanne, 2003).

Hence, the studies have presented a view of the product from different perspectives that provide a better understanding of the system and more exact information for a decision-making process.

2.2 LCA and LCC studies

As mentioned previously, LCC is a method for calculating the cost of a product or service encompassing its entire life span, i.e. from extraction of raw material, production, investments, usage and maintenance to end-of-life costs. It should be noted that not only today's costs but also possible future costs should be considered. This can be clearly seen from the following example. The results of the LCA case study – carbon dioxide emissions per kg of product from production of raw materials,

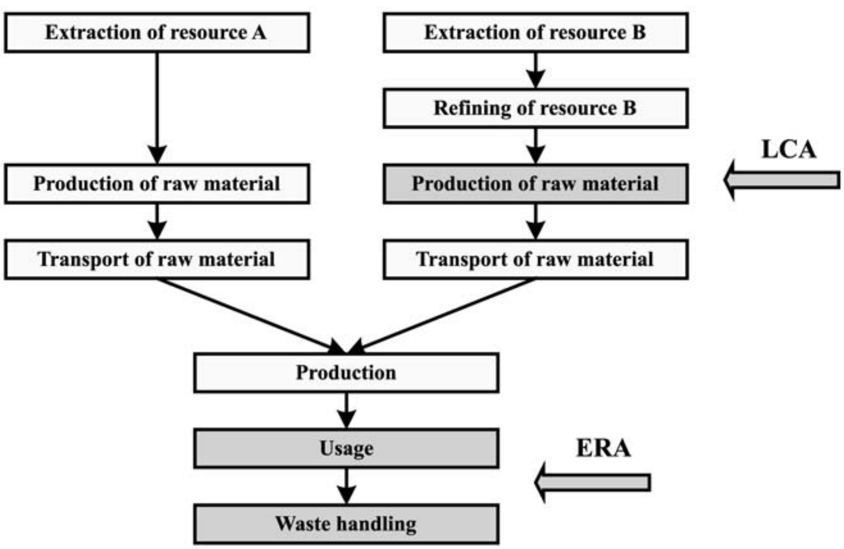

Figure 1.
Environmental impacts and risks caused by the adhesion promoter during its life cycle

transportation, manufacturing and decomposition of the product – are shown in Figure 2. If companies have to start paying environmental taxes for emitting carbon dioxide into the atmosphere not only for energy production but also for the whole life cycle of the product, it is clear from Figure 2 that a problem may arise at the decomposition stage of the product. With the introduction of CO_2 taxes the cost of the product will increase, and someone has to bear that cost. Therefore, a life cycle cost analysis is crucial in helping to identify the "hot-spots" in the product life cycle.

Another example of this type of study, a combination of LCA and LCC analysis, is still in progress. The LCC part of the study considers only environmental costs such as costs for eco-toxicity tests, environmental taxes, permits and costs for personnel working with environmental issues. The aim is to describe the connection between environmental impacts and environmental costs throughout the product life cycle as well as to identify the stages of the product life cycle where environmental costs reach their maximum. One valuable finding from the study is that information on environmental costs is hard to find, and views of what should be included in the concept of environmental costs vary significantly. The results of the study will soon be published on the DANTES web site.

The first experience in performing parallel LCA, LCC and ERA studies has boosted our expectations about the great potential this type of study has to offer in ensuring more sustainable environmental management practices. These studies have shown that the interesting possibilities that parallel LCA, LCC and ERA analyses seem to proffer for industry are still far from exhausted in the realms of research. Hence, we look forward to exploring and creating more possibilities during the DANTES project.

3. Need for more simplified tools

The use of LCA, LCC and ERA methodologies is not very widespread within industry, mainly due to their complexity. Also, not all companies are familiar with Environmental Product Declarations (EPD), a tool that presents quantified environmental data for products or systems based on information from a LCA

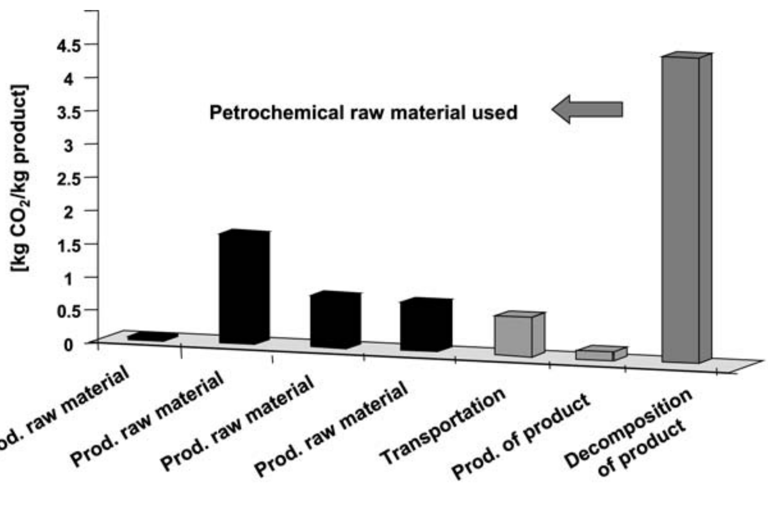

Figure 2.
Carbon dioxide emissions from the whole life cycle of a product

conducted according to ISO Standards. According to the experience of ABB, the large cost of developing EPDs is one of the barriers for its efficient implementation. The major part of the cost comes from the LCA study. Another barrier is the need for a relatively high level of environmental competence among personnel that companies often lack today (Karlson and Imrell, 2003).

The common opinion about environmental assessment and communication tools and their use by companies is that the tools are very complex and a lot of time and resources are needed to perform the analyses. Moreover, education is also a crucial component in implementing and working with the tools. The person working with the environmental assessment and communication tools should not only have knowledge of the methodology, but should also know how to use the results in order to communicate the environmental information to internal and external stakeholders.

Hence, the development of easy-to-use environmental assessment and communication tools may be necessary. The first attempt was made by ABB when the company developed the LCALight and LCCLight tools in order to educate more people in environmental issues and simplify environmental work within the company.

LCALight is a web-based LCA tool that can be used to perform easy and adequate environmental impact calculations. It allows the calculation of environmental impact from the use of raw materials, energy and transportation. LCALight is well suited to self-learning, and can be used to learn about LCA methodology.

LCCLight allows a user to enter cost data for different life cycle phases of the product and evaluate the impact on the total cost. The tool is very wide-ranging; it gives the user the possibility to compare the total cost of different alternatives, the effect of different maintenance strategies, including the cost of failures, breakdown and replacement, etc.

The tools and more information about them can be found on the project's web site (see www.dantes.info/Sustanabillitytools/Software/enviro_soft.html).

It should be noted that there are some important issues to consider when using simplified information-handling tools. Firstly, each tool requires a well-defined, explicitly stated scope. Secondly, a considerable number of simplifications and assumptions are made during the development of easy-to-use information-handling tools. Thus, the user needs to be aware of them to interpret and use the results in the correct way.

Information-handling tools often use default values to decrease the amount of data that has to be entered by the users. Therefore, it is important that the default data is well documented and easy to update. Data quality and transparency are also essential aspects that need to be considered.

4. Strategies for using environmental methods and tools

Nowadays, efficient handling and communication of environmental information by a company can provide a number of economic advantages as well as assist in building credibility among internal and external stakeholders. Environmental information can be used internally to monitor and control environmental performance and externally to communicate the company's environmental performance. The internal stakeholders in need of this information are employees working in product and process development, production process monitoring, purchasing of raw materials, marketing and environmental controlling (Svending, 2003). External stakeholders may include customers, competitors, suppliers, communities, shareholders, authorities, unions, media, social and political groups, and trade and industry associations.

As mentioned previously, the goal of the DANTES project is to demonstrate how and when to use different methods and tools in order to facilitate handling and communication of environmental information, and give guidelines on how to use these tools for different types of company functions (e.g. research and development, production, supply chain, marketing and environmental support). The use of environmental tools in different parts of the company is described below.

4.1 Research and development

Strategies for eco-efficiency evaluation in research and development should ensure the integration of sustainability objectives into product and process development. Tools such as environmental risk assessment (ERA) and life cycle assessment (LCA) can be used for this purpose. These tools can be complemented by the stage gate model, design for environment (DfE) and design for recycling (DfR), as described below (Svending, 2003).

A common purpose of the stage gate model is to provide a framework for better management of product development projects. Many different variants of gate models can be found in companies, but they are basically designed in the same way and based on the same principles.

In the stage gate model, in order to proceed from one stage to the next, a gate has to be passed. This is done during a gate review meeting. The criteria to work with on the gate review are selected so that important aspects such as market and financial attractiveness, technical feasibility, HSE (health, safety, and environment) and regulatory as well as supply options are considered at all stages from the beginning of the project to the end. If the project runs into serious problems the gates can be used to revise the scope and planning, or to stop the project. The model is also used to predict the release date, and to confirm that the product is ready for release.

Tools such as design for environment (DfE), a systematic way of incorporating environmental considerations into the design of a product or process, and design for recycling (DfR), a process for designing and manufacturing goods in a way to enable safe and efficient recycling, offer new perspectives with product and business focus. They can be powerful tools to make the company more competitive and more innovative, as well as more environmentally responsible.

4.2 Production

In order to have environmentally sound production processes as well as to fulfill other sustainability demands, companies very often implement environmental management systems (EMS). EMSs are commonly based on ISO Standards and/or the voluntary European Environmental Management Auditing Scheme (EMAS).

EMS is used to control the environmental performance of the company. The controlling process is a repeating loop of measuring actual company performance, comparing it with defined standards and taking managerial actions. The main reason to measure the environmental performance is the desire of the company to achieve its objectives and targets in consistency with its policy. Other reasons may include comparing indicators over time in order to see trends, empowering environmental policy by monitoring environmental objectives, and allowing benchmarking between companies (Svending, 2003).

Environmental performance indicators (EPI) are another tool that can be used to evaluate an organization's environmental performance. EPIs may help in identifying the most significant environmental impact and also to clarify and communicate the company's environmental goals and progress to employees and stakeholders. The choice of EPIs depends on their intended use, the organization's environmental policy, and data accessibility.

4.3 Supply chain

A supply chain strategy should consider all goods, services and transports purchased from internal and external suppliers. Evaluating suppliers' fulfillment of sustainability demands is a main component of a supply chain strategy. Thus, suppliers are usually asked to provide companies with environmental information on the products they deliver. The requested data typically comprise life cycle assessment information on specific products (Svending, 2003).

4.4 Marketing

A marketing strategy should ensure the communication of the environmental performance of the company to customers and other stakeholders. Well implemented actions can lead to an improved company image and provide products with additional market potential.

Product information material, environmental labeling, environmental product declarations (EPD), sustainability performance indicators (SPI), safety data sheets (SDS), and environmental and sustainability reports are all tools that can be used as components in building a marketing strategy for a company's products or services.

4.5 Environmental support

The role of environmental support is to help different parts of the company make improvements to their environmental performance. Areas where environmental support may be needed are:

- different organizational procedures, such as implementation and maintenance of an environmental management system;
- environmental assessment studies, which may include life cycle assessment, life cycle cost analysis, and environmental risk assessment;
- collection and analysis of environmental data;
- participation in product and process development processes;
- internal or external communication, which may include preparation of environmental product declarations, environmental and sustainability reports, sustainability performance indicators;
- internal audit of manufacturing sites and monitoring, correction and auditing of environmental management system; and
- environmental training of personnel.

Strategies for using environmental methods and tools will be further developed during the DANTES project. However, one example of a supply chain strategy for carrying out transportation studies is described below.

4.6 Strategies for carrying out transportation study

In order for a company to comply with environmental requirements and show concern and commitment in the field of transportation, information about environmental impacts from transportation of raw materials and products may be necessary. The question is which methods and tools can be used to evaluate the environmental impact from the transportation and how to perform such a study? A working method for carrying out transportation studies (see Figure 3), developed on the basis of a project conducted by Akzo Nobel Surface Chemistry, Cellulosic Specialties in Örnsköldsvik, Sweden (Bogeskär, 2002) is described below.

4.6.1. Interested parties. Parties interested in environmental information on transportation activities are authorities, company management, customers and various NGOs. If a company gets a request for such information, it may consider carrying out a study including the stages described below.

4.6.2. Description of the task. First, the problem is defined and tasks are set. In the case of transportation study, the problem is to identify and minimize impacts from the transport of raw materials and products to and from the company.

4.6.3. Description of the working procedure. This includes scope definition, limitations of the study, preparation of a questionnaire for transport companies, and a survey. When answers from transport companies are collected, the next step is to document and analyze the information received (e.g. tonnage, distances, means of transportation, etc.). Moreover, the data on energy use and emissions from different means of transportation also need to be collected in order to calculate total emissions and energy use for transport of raw materials and goods. Environmental performance indicators (EPI) (see Manuilova, 2003) can also be prepared, if needed.

