Original paper

Clean Techn Environ Policy 5 (2003) 232–239
DOI 10.1007/s10098-003-0205-z

Eco-efficiency reporting exemplified by case studies

Annik Magerholm Fet

Abstract This paper presents current and future trends and requirements for environmental, eco-efficiency and sustainability reporting. Further it defines the concept of eco-efficiency, and describes ways of developing eco-efficiency indicators for production sites and for product chains. Eco-efficiency measures give indications both on economic and on environmental performance. These indicators are then exemplified by results from case studies within Norwegian and European industrial companies. Some of these projects have also laid the foundation for environmental accounting and reporting systems in local communities. Eco-efficiency as a tool for measuring the performance along product value chains is demonstrated in the paper. Product oriented eco-efficiency indicators are seen in the context of the international efforts on standardisation of environmental product declarations (EPDs), which are ways to report the environmental performance of products. This is exemplified with cases from furniture production value chains. The presentation focuses further on the concept of corporate social responsibility and on the challenges of how to incorporate this in future sustainability reporting.

Introduction

There are different types of reporting systems on environmental performance and eco-efficiency. Eco-efficiency covers economic performance in addition to the environmental performance, while sustainability reporting encompasses social, economic and environmental aspects: the "triple bottom line". Today, the trend has shifted from traditional environmental reporting to eco-efficiency reporting and sustainability reporting.

Indicators are frequently used to report environmental performance. Figure 1 shows the three pillars in sustainable development as the corners of a triangle, and indicates reporting at different levels.

Organisations such as the United Nations' Environment Program (UNEP), the World Business Council for Sustainable Development (WBCSD 2000) and the Organisation for Economic Co-operation and Development (OECD) have a strong influence on the requirements for such reporting (OECD 2001). One of the initiatives by UNEP is the Global Reporting Initiative (GRI). GRI was established in 1997 with the mission of developing globally applicable guidelines for reporting on economic, environmental, and social performance. The GRI's Sustainable Reporting Guidelines (UNEP 2002) represents the first global framework for comprehensive sustainability reporting. The latest version came out in September 2002, which gives guidance to reporters on selecting generally applicable and organisation-specific indicators, as well as integrated sustainability indicators. In order to compare different systems, it is necessary to follow standardised ways of reporting by means of a set of understood indicators.

Performance indicators

The GRI Indicator Framework organises the performance indicators in accordance with the following hierarchy, see Fig. 2:

- *Category*: the broad areas, or groupings, of economic, environmental, or social issues of concern to stakeholders (e.g., human rights, direct economic impacts).
- *Aspect*: the general subsets of indicators that are related to a specific category. A given category may have several aspects, which may be defined in terms of issues, impacts, or affected stakeholder groups.
- *Indicator*: the specific measurements of an individual aspect that can be used to track and demonstrate performance. These are often, but not always, quantitative. A given aspect (e.g. water) may have several indicators (e.g., total water use, rate of water recycling, discharges to water bodies). A pillar of the GRI framework is that aspects and indicators derive from an extensive, multistakeholder consultative process.

GRI performance indicators are classified along the following lines:

- *Core indicators* (or general applicable indicators) are those relevant to most reporters; and of interest to most stakeholders.

Received: 28 October 2002 / Accepted: 1 April 2003
Published online: 12 June 2003

A. M. Fet
Department of Industrial Economics and Technology Management, The Norwegian University of Science and Technology (NTNU), 7491 Trondheim, Norway
E-mail: fet@iot.ntnu.no

This paper was presented at NATO's Advanced Research Workshop, Maribor, Slovenia, 13–17 October 2002.

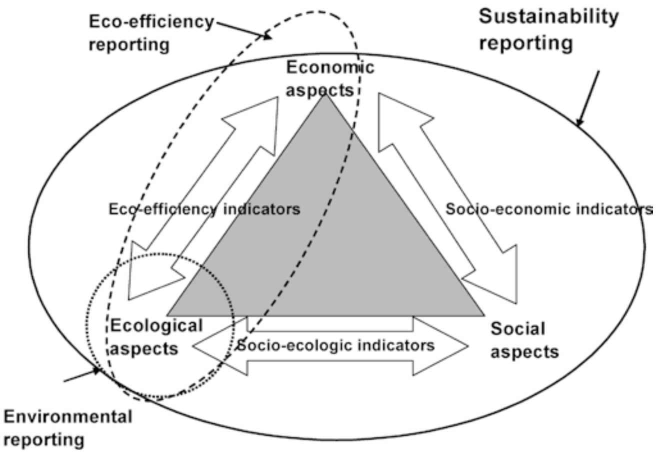

Fig. 1. Sustainability reporting

– *Additional indicators* (or business specific indicators) are viewed as leading practice in economic, environmental, or social measurements, and in providing information of interest to stakeholders who are particularly important to the reporting entity.