4.6.4. Methods and tools used to fulfill the task. Methods and tools that can be useful in this work are a life cycle assessment tool, questionnaires, environmental data on energy consumption and emissions from different types of transportation means that

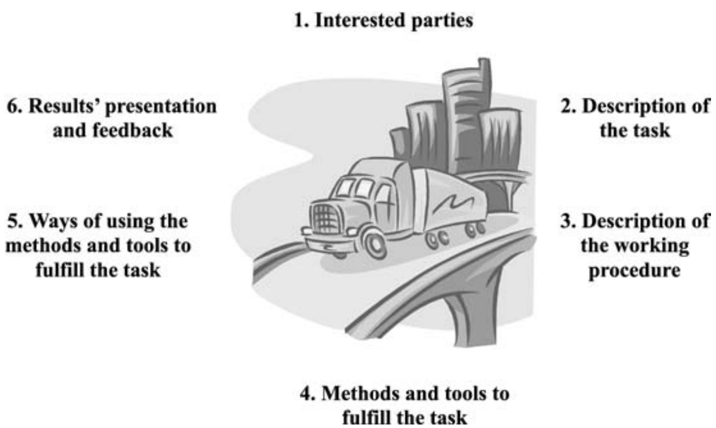

Figure 3.
Strategies for carrying out transportation studies – main stages

can be found at the Network for Transport and the Environment (NTM) web site (see www.ntm.a.se/).

4.6.5. Ways of using the methods and tools to fulfill the task. Questionnaires for transport companies proved to be a good way of collecting information that can be then documented, for example, in Microsoft Excel. The NTM web site may be used to find data on energy use and emissions from different means of transportation. A life cycle assessment tool, for example EcoLab, is then applied to assess the environmental impact from transportation. More information about the LCA methodology and LCA tools can be found at the DANTES project's web site (see www.dantes.info). The web site also provides information on EPIs for transportation.

4.6.6. Presentation of results and feedback. The results from the study are usually presented in a form of written report. A separate report on EPIs can also be prepared.

The detailed procedure and more information about the study can be found on the project's web site (see www.dantes.info/Strategies/strategies.html).

5. Conclusions

As the name implies, DANTES (Demonstrate and Assess New Tools for Environmental Sustainability) was contrived to educate industries how to use sustainability tools to address environmental problems. These tools are life cycle assessment (LCA), life cycle costing (LCC), environmental risk assessment (ERA), Environmental Product Declarations (EPD) and environmental performance indicators (EPI).

The overall goal of the project is to bridge the gap in knowledge of existing sustainability tools, as well as their large-scale applications in companies. The results from the project will be translated into strategies for eco-efficiency evaluation based on existing tools.

The DANTES project will be completed by the end of August 2005. Until then, a number of cases studies and other various projects will be conducted so as to fulfill the goals of the project. The web site (see www.dantes.info) will be continuously updated with new content so that users can gain valuable access to the results and tools used in the development, implementation and follow-up of companies' sustainability strategies. The following information can be found at the web site:

- examples of LCA, life cycle inventory (LCI), LCC and transport calculation software tools;
- examples of LCI and toxicological databases;
- guidelines for using these tools within different parts of the company (e.g. research and development, production, supply chain, marketing and environmental support);
- results of case studies carried out during the project; and
- other reports and findings as well as environmental education materials.

The project has very bright prospects, as it will help to educate participating companies to grow and develop "greener" products, as well as environmental consciousness. It will also disseminate information to other associates in Europe and elsewhere. DANTES will support companies with tools and competence in line with product-related policy, which is one of the driving forces behind new business idea. Hence, the results from the project will support companies in both environmental and product development issues in a cost-efficient way.

Note

1. Information about the EU Life-Environment Program can be found at http://europa.eu.int/comm/environment/life/home.htm

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Eco-efficiency: inside BASF and beyond

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Abstract

Purpose – Aims to demonstrate how BASF's eco-efficiency can be used for sustainable decision making at all levels, from industrial to consumer.

Design/methodology/approach – Three case studies are described as examples of the potential applications of eco-efficiency both within industry and extensively in the consumer sector.

Findings – The first case study describes its use for dyeing facilities in Morocco, the second demonstrates how the most eco-efficient product transport modes can be selected, and the third shows how eco-efficiency can help the consumer decide whether to purchase a new household appliance.

Originality/value – Eco-efficiency can support sustainable decision making not only within the company, but also industry-wide and beyond.

Keywords Ecology, Resource efficiency, Textiles, Transportation, Household products

Paper type Case study

Introduction

BASF, the world's leading chemical company, had sales of approximately $42 billion in 2003 and over 87,000 employees worldwide. BASF's product portfolio ranges from chemicals, plastics, performance products, agricultural products and fine chemicals to crude oil and natural gas. A guiding principle within BASF is ensuring sustainable development. This means pursuing economic success, environmental protection and social responsibility. Thereby future generations will benefit from the way business is conducted in the present.

Eco-efficiency is one of BASF's strategic tools to ensure sustainable development. Eco-efficiency assesses the environmental and economic impact of products and processes over their entire life cycle. The tool has been used within BASF as well as in cooperation with external parties such as governmental agencies and customers. Its application, development and use are based on the philosophy that sustainable products and processes are key to responsible business acumen and future success.

For a tool to be applied effectively, flexibility and user-friendliness are essential. Eco-efficiency starts with a "base case" which includes certain input data for the production, use, and disposal of the product or process being assessed. The analysis is then expanded to include "scenarios", for which the input data are varied in order to determine the effect on the study results.

The eco-efficiency manager is a software program that enables the end user to easily manipulate the input data in order to assess the environmental and economic impacts of their decisions. These variables could reflect current or potential scenarios, such as different production methods using the same raw material, different raw materials, or different cost structures.

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Three case studies are presented:

(1) An eco-efficiency manager for a textile dye works in Morocco.
(2) An Eco-Logistix manager for transportation logistics decision making.
(3) An eco-efficiency on refrigerators with potential application in the consumer sector.

Eco-efficiency: the methodology

BASF's eco-efficiency methodology was developed in 1996, and to date over 220 analyses have been completed. It is based on the principles of ISO 14040, with additional enhancements that allow the results to be used as a concise decision-making tool (Saling *et al.*, 2002).

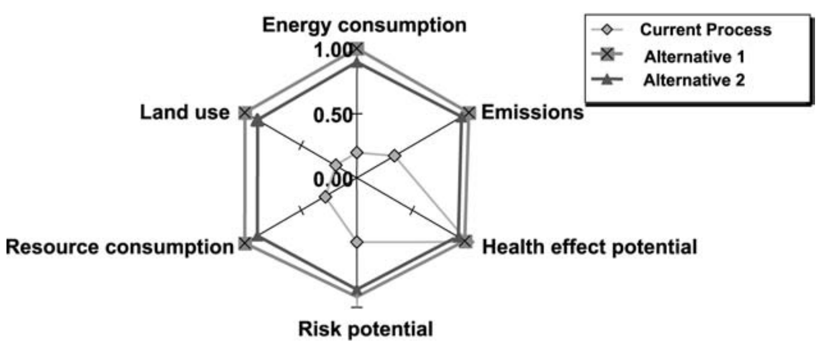
Six environmental categories are evaluated:

(1) Raw materials consumption.
(2) Energy consumption.
(3) Land use.
(4) Air, water and solid waste emissions.
(5) Toxic potential of the substances employed and released.
(6) Potential for misuse and risk potential.

Life-cycle data are compiled for each of these categories, a weighting scheme is used to aggregate the results, and they are normalized in order to generate the "ecological fingerprint" (see Figure 1). The best alternative lies towards the center of the fingerprint. This clearly depicts the relative impacts of the alternatives in each of the environmental categories.

To address the economic aspects of sustainability, cost data for the life cycle of the product is gathered. This includes but is not limited to costs for production, transport, maintenance, labor, etc. In this way the economic impacts and viability of the alternatives are evaluated.

The final output of the eco-efficiency tool is the portfolio, which depicts the environmental and economic impacts on one graph (see Figure 2). The portfolio



Note: 1.0 = worst position, better results ordered relatively <1

Figure 1.
Ecological fingerprint

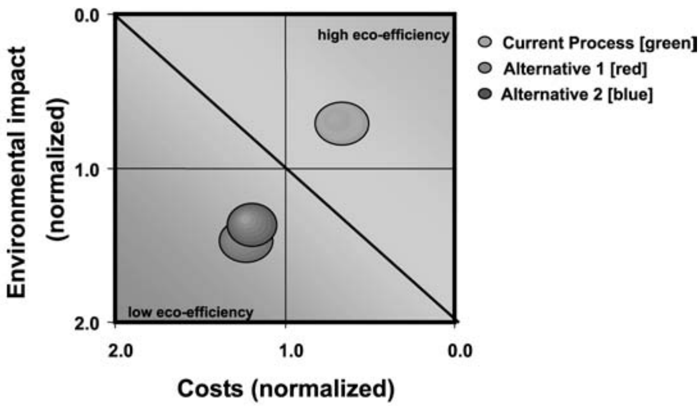


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Figure 2.
Eco-efficiency portfolio

concisely demonstrates the relative eco-efficiency of the different alternatives, so that decision-makers can quickly assess the results. The fingerprint and supporting data are then available for a more detailed view.

Case study 1: textile dye works

The eco-efficiency manager for textile dye works in Morocco was developed by BASF for the United Nations Environmental Protection and United Nations Industrial Development Organization (UNEP/UNIDO) National Cleaner Production Center (NCPC) in Morocco. The goal was to provide a tool to support sustainable development in emerging markets for use by developing industries.

Eco-efficiency was used to assess various dyeing processes and products. The system boundaries used are depicted in Figure 3.

Production of process utilities, such as water, steam and electricity, and dyes and auxiliaries was first considered. Next, processing steps, including pre-treatment, dyeing and finishing of the fabric were evaluated. Finally, air, water and solid wastes and their disposal were analyzed. These results were then combined with a

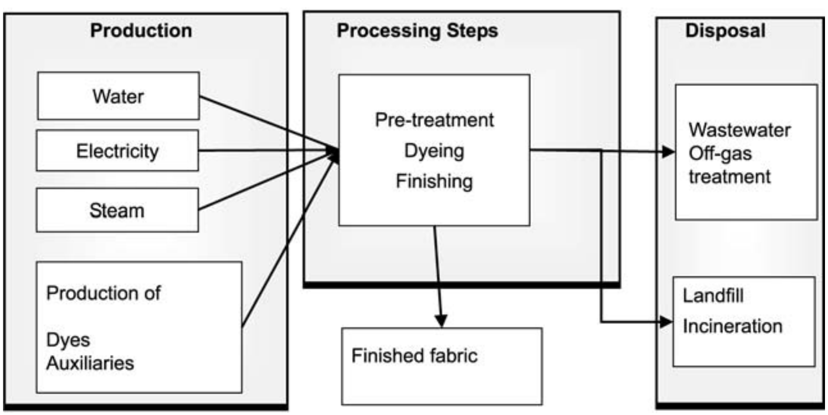


Figure 3.
System boundaries for textile dye works

cost-analysis tool which included raw material and equipment prices. Thus the eco-efficiency of various alternatives could be determined.

The eco-efficiency results were then assembled in an eco-efficiency manager. This is a software tool which allows the user to specify input variables such as:

- fabric quantity, number of processing steps, and processing time;
- chemicals used;
- utility consumptions;
- process emissions; and
- costs.

The output of the software includes a portfolio and ecological fingerprint comparing the various alternatives, and detailed comparisons for emissions, energy and raw material consumption, land use, toxicity and risk potential.

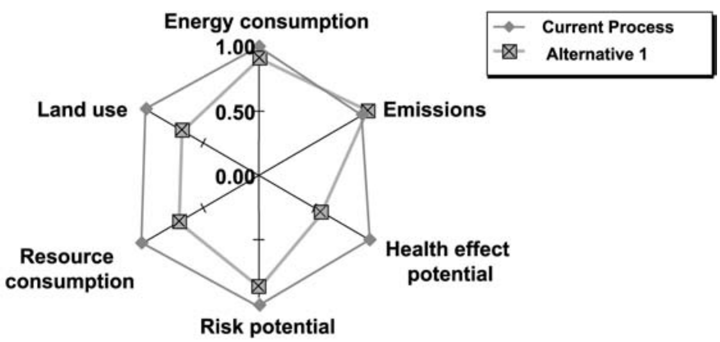
Figures 4 and 5 show the fingerprint and portfolio for pre-treatment, dyeing and after-treatment for yarn or fabric, using two different chemicals. The current process uses a chemical with a less expensive initial cost, and upon first glance would appear to be the best alternative. However, once the overall environmental and cost impacts of both processes are considered, Alternative 1 results in less environmental impact for the same total cost. This example demonstrates how the eco-efficiency manager can be used to determine the most eco-efficient alternative, and present the results in a concise format that can be used by decision-makers.

The NCPC and BASF Morocco were trained in the use of this tool, to enable them to provide it as a consulting service for dye houses. Upon completion of the pilot project in Morocco, UNIDO anticipates initiating similar programs in all 23 of its NCPCs.

Case study 2: logistics eco-efficiency manager

Every business must consider transportation of goods, and often the question is asked: what is the best mode of transportation? BASF developed an internal tool to enable our businesses to make sound decisions, both environmentally and economically.

An eco-efficiency analysis was conducted which considered various transportation alternatives. The results were transformed into an eco-efficiency manager, which can be used to determine the best alternatives. The input variables specified include:



Note: 1.0 = worst position, better results ordered relatively <1

Figure 4.
Ecological fingerprint of textile dye works

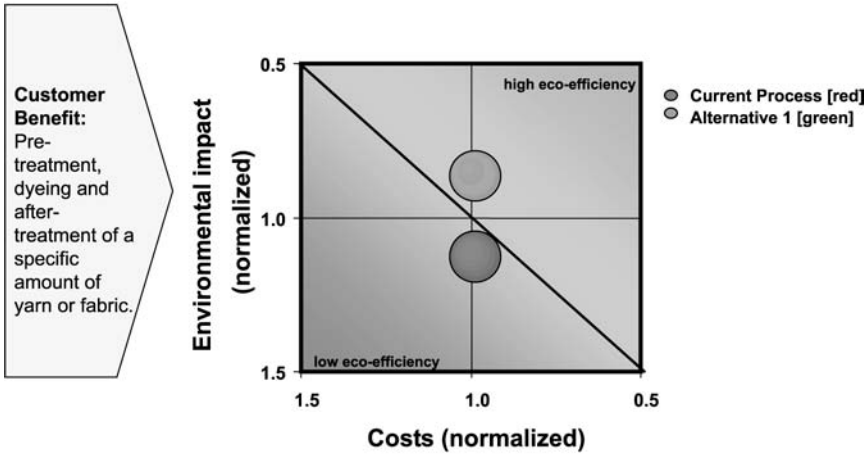


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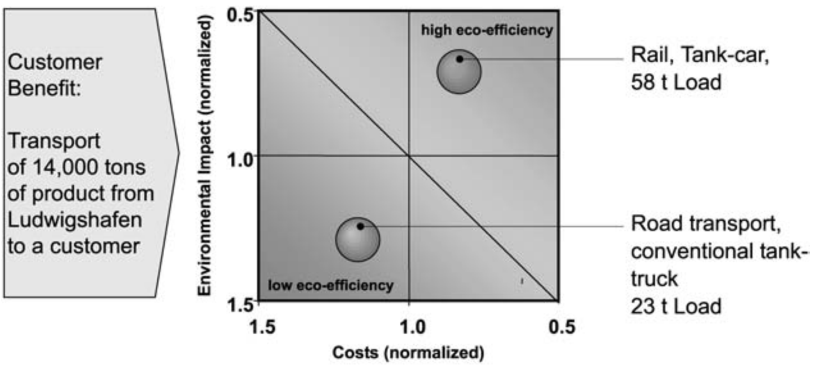
Figure 5.
Eco-efficiency portfolio textile dye works

- payload;
- chemical hazard class;
- shipping fees;
- distances for land and/or sea;
- number of transfers; and
- open/closed filling systems.

Similar to Case Study 1, the output includes a portfolio, an ecological fingerprint and detailed comparisons of the various environmental impact categories. In addition, carbon dioxide savings potential is highlighted.

Figure 6 shows an example of the use of the Eco-Logistix software. A total of 14,000 metric tons of material were to be shipped from a production location to another site in



Note: The original of this diagram is coloured

Figure 6.
Eco-efficiency portfolio for logistics manager

Europe. Shipping via rail and truck were compared, with payloads and distances of 58 tons for 755 km and 23 tons for 698 km, respectively.

Eco-Logistix showed that transport via rail was significantly better both environmentally and economically than transport via truck. This demonstrates how the tool can be used both by customers and internally when making decisions with regards to material movement.

Case study 3: refrigerators for household use

Consumers are often faced with the decision whether they should replace an appliance. Initially one might assume that continued operation of an existing appliance is environmentally and economically preferable to purchasing new, since it avoids the purchase and production of a new appliance and the disposal of the old. In an effort to quantify these options, an eco-efficiency analysis was done by BASF, commissioned by the German Green Party and the Wuppertal Institute. Figure 7 depicts the alternatives analyzed.

The use of a 143-liter capacity refrigerator over five years is considered. Production, use and disposal of the appliances and the associated costs are included. Two alternatives are compared:

(1) Continued use of a ten-year-old refrigerator with 260 or 330 kWh/year average consumptions.

(2) Purchase and production of a new high- or medium-efficiency refrigerator and disposal of the old one.

Figure 8 shows the resultant portfolio, which demonstrates that consumers who own a lower-efficiency old refrigerator (Old 2) can significantly reduce environmental impacts at only slightly higher costs by purchasing a new refrigerator (New B or New A). Additionally, the old appliance with lower energy consumption (Old 1) is the most eco-efficient, and in order to achieve significant environmental benefits the consumer would need to purchase a new high-efficiency refrigerator (New A), but would incur some cost. Finally, the new refrigerator with the lowest energy consumption (New A) provides the greatest environmental benefits at the same total cost as the new refrigerator with higher energy consumption (New B).

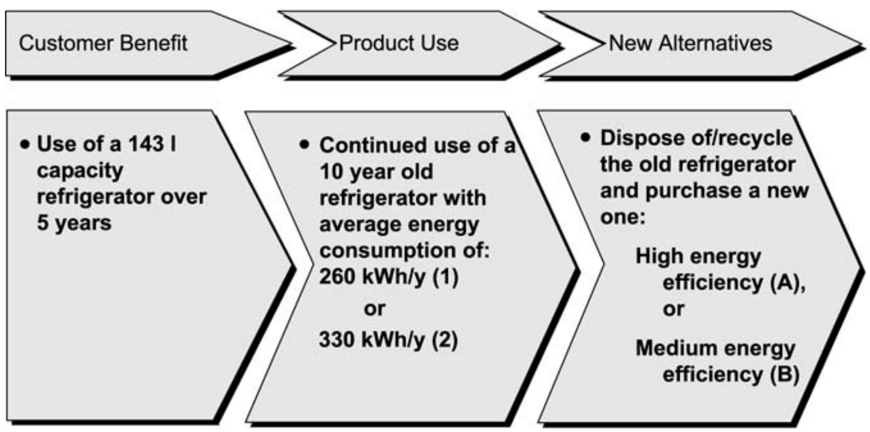


Figure 7.
Refrigerators for household use

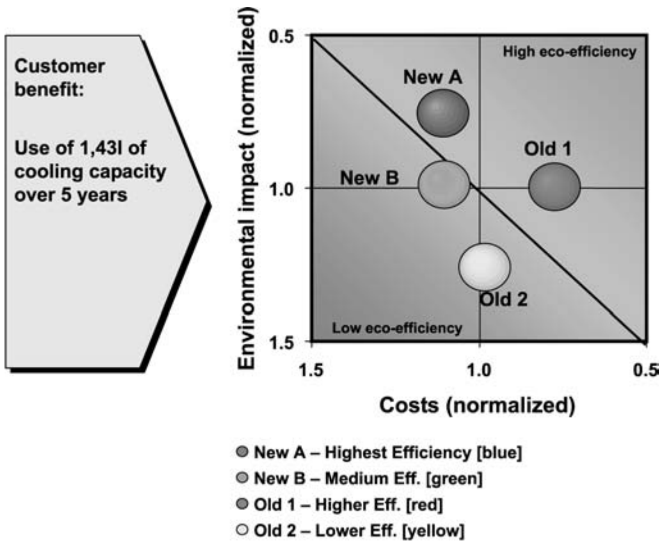


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Figure 8. Eco-efficiency portfolio for refrigerators

This demonstrates another case where eco-efficiency can be used as a practical decision-making tool to determine the most sustainable alternative, at a consumer level.

Conclusions

BASF is committed to sustainability, both within the company and beyond. In support of this, we have developed an analysis method for products and processes, as well as a user-friendly interface to make this method more accessible to customers and other external parties. These three case studies demonstrate how BASF's eco-efficiency can be used for sustainable decision-making at all levels, from industrial to consumer. We offer our customers workshops, courses and joint projects in support of this. Thereby eco-efficiency can support sustainable decision-making not only within the company, but industry-wide and beyond.

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Eco-intensity analysis as sustainability indicators related to energy and material flow

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Abstract

Purpose – Aims to use simple ratios as sustainability indicators to evaluate the environmental intensity in local regions and industrial sectors. These ratios could be compared across regions and industrial sectors to give a comprehensive evaluation of sustainability.

Design/methodology/approach – A total of 16 industrial categories (agriculture, mining, food, fiber, pulp, chemical, coal and petrol, cement, steel, metal, non-ferrous metals, construction, energy supply, transport, service, and commercial) were considered, using data from the national physical distribution census, the national and prefectural input-output tables, and the comprehensive energy statistics for Japan in 1995. The objective environmental load items were carbon dioxide, nitric oxide, sulfuric oxide, and suspended particulate matter emissions.

Findings – The regions included all 47 Japanese prefectures and the data for each prefecture considered 16 industrial categories based on the national physical distribution census and national input-output tables for 1995. The ratio of the primary energy supply to the total material input for service industries ranged from 0.1 to 0.5 TOE/10^3 ton for the 47 prefectures.

Research limitations/implications – Not all the variations in these sustainability indicators have yet been examined and there are probably other complicated relationships between sustainability and regional or industrial characteristics. More effort needs to be put into estimating eco-efficiency or eco-intensity, considering recycled energy or material utilization in order to develop a practical method of evaluating regional or industrial sustainability.

Practical implications – Several life cycle approaches used to quantify environmental efficiency related to energy and material flows were investigated as applications of life cycle tools in emerging markets, including the service industry and public sector.

Originality/value – The novelty of the investigation lies in analyzing detailed energy flow characteristics and in combining energy flow and material flow. Another objective of this paper is to present a current case-study experience in one type of eco-intensity analysis for Japanese service industries.

Keywords Ecology, Energy management, Materials management, Japan

Paper type Research paper

Introduction

In order to develop a sustainable society, an indicator that relates our understanding of the present state of urban metabolism to social activity is required. Studies have investigated the amount of material required based on social activity, e.g. material flow accounting (Adriaanse *et al.*, 1997), and have included a macroscopic analysis of specific categories of material distributed among industries in Japan. Toward a future

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sustainable society, we must consider a kind of "trilemma" of resources involving energy, the environment, and the economy. Sustainability indicators should ensure improved eco-efficiency, which means reduced eco-intensity. Using such sustainability indicators, we can promote regional or industrial transformation. Recent uses of sustainability indicators have been already reported for several local regions and industrial sectors. Quantitative indicators of the physical/biological aspect of sustainability could be applied to an agricultural county, using energy, water, soil, and nitrogen as numeraires (Herendeen and Wildermuth, 2002). We present some eco-intensity evaluation methods as potential sustainability indicators for effective environmental management. The novelty of our investigation lies in analyzing detailed energy flow characteristics and in combining energy flow and material flow. Another objective of this paper is to present a current case-study experience in one type of eco-intensity analysis for Japanese service industries.

Eco-intensities in viewing energy and material flows

A local city council project aimed to construct material and energy flow analysis models producing an integrated approach to improving overall sustainability (Krishnamohan *et al.*, 2000). Their analysis highlighted the ultimate fate of inputs, products/services and wastes, and showed that help in minimization of resource consumption and/or development of potential synergies between organizations was crucial in terms of resource exchange. Also, a first step was made in bridging the gap between the various types of analysis of material flows in the economy (Bouman *et al.*, 2000), by discussing the main differences and similarities of three often employed model types:

(1) Substance flow analysis.

(2) Life cycle assessment.

(3) Partial economic equilibrium analysis.