In addition to the sustainability indicators on economic, social, and environmental aspects, a fourth dimension of information is necessary: *integrated performance*. GRI has not identified a standardised set of integrated performance indicators, but integrated measures are categorised as:

– *Systemic indicators* that relate the activity of an organisation to the larger economic, environmental, and social systems of which it is a part. For example, an organisation could describe its own performance in relation to the overall system.
– *Cross-cutting indicators* that directly relate two or more dimensions of economic, environmental, and social performance as a ratio. Eco-efficiency measures are the best-known examples (see Fig. 1 for other cross-cutting indicators).

The economic performance indicators used in eco-efficiency primarily focus on the profitability of an organisation for the purpose of informing its management and shareholders. The focus of economic performance measurement in sustainability reporting is on how the economic status of the stakeholder changes as a consequence of the organisation's activities (direct impact) rather than on changes in the financial condition of the organisation itself (indirect impact). Indirect impacts include externalities that create impacts on communities, e.g. costs or benefits arising from a transaction that are not fully reflected in the monetary amount of the transaction. 233
A community can be considered as anything from a neighbourhood, to a country, or even a community of interest such as a minority group within a society. See Table 1 for the aspects under each category suggested by GRI. Under each aspect GRI suggested a set of core indicators and additional indicators.

Eco-efficiency

WBCSD defines eco-efficiency as "the delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impact and resource intensity throughout the life cycle, to a level at least in line with the earth's estimated carrying capacity" (DeSimone and Popoff 1997).

To develop eco-efficiency measures, information on both the economic and the environmental performance is needed. The eco-efficiency can be calculated using the following formula:

$$\text{eco} - \text{efficiency} = \text{product or service value per environmental influence} \quad (1)$$

For a production site the value can be yearly production volume, total sale or turnover. The environmental influence can be the environmental impact within one aspect, or an aggregated value, which requires weighting between the aspects. So far measures of eco-efficiency have mainly focused on specific production sites. To evaluate the

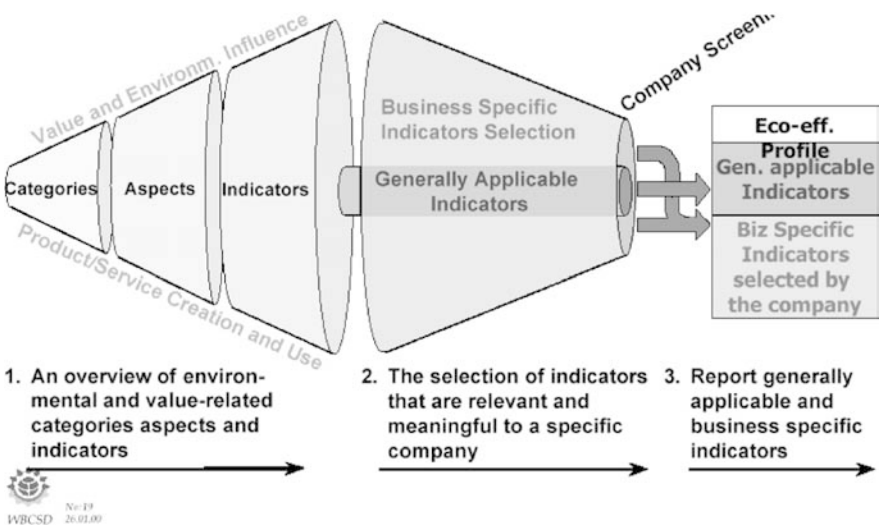

Fig. 2. WBCSD framework of indicators (WBCSD 2000)

Table 1. Categories and aspects for economic, environmental and social performance indicators (UNEP 2002)