Consider a kind of "trilemma" involving the environment, energy, and the economy. The following simple equation, i.e. equation (1), shows a way to identify one type of eco-intensity related to energy and material flows:

$$L_i = \frac{L_i}{E_i} \times \frac{E_i}{M_i} \times \frac{M_i}{P_i} \times P_i.$$

In this equation, L_i is the environmental load emission (e.g. carbon dioxide emission), E_i is the energy consumption or primary energy supply, M_i is the total material input or requirement, and P_i is the gross domestic product or amount of industrial product. Since the eco-intensity should be inversely proportional to the eco-efficiency, any reduction in carbon dioxide emissions with economic growth requires remarkable reductions in three ratios: CO_2/energy, energy/flow, and flow/GDP. These are potential sustainability indicators.

Data and methods

We considered 16 industrial categories (agriculture, mining, food, fiber, pulp, chemical, coal and petrol, cement, steel, metal, non-ferrous metals, construction, energy supply, transport, service, and commercial) using data from the national physical distribution census (Transport Economy Research Center, 1997), the national and prefectural input-output tables (Japan Statistical Association, 1997), and the comprehensive energy statistics (Agency for Natural Resources and Energy, 1997) for Japan in 1995. The objective environmental load items were carbon dioxide, nitric oxide, sulfuric oxide, and suspended particulate matter emissions. Data on these life-cycle environmental emissions are available in the embodied energy and emission intensity database (Nansai *et al.*, 2000) uploaded by the National Institute for Environmental Studies in Japan. The regions studied were all 47 Japanese prefectures. The average population of a prefecture is about three million and the average area is about 8,000 square kilometers. The major market area is the central zone, which covers about 600 kilometers between Tokyo and Osaka. The prefecture farthest from Tokyo is Okinawa, which is over 2,000 kilometers away.

Figure 1 is a simple outline of the analysis that we used to evaluate regional and industrial eco-efficiency or eco-intensity related to energy and material flow. First, we estimated the primary energy input and material input for each industrial sector in each region. Energy demand consists of the net energy use and energy lost considering generation efficiency and transmission loss. Energy supply consists of the primary energy input and recycled energy recovered. Then, we analyzed relationships between these estimated values to evaluate eco-intensity as sustainability indicators for a region or industry.

The ratio of the environmental load to energy flow as a measure of industrial eco-intensity

Figure 2 shows the ratio of carbon dioxide emissions to the primary energy input for each industry. These ratios represent the industrial eco-intensity for the entire country. The cement industry has the greatest impact because of the large limestone consumption. Construction also has a major impact because of the ripple effect. For the ratio of nitric oxide emissions to primary energy input (see Figure 3), agriculture and transportation have the greatest effect because of the large amounts of direct emissions via several routes. The ratio of sulfuric oxide and suspended particulate matter to primary energy input showed similar tendencies.

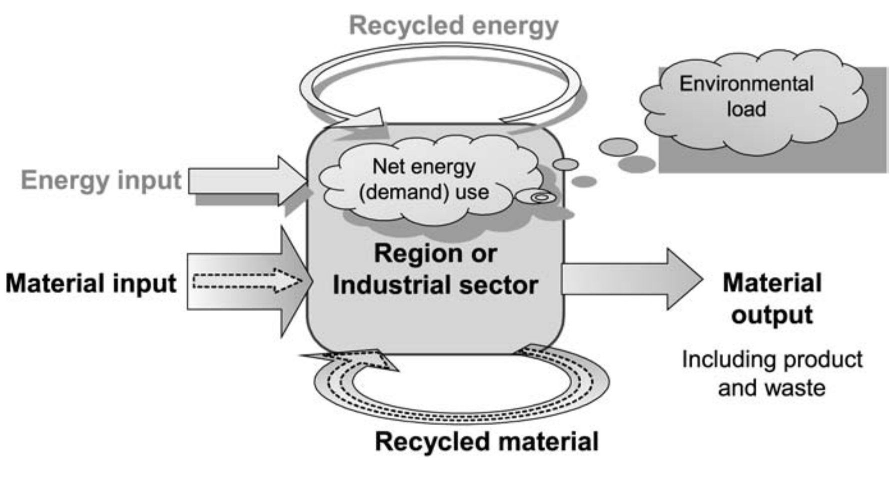

Figure 1.
A simple outline of the analysis used to evaluate regional and industrial eco-efficiency or eco-intensity

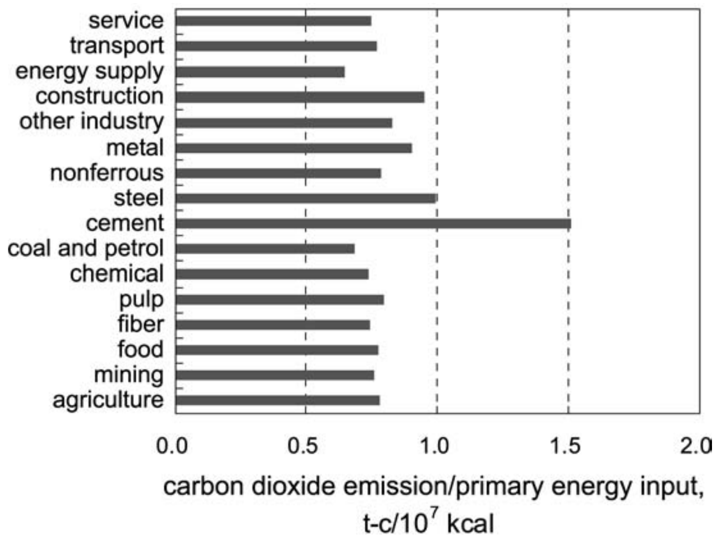

Figure 2. Ratio of carbon dioxide emissions to primary energy input for each industry

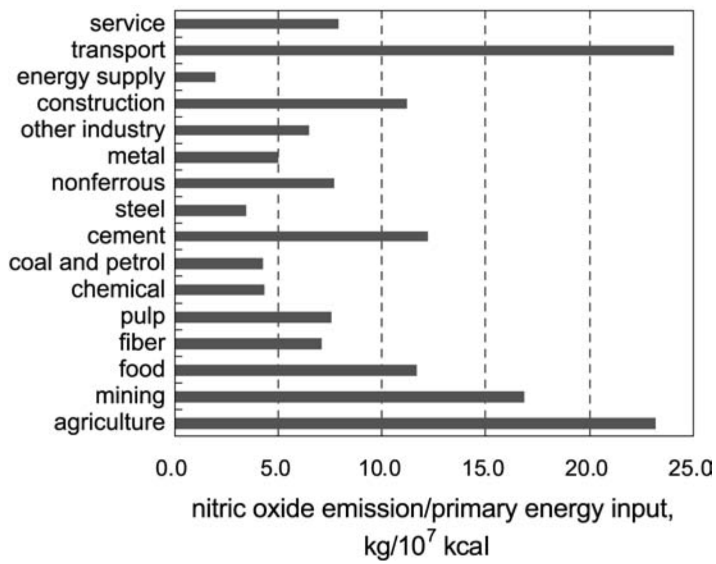

Figure 3. Ratio of nitric oxide emissions to primary energy input for each industry

The ratio of energy flow to material flow for the service industry as a measure of the regional eco-intensity

In some cases, the ratio of the energy flow to material flow was investigated as another possible way to evaluate the eco-intensity. This type of indicator is derived by converting mass units into thermal units. We investigated several such combinations, where the energy flow data were estimated as life-cycle values and the material flow data were estimated as direct material input or output without hidden flow.

The ratio of the primary energy input to the total material input varied significantly between industrial sectors. Focusing on the regional variation in this intensity for the service industry, Figure 4 shows the relationship between the ratio of the primary energy input to the total material input of the service industry and the population of each prefecture. In different prefectures, this ratio ranged from 0.1 to 0.5. The units of this ratio are the ton oil equivalent (TOE) energy per mass kiloton. This relationship suggests an optimal population size from the perspective of the eco-intensity of the service industry. Figure 5 implies that another relationship gives the optimal economic potential from the perspective of eco-intensity for the service industry. Here, the GDP is the gross domestic product of each prefecture. In this way, several interesting relationships between eco-intensity and regional characteristics, such as the regional population or regional economic potential, were obtained.

The ratio of net energy use to product output also varied significantly between industrial sectors. We compared the regional variation in this intensity for the service and chemical industries. Figure 6 shows the relationship between the ratio of net energy use to product output for the service industry and the distance each prefecture is from Tokyo, which reflects the location of the region with respect to the major market. The ratio of net energy use to product output for the service industry in each prefecture ranged from 0.2 to 1.4. There was an interesting relationship between this ratio and the distance from the major market. This relationship was positive for some industrial sectors and negative for others. Focusing on the service industry, this relationship suggests that the distance from the major market has a negative effect on eco-efficiency. By contrast (see Figure 7), in the chemical industry, this relationship suggests that the distance reduces the eco-intensity or improves the eco-efficiency. This difference might result from differences in site location or the supply chain system for those two industrial categories.

Conclusions

The authors used simple ratios as sustainability indicators to evaluate the environmental intensity in local regions and industrial sectors. These ratios could be compared across regions and industrial sectors to give a comprehensive evaluation

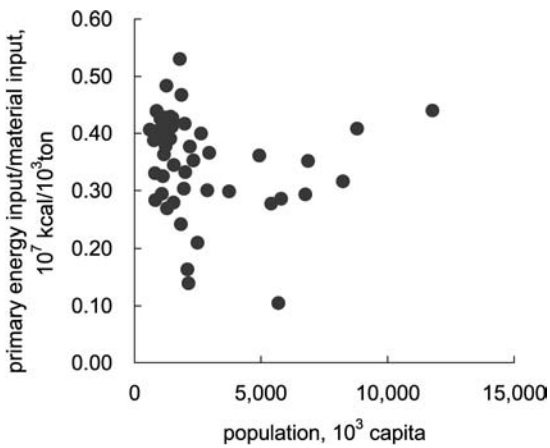

Figure 4.
Relationship between the ratio of primary energy input to the total material input of the service industry and population of each prefecture

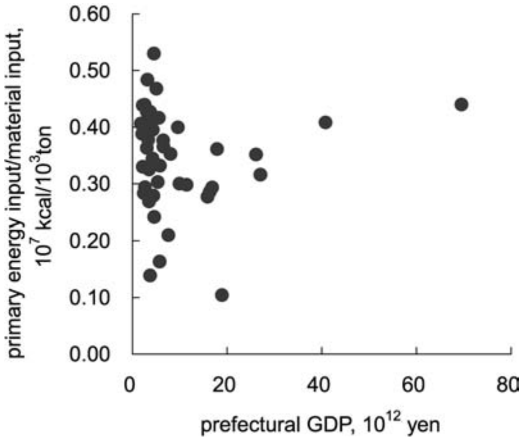

Figure 5.
Relationship between the ratio of primary energy input to the total material input of the service industry and the GDP of each prefecture

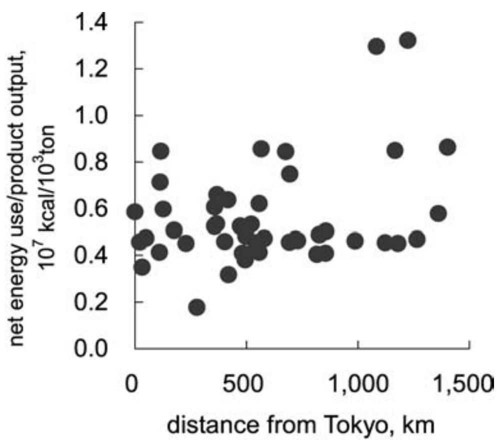

Figure 6.
Relationship between the ratio of net energy use to product output for the service industry and the distance of each prefecture from Tokyo

of sustainability. Several relationships between the ratio of primary energy input to total material input and regional or industrial characteristics were obtained, and these suggested an optimal population size or economic growth potential. Relationships between the ratio of net energy use to product output and regional or industrial characteristics were also obtained, such as the distance from major markets.

However, we have not yet examined all the variation in these sustainability indicators and there are probably other complicated relationships between sustainability and regional or industrial characteristics. We need to put more effort into estimating eco-efficiency or eco-intensity considering recycled energy or material utilization in order to develop a practical method of evaluating regional or industrial sustainability.

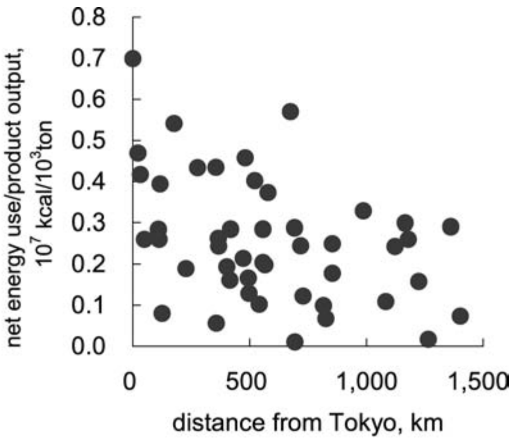

Figure 7.
Relationship between the ratio of net energy use to product output for the chemical industry and the distance from Tokyo for each prefecture

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The contribution of life cycle assessment to global sustainability reporting of organizations

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Abstract

Purpose – Aims to investigate the contribution of life cycle assessment to global sustainability reporting of organizations.

Design/methodology/approach – Assesses the current state of global sustainability reporting and points out future trends of reporting within the three dimensions of economy, environment and society.

Findings – The internal and external communication of the corporate performance is a very important company way to sustainable development. The communication of the corporate performance comprises the strategic and operational goals, the corporate performance data on inventory level, the translation of the inventory data to sustainability core indicators as well as the performance evaluation in terms of sustainability. The future trends on policy level and in customer demands are moving towards a product-related consideration of sustainability issues, the inclusion of indirect effects over the life cycle in addition to the site-related effects of companies' activities, the analysis of results on impact level as well as the automation of data administration.

Originality/value – The methodology of life cycle assessment (LCA) provides the main starting-point for global sustainability reporting including the emerging future trends in this context. This paper shows that results of impact assessments as central parts of an LCA are a good basis for creating significant indicators for sustainability reports.

Keywords Life cycle costs, Sustainable development, Reports

Paper type Conceptual paper

1. Status quo of global sustainability reporting

1.1 From the vision of sustainability to global reporting

Today's companies have to find a way between focusing on profit on the one hand and also concentrating on other issues like social concerns or environmental issues. This sustainable approach leads to an integrative corporate policy that, in addition to economic aspects, also considers social and environmental concerns. According to Brundtland (World Commission on Environment and Development, 1987) sustainability is defined as follows: "Meeting the needs of the present generation without compromising the ability of future generations to meet their needs".

The Global Reporting Initiative (GRI) (Global Reporting Initiative, 2002) interprets global sustainability reporting in terms of the most widely accepted approach of

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defining sustainability as economic, environmental and social performance – known as the triple bottom line (see Figure 1). Sustainability reporting provides information on these three dimensions associated with the concept of sustainable development as it concerns a company's performance.

Sustainability reporting within companies nowadays focuses on sustainability issues within the direct corporate context. The sustainability report of a company gives information on the current status of corporate sustainable development, taking into account companies' activities directly linked to the production of their whole product spectrum. The reporting does not include product-related information. Furthermore, the life cycle approach is not taken into consideration consistently within sustainability reporting. For this reason, reporting on indirect effects regarding the sustainable development of a company is not taking place in a consistent way. Direct effects underlie direct corporate control, whereas indirect effects cannot be controlled completely by the company. Corporate sustainable development is described and reported via quantitative but mainly qualitative parameters. Aggregation of the sustainability parameters is therefore not possible in a uniform way. In addition, and due to the fact that no uniformity in parameter aggregation can be achieved, reporting on results takes place mainly at the inventory level. Inventory data is information that can be measured or directly determined and specified (e.g. carbon dioxide emissions). In contrast to the inventory level, impact data has to be calculated or determined on the basis of the inventory data to give information about the contribution of inventory parameters to certain impacts or effects (e.g. global warming potential – GWP).

What is the future of the idea of global sustainability reporting? Based on the idea of corporate sustainable development, the long-term aims and principles are specified and reported in the context of the corporate policy. Furthermore the tasks, responsibilities and procedures of sustainable development have to be defined, and corporate sustainability performance has to be described, with its strengths and weaknesses. Internal and external communication of corporate performance and corporate policy in terms of sustainable development are very important ways of providing information on a company's path to sustainable development. Sections 2 and 3 of this paper point out future trends in global sustainability reporting in comparison to the current status of sustainability reporting within the three dimensions of economy, environment and society.

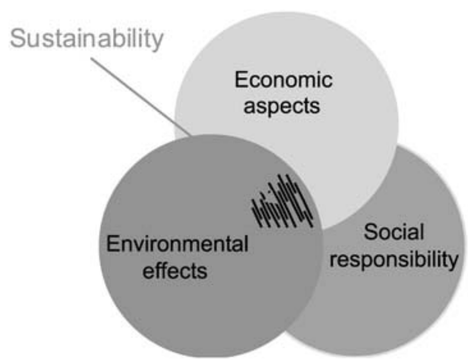

Figure 1.
Common definition of sustainability

1.2 Internal and external communication of corporate performance
Communication of corporate performance comprises strategic and operational goals, corporate performance data at the inventory level, the translation of the inventory data to sustainability indicators, and performance evaluation in terms of sustainability.

1.2.1 Strategic and operational goals. Strategic and operational goals have to be specified as a reference point for further sustainability work. These goals serve as the basis for the evaluation of corporate sustainable development.

1.2.2 Performance data. Corporate performance in terms of sustainability has to be described on the basis of inventory data on the economic, environmental and social levels. The economic data comprises information on cost efficiency, know-how, investment, outsourcing, etc. Information in the environmental dimension concerns raw material consumption, material efficiency, emissions and waste, etc. The social dimension covers information such as working conditions, accidents and employee rights.

1.2.3. Analysis of performance data – translation to core indicators. Based on performance data at the inventory level, no interpretation of corporate sustainability performance is possible due to the huge amount of particular sustainability parameters describing the economic, environmental and social dimensions. In addition to the specification on the inventory level, this data has to be translated into core indicators in order to focus on the relevant aspects of the communication of companies' sustainable development. The translation and aggregation of inventory data to core indicators enables holistic analysis and evaluation of companies' sustainability work.

1.2.4 Evaluation of performance. Sustainability reporting should evaluate corporate sustainability performance via measures such as benchmarking, compliance with internal goals, or fulfilment of external requirements.

2. Life cycle assessment meeting future trends in global sustainability reporting

Future trends at the policy level and in customer demands in the context of sustainability analysis and reporting are moving towards a product-related consideration of sustainability issues and the inclusion of indirect effects over the life cycle in addition to the site-related effects of companies' activities, the analysis of results at an impact level, and the automation of data administration.

The methodology of life cycle assessment (LCA) (European Committee for Standardization, 1997, 1998, 2000a, b) provides the main starting point for global sustainability reporting, including emerging future trends in this context. The LCA approach covers the product-related and life cycle view, taking into consideration upstream (and downstream) processes. Moreover, LCA provides – in addition to inventory results – results on impact level which enable a focus on relevant (environmental) effects and parameters. Furthermore, there are existing software and database solutions available on the market which can be used or extended for the purpose of environmental or sustainability reporting.

2.1 Product view
In addition to the common system boundaries of site specific analysis, the product view is also an emerging topic. Regarding the life cycle of a product from raw material extraction through production processes and use to end-of-life recycling, analysis of

economic, environmental and socio-economic effects helps to coordinate a continuous improvement process.

A product-related consideration of economic aspects is usually used for internal purposes within companies. The publication of this information is in general not in companies' interests. The aggregated economic information related to a product released to the public is the price of the product.

Regarding the environmental dimension of product sustainability, related information is of special interest from the consumer's point of view as this information enables the consumer to influence and minimize the environmental impact of his or her consumer behavior. An example of product orientation in environmental analysis is product oriented environmental management systems (POEMS) (European Union, 2001b). The methodology of life cycle assessment provides this product-related approach.

Analogous to the product-related environmental information, it is of interest for the consumer to know about the social impacts caused by his or her consumer behavior. For this reason, product-related social information is needed. Companies normally report at a company level rather than giving product-specific social information to the public.

2.2 Indirect effects

In view of companies' activities, direct and indirect effects on sustainable development can be differentiated. Indirect effects are defined as effects occurring beyond the site as a consequence of companies' activities (not directly controllable by the company), whereas direct effects can be interpreted as effects directly controllable by companies because they occur at their production site. Indirect effects can be, for example, effects related to upstream processes which are controlled by suppliers, but can be influenced by the company through its purchasing policy or through business to business cooperation in an indirect way.

Indirect economic effects occurring over the supply chain are of interest for companies for reasons of transparency in the pricing policy of suppliers. Nevertheless, this approach is very complex and requires complete support over the whole supply chain. Therefore the life cycle approach is in general not considered in detail in the context of the economic dimension of corporate sustainable development (see Figure 2).

In contrast to the economic dimension, indirect environmental effects should be considered from a corporate point of view. Environmental burdens over the whole life cycle should be taken into account as these aggregated burdens – whether direct or

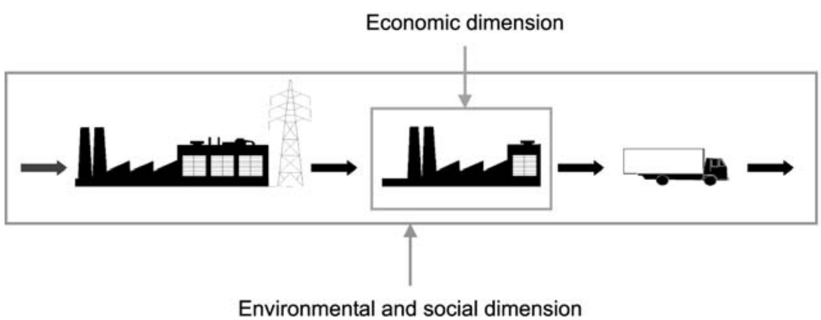

Figure 2.
Product-related life cycle view and site-specific view

indirect – represent the actual effects on the environment due to companies' activities. Companies usually focus on effects directly related to their site-specific corporate activities. But the inclusion of indirect effects, i.e. effects occurring beyond the site as a consequence of companies' activities, is being considered more and more. One example is the Eco Management and Audit Scheme (EMAS II; see European Union, 2001a) as a counterpart to ISO 14001 (European Committee for Standardization, 1996) at a European level, which demands the inclusion of indirect effects in addition to direct effects. Within life cycle assessment the environmental effects connected to the life cycle of the product under consideration is taken into account. All relevant environmental parameters over the whole life cycle are determined – from material extraction, through the production of intermediates and the end product, up to the use phase and the end of the product's life (see Figure 3).

Indirect social effects should also be taken into account from a corporate point of view. Analogous to environmental burdens it is of interest to know about the social burdens over the life cycle, as the aggregation of direct and indirect social effects represents the actual impact on society.

2.3 Analysis at the impact level

For external communication, reporting on sustainability should comprise both inventory parameters and information on impacts or effects, as the interrelation between parameters at the inventory (e.g. carbon dioxide emissions) and effects at the impact level (e.g. global warming potential) is not always known. Another reason to report on the impact level is that a reduction in the huge amount of inventory parameters is achieved via aggregation to a manageable number of effects. The route from particular inventory parameters to effect contribution is managed via indicators.

In the field of economic parameters, this aggregation of the impact level is done by means of the monetary unit based on market conditions.

Environmental impacts such as global warming potential or eutrophication potential have to be calculated on the basis of inventory parameters such as carbon

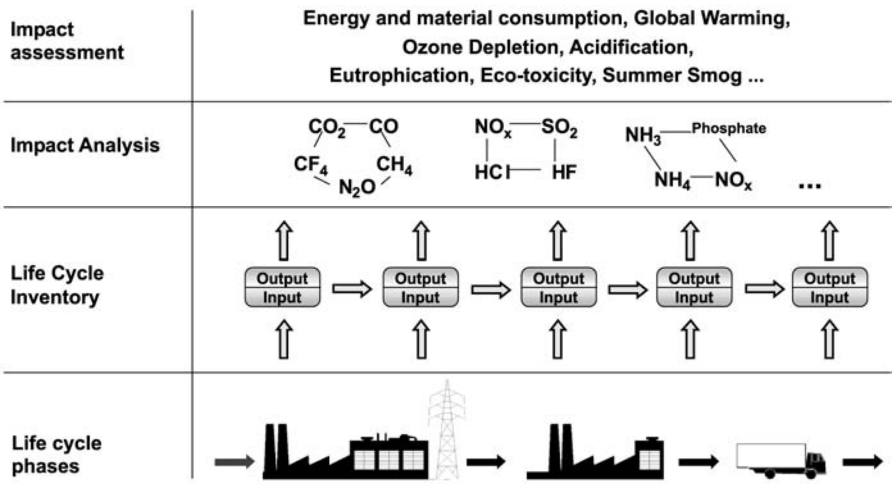

Figure 3.
The methodology of life cycle assessment

dioxide emissions, nitrogen oxides or phosphates (LCA methodology according to Center for Environmental Science, Leiden University – see Center for Environmental Science, 2001). Life cycle assessment offers the possibility to carry out environmental analysis at the inventory level as well as the impact level (see Figure 3).

Impacts within the social dimension are known (e.g. health and safety, global fairness, humanity of working conditions, etc.). However, the contribution of social inventory parameters (such as child labour, employment of women or accidents at work) to social impacts cannot yet be quantified.

2.4 Automation of data administration

The integration of different approaches does not stop at a methodological level, but also affects and comprises implementation within a software-specific context. Solutions to ease data handling (e.g. a web-based data collection system) and to make use of synergy effects of existing software tools within companies are asked for more and more.

To handle and merge all the different aspects of sustainability, an integrated software management system should be aimed for by using and integrating existing and/or implemented software tools that normally focus on just one of the dimensions mentioned.

In the field of economic analysis, various tools are available and have been approved within the strategic and organisational processes of companies. Regarding the market in environmental analysis there are several software tools and databases available and already implemented within companies that support corporate activities related to the environment (IKP/PE, 2002). The social dimension of companies' activities is currently analyzed, in most cases, with tools that were not specifically developed for social and socio-economic analysis.

2.5 Integrated analysis of the dimensions of economy, environment and society

The innovative trends described in the field of integrated economic, environmental and social analysis should be considered – as far as possible – in parallel and based on one system model. Companies have many years of experience and practicable methodological procedures in the field of economic analysis, as well as tools that are both available and approved. As shown in section 2, environmental and social analysis can take place by means of the same methodological approach and system model. To reduce the additional effort in analyzing and reporting on corporate sustainable development, the aim is to combine socio-economic and environmental analysis. The methodology and system model of life cycle assessment offer a methodological approach as well as the appropriate software tools in view of the described requirements. In sections 3 and 4 we describe the path from LCA to an integrated analysis of the dimensions of economy, environment and society, and present current activities regarding the inclusion of socio-economic aspects within an integrated analysis.

3. Integration of the socio-economic dimension analogous to life cycle assessment

The socio-economic dimension can be analyzed and reported on at the inventory level – according to the trends mentioned in section 2 – analogous to the environmental dimension in the context of global sustainability reporting on the basis of the methodology and structure of LCA.

The step of life cycle inventory analysis can be done using the same system boundaries and system model as for analysis of the environmental dimension within LCA (see Figure 4). To include all relevant social effects, direct as well as indirect effects connected to companies' activities are considered within the compilation of necessary social data as a basis for further analysis. Furthermore, social information is referred to specific products.

In contrast to the social dimension, the environmental inventory parameters can be translated within the step of impact analysis to environmental impacts. The advantage of impact analysis is the reduction of numerous inventory parameters to a certain number of communicable impacts. Furthermore, impact information provides insights as to the effects – and therefore the relevance – of inventory parameters. Regarding the step of impact analysis within the social dimension, it is currently not possible to quantify the contribution of social inventory parameters such as child labour, employment of women or accidents at work in view of the social impacts caused.

For analysis at the impact level, further work has to be done in the field of social impact analysis to enable the interpretation, assessment and reporting of results on the level of overall social effects like global fairness, health and safety, etc.

In addition to the methodological aspects, the implementation of socio-economic analysis within a software-specific environment is of importance. Due to the similarity of the analysis procedure, the social and environmental dimensions can be handled within the same system model. The software system GaBi integrates the LCA view and the socio-economic view in one system model (see Figure 5).

Similarly to the existing integration of environmental (LCA) and economic (LCC) data with the technical quality of the product, the life cycle engineering (LCE) methodology and the socio-economic aspects of a product's life cycle (LCWE; see section 4) can be integrated, yielding the decision-support design shown in Figure 6. The life cycle sustainability methodology is presently implemented into the software

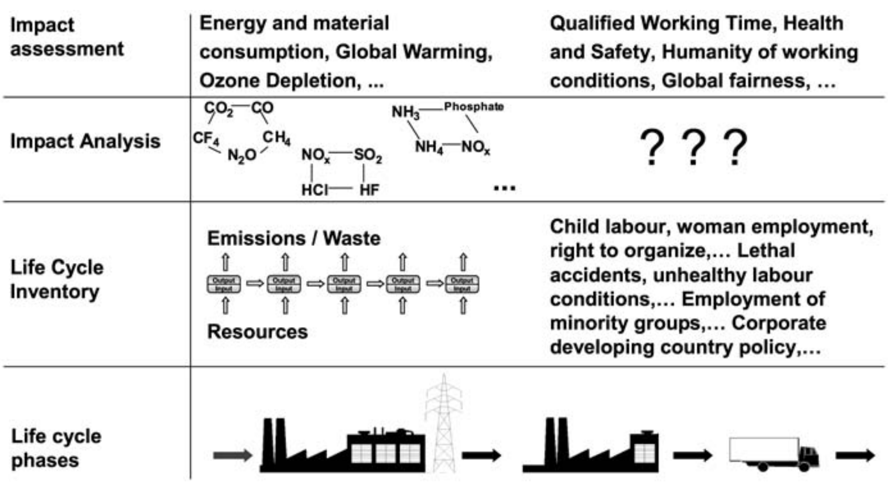

Figure 4.
Integration of the socio-economic dimension analogous to life cycle assessment

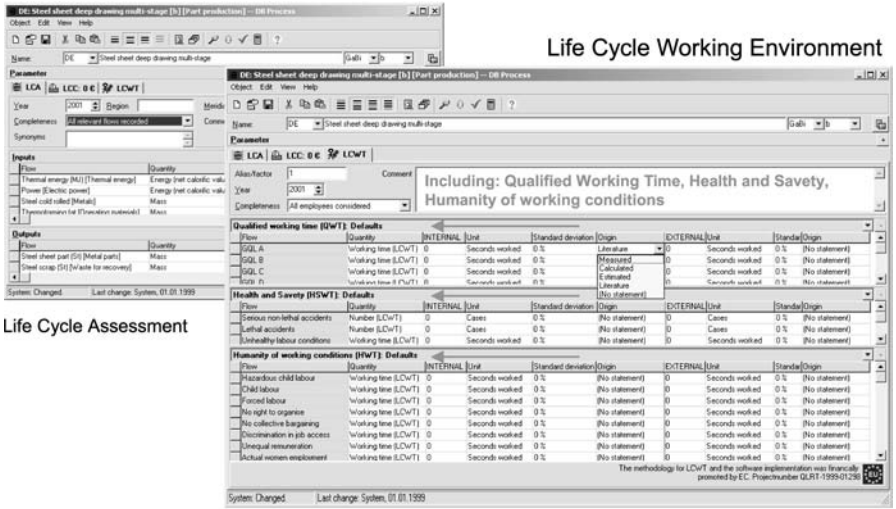

Figure 5.
Software system GaBi

system GaBi for life cycle engineering. In parallel, the social data is collected and entered into the database in order to make it available to all users of the software.

4. Process-level life cycle working environment (LCWE) inventories as basis for the social extension of LCA/LCE

4.1 Criteria for indicators/selecting and grouping of indicators

Based on an extended set of criteria – e.g. process-relatedness (Figure 7), quantifiability, additivity, international comparability, data availability, etc. – suitable measures and indicators have been identified from international publications that meet these criteria and cover an important share of the social safeguard objects. The selected indicators were grouped into three social sub-goals (see Table I).

Other research groups include indicators such as muscoloskeletal disorders, psychosocial diseases, etc., for which such data is and will be internationally unavailable for the foreseeable future. Also, the social information is related to product output as weight, energy content or absolute value (and not as added value, as proposed here). Moreover, they are based on higher aggregated industry sectors. Thus the number of accidents and diseases assigned is the same per kg of silver and iron, because both are metals and belong to the same sector. We believe that this results in an unacceptably high overall error. Also, services typically cannot be analysed.

4.2 Data calculation

The methodology for the life cycle working environment (LCWE) is based on data on various statistical and process levels including input/output tables. For the database, the core of the approach is to calculate industry-specific ratios of working time per added value of a process. This value of seconds per functional unit is overlaid with industry-specific job profiles and qualification/training profiles. This leads, after some adjustments with the help of process-specific information, to the indicators of qualified working time (Figure 8).

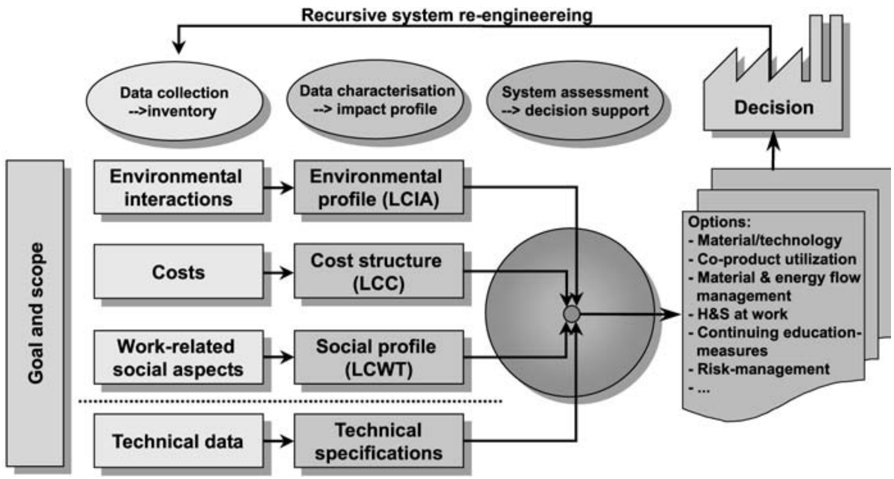

Figure 6.
Life cycle sustainability – integration of the ecological, economic, social, and technical dimensions into one software and database

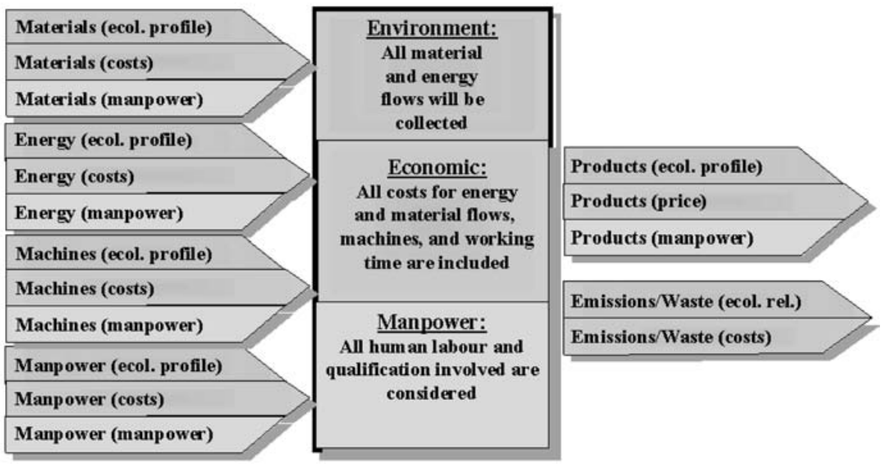

Figure 7.
Process-related information flow in the Life Cycle Sustainability model

The quantified process-specific jobs profile is also overlaid with information about accidents, health issues and general working conditions of the job type, yielding the indicators of health and safety of working time.

The humanity of working time indicators are calculated by overlaying information on compliance of the ILO conventions, share of women employees, and other information for the country in question and the industry to which the specific process belongs. In addition to this methodology, which can be explained only roughly here, it is important to deal with certain differences in the system boundaries for LCA and LCWE, while in LCA-models, the infrastructure and production of machinery depending on the goal and scope of the study is neglected in most cases. This is not possible for social aspects: these factors contribute a relevant part to the overall working time. This difficulty is solved by including these factors with the help of economic input/output models.The methodology for these average data is designed to

Goal	Indicator
Qualified working time (QWT) – Establishment of qualified jobs and support of socio-economic welfare	Duration of work (= base indicator) Qualificational profile of work Training/qualification on the job Contract duration, protection from unemployment[a] Minimum wages[a]
Humanity of Working Time (HWT) – Humanity and flexibility of working conditions	Worst forms of child labour Child labour, forced labour Discrimination (regarding access to job independently of sex, origin, religion, colour, race, disability, etc.) Equal remuneration for men and women Actual share of women work (general and in management) Right to organise in trade unions Right to bargain collectively Daily and weekly working time, breaks[a] Flexibility of working time[a] Participation and career opportunities[a] Satisfaction of employees[a]
Health and safety of working time (HSWT) – Protection of human health	Lethal accidents Non-lethal accidents Heaviness of work (noise, dust, heat, cold, contact with irritating or unhealthy substances, odour, etc.) Job-related diseases[a]

Note: [a]It is still under discussion whether it is possible to include these indicators, despite the fact that they do not fully meet the criteria for indicator-selection set-up

Table I.
Social goals and indicators (identified according to the criteria mentioned in the text) forming the core of the life cycle working environment (LCWE) methodology implemented in the GaBi software

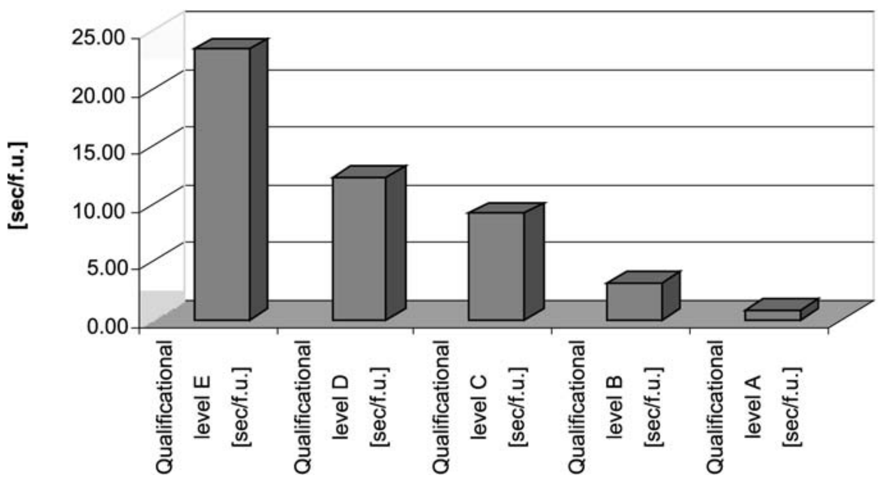

Figure 8.
Impact categories for qualified working time (QWT), in seconds per functional unit (here 1 kg) of a petro-based high-tech polymer

give results consistent to those for specific companies, where the kind of information mentioned above and company-, site- and process-specific data is collected via specific questionnaires and interviews.

4.3 Characterisation, normalisation and weighting

In order to be fully embedded into existing life cycle models, the approach has to meet the general layout of ISO 14040.5. This includes the characterisation step, but the possible normalisation and weighting steps may also be included.

The different unit flows (e.g. seconds of highest qualified working time per functional unit) cannot sensibly be grouped, for example like carbon dioxide and methane, which both contribute to the global warming potential. Hence the characterisation factor is equal to 1 for each of the indicators (i.e. each single flow equals its impact category in name and quantity). Note that in contrast to LCA where only (environmentally) negative impact categories exist, in LCWE possible (socially) positive "impact" categories also exist (i.e. both qualified working time and share of women employees can be considered as positive values).

Normalisation can be done by using the respective country-wide or worldwide values (e.g. of work-related accidents, etc.).

Weighting can also be done – in an extension of ISO 14040ff – for LCWE. It is suggested that country- or society-specific weighting factors are developed that account for the local nature of the impact categories. So far no such factors exist, but an orientation for the valuation could be questions such as how much more highly one highly qualified job should be weighted in comparison to a low qualified job, etc. Note, that the socially positively-valued impact categories mentioned above have a negative weighting factor (by convention) in order to differentiate between the negative and positive kinds of impact category.

5. Conclusions

Global sustainability reporting is a tool for reporting on companies' efforts in the field of sustainability development. This tool can be used by companies for marketing purposes, to communicate with shareholders and stakeholders or to gain economic benefits (e.g. via the Dow-Jones Sustainability Index).

The trends in terms of the analysis of corporate sustainable development are moving towards:

- product-related analysis;
- inclusion of indirect effects via the life cycle approach;
- analysis on impact level; and
- automation of data administration.

The methodology of life cycle assessment (LCA) provides the main starting point for global sustainability reporting, including the emerging future trends in this context. The LCA approach covers the product-related and life cycle view, taking into consideration upstream (and downstream) processes. Moreover LCA provides – in addition to inventory results – results on impact level which enable a focus on relevant (environmental) effects and parameters. Furthermore, there are software and database solutions existing and available on the market which can be used or extended for the purpose of environmental or sustainability reporting. With a manageable initial effort for a database using existing databases as a good starting point and a modular and parameterized model, regular updates for yearly reports are practicable, quick and easy.

Results of impact assessments as central parts of an LCA are a good basis to create significant indicators for sustainability reports. They show environmental performance on a scientific basis and claim to include all relevant environmental problems. LCA is a tool that is highly efficient and relatively easy to use, and combines scientifically based results and manageability.

The social or socio-economic dimension of sustainability can be analyzed and reported within the scope of an LCA using the same system boundaries, system model and software system. The consistent integration of important social criteria into LCA is suggested as a substantial step towards sustainability.

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News from the net

Volvo Adventure – an international award to reward young environmentalists

A web site announces the Volvo Adventure Award, offered every year. The Volvo Adventure is an exciting opportunity for existing and new environmental action projects.

The Volvo Adventure, arranged in collaboration with the United Nations Environmental Programme (UNEP), offers to reward young people who run their own environmental projects. Young people around the world are setting up their own project groups, choosing a subject they can deal with and deciding how they should approach it. It could involve improving the situation for animals, improving water quality or using energy resources more wisely.

The adventure can begin!

For these young people it could be an adventure that offers a chance to make new friends all over the world, attract international attention and ultimately win a spectacular prize, such as the opportunity to present their project at an international conference in Sweden, and the chance of a financial reward that could make it possible to run, improve or enhance their project.

Who can enter?

Anyone aged between 10 and 16 years of age working on a practical environmental project can enter for the award. They need to be working in groups of two to five people and actively involved in devising and managing the project. They can win an all expenses paid trip to Sweden to present their project to an international jury and present their agenda for action to UNEP.

Why not enter your own project? The aim is that you should be able to run it as a school or community project and present your ideas on the internet.

Start on the web site

What do you need to do to get started? Go to the Volvo Adventure web site (see www.volvoadventure.org). There you will find everything you need to register your project. You will then receive a start-up package with instructions on how to proceed.

Even if by the time this issue of *MEQ* is out the deadline may have passed, this useful internet resource can be used in applying for the 2005 one! Now you have a chance to promote your network's projects!

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News

Lithuanian, Swedish nuclear closures confirmed

By the time this issue of *MEQ* is published, the Lithuanian government will have shut one of two reactors at the Soviet-era Ignalina nuclear power station. It had been scheduled to close by 2005 as part of Lithuania's accession agreement with the EU, but the timetable had been in doubt. Meanwhile, the Swedish government has set 31 May 2005 as a preliminary deadline for shutting the second and final reactor at the Barseback nuclear power station.

Green corporate performance bonus identified

Further evidence that companies most committed to sustainable development show stronger market performance has come from a joint study by investment bank Morgan Stanley and environmental rating agency Ökom. The share prices of 207 "best-in-class" firms recommended by Ökom have outperformed others by nearly 17 per cent since 2001. Ökom chief executive Robert Hassler insisted that the difference could not be put down to exceptional factors, but showed "once again that sustainability produces added value".

Levels of radioactivity in the Baltic Sea continue to decline

Concentrations of the artificial radionuclide caesium-137 in Baltic Sea fish and surface waters are declining, according to the latest assessment by HELCOM. Radioactivity is now slowly transported from the Baltic Sea to the North Sea via Kattegat. Minor amounts of radioactivity from the Sellafield nuclear reprocessing plant in the UK are transported in the opposite direction. Routine discharges of radioactivity from nuclear power plants in the Baltic Sea area are small and are only detectable locally.

Overall, the levels of radioactivity in the Baltic Sea water, sediments and biota have shown declining trends since the Chernobyl accident in 1986, which caused the most significant fallout over the area. Other important sources of artificial radioactivity are global fallout from atmospheric nuclear weapons tests performed during the late 1950s and early 1960s and discharges from nuclear reprocessing plants in Western Europe, including Sellafield in the UK and La Hague in France. At present the latter sources have become of minor radiological importance, due to the significant reduction of discharges from Sellafield during recent years. Today, the radioactivity in Baltic fish is clearly below the limit for radioactivity in fish according to EC recommendation.

The maximum annual dose since 1950 to humans frequently consuming Baltic fish and living in close vicinity of the sea (critical group) is below the dose limit for the exposure of the general public set out in the EU Basic Safety Standards. Further details are available at: www.helcom.fi/helcom/news/462.html

UK material productivity "up 50 per cent since 1990"

Britain's material productivity – per capita wealth divided by material consumption – increased by 54 per cent between 1990 and 2003, latest official environmental accounts show. The data show a substantial decoupling between economic growth and resource use, one of the government's key environmental policy aims. According to the

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accounts, UK domestic material consumption fell 1 per cent in 2003 to 667 million tonnes, its lowest level since 1984. Within the total, imports, as opposed to domestic production, are taking an ever larger share. The trend appears to confirm recent warnings that European countries are increasingly shifting the environmental burden of their resource use to third countries.

Total UK environmental taxes remained broadly stable in 2003. However as a share of all taxation they fell for a fourth straight year to 8.6 per cent. Within the total, revenues from the UK's landfill tax rose strongly, while a new levy on virgin aggregates began to bite properly. Revenues from air passenger duty fell for the third year running.

EU-15 "could be totally renewable by 2050"

The "old" EU-15 states could shift completely to renewable energy by 2050, so eliminating fossil greenhouse gas emissions, according to pro-renewables NGO Inforse-Europe. Key to the group's vision is a massive, sustained improvement in energy efficiency, combined with little or no demand growth, leading to a four-fifths reduction in overall energy demand by 2050. The NGO calculates how renewable energies could be boosted to supply all this energy demand by then. The EU-15 are currently not on track to hit an existing 2010 target of a 12 per cent renewables share. Further details are available at: www.inforse.org/europe/Vision2050.htm

Books and resources

Report states that EU ships ignore international pollution rules

Almost 40 per cent of ships flying an EU member state flag have recently failed to meet international rules on dumping toxic substances at sea, according to a new report from marine NGO Oceana. Some national vessel types failed to come up to scratch on every inspection carried out since 2000.

Checks carried out over the last four years on implementation of the international Marpol convention apparently revealed frequent deficiencies or violations. The treaty was agreed in the 1970s to control maritime pollution from oil, chemicals, harmful packaged substances, sewage and garbage.

The NGO says their findings highlight the need to reintroduce mandatory criminal sanctions against ship source pollution to a proposed EU directive, now coming up for its second reading in the European Parliament.

Transport ministers this summer decided the proposal should not specify that sanctions be criminal. Oceana focuses particularly on marine hydrocarbon pollution, caused by tank washing and dumping bilge water, which it claims has led to concentrations of polycyclic aromatic hydrocarbons (PAHs) that "could endanger marine life and public health".

The report is available at: http://europe.oceana.org/downloads/report_marpol_eu_chronic_ hydrocarbon_contamination.pdf

Prioritising local environmental concerns

Recent research examined the extent to which local strategic partnerships have been able to bring the local environment to the forefront in their local neighbourhood renewal strategies. The study found that residents in poor neighbourhoods have repeatedly raised concerns about the condition of their local environments in consultation exercises, and local policy-makers and practitioners working in neighbourhood renewal areas recognise that they need to find effective solutions to local environmental concerns.

However, failure to respond to these doorstep issues fuels local people's beliefs that both local and national government are unable to deliver policies which embrace local needs and concerns, and efforts can also be hampered by a lack of local knowledge.

The researchers suggest that local strategic partnerships would benefit from guidance on how to build "environment" into existing structures.

Copies of the report, written by Karen Lucas, Sara Fuller, Antony Psaila and Diana Thrush of the Centre for Sustainable Development, University of Westminster, London, can be ordered from the Joseph Rowntree Foundation web site (see www.jrf.org.uk/bookshop/) or from the distributor, York Publishing Services (see www.yps-publishing.co.uk).

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The Economics of Energy Efficiency: Barriers to Cost-Effective Investment

Steve Sorrell, Eoin O'Malley, Joachim Schleich and Sue Scott
Edward Elgar
London
2004
360 pp.
ISBN 1840648899
£65.00 (web price £58.50)

This book explores the nature, operation and relative importance of different barriers to energy efficiency through a comprehensive examination of energy management practices within a wide range of public and private sector organisations. The authors use concepts from new institutional economics to explain individual and organisational behaviour in relation to energy efficiency, and identify the mechanisms through which such barriers may be overcome. In doing so, they are able to shed new light on the "barriers debate" and provide a valuable input to the future development of climate policy.

Combining a critical evaluation of different theoretical perspectives with detailed case study research, this significant new book analyses how and why organisations waste energy and suggests practical policy measures to help prevent these losses.

Assessing Impact – Handbook of EIA and SEA Follow-up

Edited by Angus Morrison-Saunders and Jos Arts
Earthscan
London
2004
360 pp.
ISBN 1844071391
On-line discounted price £40.50

Written and edited by an authoritative team of internationally known experts in environmental impact assessment (EIA), this is the first book to present in a coherent manner the theory and practice of EIA and strategic environmental assessment (SEA) follow-up.

Without some form of follow-up, the consequences of impact assessments and the environmental outcomes of development projects will remain unknown. Assessing Impact examines both EIA follow-up and the emerging practice of SEA follow-up, and showcases follow-up procedures in various countries throughout Europe, North America and Australasia. Theoretical and legislative perspectives are examined in the light of detailed case study examples, and the authors present a micro-, macro- and meta-scale analysis of EIA practice ranging from individual plan and project level through to the jurisdictional level, as well as an analysis of the concept of EIA.

Full coverage is given to the roles of proponents, both private and governmental, EIA regulators and the affected public in designing and executing follow-up programmes. This book is the must-have tool for impact assessment professionals, academics, regulators and proponents working on projects of all scales in all jurisdictions.

Blue Genes: Sharing and Conserving the World's Aquatic Biodiversity

David Greer and Brian Harvey

Earthscan
London
2004
248 pp.
ISBN 1844071057
On-line discounted price £58.50 (hardback)

By 2020, the world will be eating almost as much farmed as wild fish, marine bacteria could yield the cure for cancer and deep-sea bacteria may be exploited to gobble up oil spills. Science is moving ahead at a staggering speed, and the demand for genetic resources is growing rapidly – yet governance and policy lag far behind.

This work is the first to look at the issues of ownership, governance and trade in aquatic genetic resources. *Blue Genes* describes the growing demand for aquatic genetic resources, and the desperate need to fill the policy vacuum for the management and conservation of aquatic biodiversity as a foundation for rules governing access to and use of aquatic genetic resources. Special attention is paid to the rights of indigenous and local communities providing access to those resources, and their role in managing and conserving aquatic biodiversity.

The book concludes with policy recommendations specifically tailored to aquatic resources, and uses six case studies from four continents to illustrate key issues.

The Estuarine Ecosystem – Ecology, Threats and Management (3rd ed.)

Donald S. McLusky and Michael Elliott

Oxford University Press
Oxford
2004
222 pp.
ISBN 0-19-853091-9
£60.00 (hardback)

For the inhabitants of many of the world's major towns and cities, estuaries provide their first and nearest glimpse of a natural habitat. Despite the attempts of man to pollute or reclaim it, the estuarine ecosystem continues to provide a fascinating insight into a natural world where energy is transformed from sunlight into plant material, and then through the steps of a food chain is converted into a rich food supply for birds and fish.

This book provides a concise, readable introduction to estuarine ecology. First published in 1981, it soon established itself as the principal textbook of choice in the UK and Northwest Europe. This new edition builds upon the strengths of the earlier editions but has been thoroughly revised throughout. The new co-author brings a human impact dimension to the revised book. It is written for advanced undergraduate and graduate students (particularly taught masters) who have had a general ecology course, but no further training in estuarine science. It will be useful to both professional researchers and practical managers in marine ecology and environmental science who seek a compact but comprehensive introduction to estuarine ecology.

Changing Sea Levels – Effects of Tides, Weather and Climate
David Pugh
Cambridge University Press
Cambridge
2004
280 pp.
ISBN 0521532183
£30.00

Flooding of coastal communities is one of the major causes of environmental disasters worldwide. This textbook explains at a basic level how sea levels are affected by astronomical tides, by weather effects that generate extreme flooding events, and over the longer term by ocean circulation and climate trends. It also indicates how sea level changes are related to changing risks, coastal dynamics, geology and biology, and outlines some of the economic and legal implications.

Based on courses taught by the author in the UK and the USA, this book is aimed at undergraduate students at all levels, with the text developed in such a way that non-basic mathematics is confined to Appendices and a web site (see http://publishing.cambridge.org/resources/0521532183/). *Changing Sea Levels* will also interest and inform professionals in many fields including hydrography, coastal engineering, geology, biology and also coastal planning and economics.

Diary

2005

8th Annual Conference of the Environmental Management Accounting Network (EMAN)
10-11 May, Erasmus Centre for Sustainability and Management (ESM), Erasmus University, Rotterdam, The Netherlands
The 8th Annual Conference of the Environmental Management Accounting Network Europe (EMAN-EU) has as its theme "Corporate Social Responsibility and Innovations in Management Accounting". The conference theme addresses the issues of how companies and other organizations not only have implemented sustainability tools and concepts but also how this information is incorporated into decisions making and decisions making processes. There will also be opportunity at the conference to present papers on other themes related to innovations in management accounting, sustainability accounting and decision-making. Papers are invited to any of these themes and broadly on any area related to innovation in environmental management accounting from both researchers as practitioners. For more information about the event and about EMAN, please visit www.eman-eu.net

2nd International Conference on Integrative Approaches towards Sustainability – Baltic Sea Region Sharing Knowledge Internally, across Europe, and Worldwide – "SHARING"
11-14 May, Jurmala, Latvia
The University of Latvia is pleased to invite all interested colleagues to attend the 2nd International Conference on "Integrative Approaches Towards Sustainability", to be held in Jurmala, Latvia on May 11-14, 2005. The conference aims to strengthen the integration of the region's RTD community and promotion of sharing its knowledge and expertise internally, across Europe (including the Mediterranean and Black Sea regions) and worldwide by inviting distinguished researchers to Latvia to:

- discuss the global goals defined by EU Council in Gothenburg, scientifically based thresholds of sustainability and points of no return with certain focus on the Baltic Rim;
- discuss corporate responsibility and sustainability in the regional decision-making process;
- share knowledge and expertise, in particular, focusing on agriculture, forestry, education and university-municipality partnership – key and advanced fields for sustainability in the region;
- train the young researchers of the Baltic Sea Region and similar regions such as the Mediterranean and Black Sea; and
- promote further integration of researchers of the Baltic States in European networks targeted to sustainable development.

The target audiences of the meeting are Baltic Sea region students, researchers, politicians, and economists dealing with validation of methods, indicators and tools

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with special respect to sustainability requirements in the Baltic Sea region as well as students and representatives of the RTD community from Mediterranean and Black Sea regions. The official conference language is English. Further details are available at: http://www.lu.lv/Sharing/

International Conference "Soil Conservation issues in Nordic Countries"
25-26(28) May, Tartu, Estonia
The conference will look at soil cover constraints and degradation features, bearing in mind the characteristics of rural areas in the Nordic regions. It will also consider concepts and socio-economic aspects of soil protection policy and the different measures for implementation of soil conservation in Nordic countries. The conference on soil conservation precedes immediately to one of the conferences in the conference series of the Landscape Tomorrow European Research Network (LT). The title of the succeeding conference is "Multifunctional Land Use – Meeting Future Demands for Landscape Goods and Services. For further information see: www.geo.ut.ee/LTconference

The events are Organized by the Department of Soil Science and Agrochemistry, of the Estonian Agricultural University (EAU) in Tartu, in collaboration with the Institute of Geography, the University of Tartu (UT), the European Society of Soil Conservation (ESSC) and the Landscape Tomorrow European Research Network (LT). For further information on the ESSC Conference (and its Council meeting) please visit the web site: www.zalf.de/essc/essc.htm

6th International Conference "Environmental Engineering"
26-27 May, Vilnius Gediminas Technical University, Vilnius, Lithuania
The Conference will be hosted by the International Federation of Surveyors (FIG) and International Academy of Ecological and Life Protection Science (Russia), Lithuanian Water Suppliers Association and Baltic Road Association. The conference will have five sections:

(1) Environmental Protection.
(2) Water Management and Hydraulics.
(3) Urban Transport System.
(4) Roads and Railways.
(5) Technologies of Geodesy and Cadastre.

For more information, please visit the web site: www.vgtu.lt/Enviro2005/

6th International Conference of the European Society for Ecological Economics
14-17 June, Lisbon, Portugal
This conference will provide a forum for scientific debate and discussion on theoretical and practical issues in the field of ecological economics, focusing on the links between science, society and policy. The general theme of ESEE 2005 will be Science and Governance – The Ecological Economics Perspective. A new attitude of open, transparent and inclusive governance in the formulation of sustainable development is being adopted in a number of fora. In this context, expanding the definition and scope

of what is considered policy relevant science is critical to the ecological economics scientific community. Increasingly, the need to integrate the expertise of scientists with the specific knowledge of practitioners, consumers, user groups and other stakeholders is considered important. The ecological economics scientific community needs to consider the challenges and requests raised by these new demands and discuss their implications in terms of the need to develop new concepts, methodologies and tools. For more details, information on how to register and submit papers, please visit www.esee2005.org/

IWA Specialist Conference "Nutrient Management in Wastewater Treatment Processes and Recycle Streams"
18-21 September, Krakow, Poland
The IWA Specialist Conference "Nutrient Management in Wastewater Treatment Processes and Recycle Streams" will be held in Krakow, Poland, on 18-21 September 2005. Its aim is to gather the best practitioners in the field and to present the current state of knowledge in municipal wastewater treatment and discuss design and operational upgrades to biological nutrient removal (BNR) plants, to present pre-design studies, operational control strategies, modeling, kinetics and remedial measures to offset the operational and design deficiencies. Insight into the financing of the treatment plant infrastructure and available financial aid into operator training and plant management will also be covered. This unique workshop-format conference is held under the auspices of the IWA Specialist Group on Design, Operation and Costs of Large Wastewater Treatment Plants and IWA Specialist Group on Nutrient Removal and Recovery. The conference is organized by LEMTECH Konsulting, with input from the Water/Wastewater Treatment Plant Operators Association, and a consortium of universities, led in Poland by Poznan Technical University and the University of Manitoba. English is the official language of the conference. English to Polish cabin translation will be available. Further details at: www.bnr2005.krakow.pl/

Sardinia 2005 – 10th International Waste Management and Landfill Symposium
3-7 October, Cagliari, Italy
The themes of the Symposium are:

- Waste Policy and Legislation;
- Waste Management Strategies;
- Public Concern and Education;
- Waste Management Assessment and Decision Tools;
- Waste Characterisation as a Tool for Waste Management Strategies;
- New Concepts for Waste Collection;
- Waste Minimisation and Recycling;
- Biological Treatment;
- Thermal Waste Treatment;
- Mechanical Biological Treatment Prior to Landfilling;
- Sanitary Landfilling;

- Integrated Wastewater and Solid Waste Management; and
- special sessions (Waste management in developing and low income countries, BAT – Best Available Technology, IPPC regulations.)

Further details are available from: Eurowaste srl, Via Beato Pellegrino, 23, I-35137 Padova, Tel.: +39 049 8726986, Fax: +39 049 8726987, E-mail: eurowaste@tin.it, Continuously updated information is available on the event's web page: www.sardiniasymposium.it

Feature

EU utility chiefs stand up for nuclear power

Chief executives of over 20 electricity and nuclear service firms recently launched a joint declaration in Brussels calling for Europe to keep nuclear power "at the heart" of its energy supply system. Only in this way can the twin challenges of climate change and energy security be faced, they insisted.

The signatories include the bosses of major utilities such as RWE and E.ON of Germany, EDF of France, Electrabel of Belgium and Vatenfall of Sweden – all of them nuclear generators – plus specialist nuclear firms like Westinghouse and Areva.

Nuclear power faces an uncertain future in Europe – notably due to official phase-out programmes in Sweden and Germany. But the sector appears to believe the tide is shifting back in its direction notwithstanding denials from anti-nuclear leaders like Germany's Environment Minister Jürgen Trittin.

A new poll shows that Finnish public opinion has turned in favour of nuclear power. Companies such as RWE and the nuclear services firm BNFL claimed that things were moving in the same direction in Sweden and the UK respectively.

Their optimism is also reflected in an upsurge in decisions to build new nuclear capacity. Finland opted for one new plant in 2002, the first such decision in Europe for a decade. In 2004, France launched plans to develop a new generation of reactors to replace its current extensive nuclear capacity. In addition, Turkey's government announced plans to construct three nuclear power stations, the first by 2011. The country abandoned its previous nuclear energy ambitions in 2000. Energy Minister Hilmi Guler predicted the plants should ultimately meet up to 10 per cent of Turkish electricity demand.

The European Commission proposed a directive aimed at safeguarding security of electricity supply in the EU in December 2003. The nuclear sector is particularly optimistic that a coming debate on tougher carbon dioxide reductions post-2012 will play in its favour.

Industry leaders think that, as fighting climate change moves to the top of the agenda, keeping the nuclear option becomes more urgent.

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