	Category	Aspect
Economic	Direct Economic Impacts	Customers Suppliers Employees Providers of capital Public sector
Environmental	Environmental	Materials Energy Water Biodiversity Emissions, effluents, and waste Suppliers Products and services Compliance Transport Overall
Social	Labour Practices and Decent Work	Employment Labour/management relations Health and safety Training and education Diversity and opportunity
	Human Rights	Strategy and management Non-discrimination Freedom of association and collective bargaining Child labour Forced and compulsory labour Disciplinary practices Security practices Indigenous rights
	Society	Community Bribery and corruption Political contributions Competition and pricing
	Product Responsibility	Customer health and safety Products and services Advertising Respect for privacy

eco-efficiency of a product, information concerning its entire life cycle is required to allow an evaluation of its environmental and economic performance.

The performance can be measured/calculated by economic performance indicators and environmental performance indicators (EPIs). Equation (1) can be transformed to:

$$\text{Eco} - \text{efficiency indicator} = \frac{\text{economic performance indicator}}{\text{environmental perfomance indicator}} \qquad (2)$$

The WBCSD's framework of indicators is shown in Fig. 2.

Methodology

The GRI framework focuses on indicators that are most relevant to the stakeholder. However, to decide upon the most significant environmental aspects, relevant data is needed. One way of collecting the data and selecting the most relevant indicators is to use the methodology described in the ISO 14031 code on "Environmental Performance Evaluation" (ISO 1998). The methodology is illustrated in Fig. 3.

To analyse the data and evaluate the information, as in assessing the environmental impact, the methodology recommended by ISO 14040 can be used (ISO 1996). The methodology consists of these main steps:

1. Goal and scope definition
2. Inventory

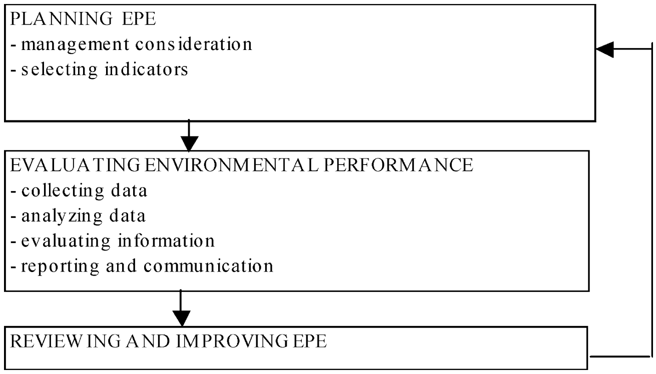

Fig. 3. ISO 14031 methodology

3. Impact assessment
4. Interpretation

For impact assessment the following procedures are used:

3a Classification; the step where the different substances are classified under the impact category they contribute to.
3b Characterisation; the step in which the relative contribution of each substance within each category is calculated.
3c Normalisation and evaluation; the step where the total contribution within each category is evaluated against the mean values in e.g. a society. Very often different weightings are used to compare the impact categories against each other.

The choice of environmental impact categories can be e.g. global warming, acidification, eutrophication, biodiversity, etc., or the aspects recommended by GRI. A similar methodology should be established for the selection of economic performance indicators. However, that is not a part of this presentation. An appropriate methodology for deciding the most relevant eco-efficiency indicators used for reporting can be described by:

1. Define the system, subsystems and system boundaries, and the functional unit if the system is a product.
2. Establish economic and environmental performance indicators.
3. Define eco-efficiency indicators for the system (by means of established methods, see above).
4. Collect and evaluate data for quantification of value creation and environmental impact.
5. Test the eco-efficiency indicators among the most important stakeholders.
6. Use the eco-efficiency indicators in reporting.

Case studies

The use of indicators is demonstrated by a few case studies. Case 1 demonstrates the use of site-specific EPIs and eco-efficiency indicators, while case 2 demonstrates a few systemic indicators used by companies and their related municipalities. Eco-efficiency indicators are not yet included. Case 3 demonstrates how eco-efficiency indicators can be used for the purpose of comparing alternative fuel types for recreational boats. The last case, case 4, shows an attempt to use eco-efficiency of products.

Case 1: site-specific indicators

These results are from the company A/S Olivin in Norway (Olivin 2001). It is the world's largest supplier of olivine based products. During the year 2001, 2.08 million tons of bulk sand, 50,600 tons of packaged sand and 22,530 tons of refractory products were produced. The total sales in 2001 were 365 million NOK, and the company had 194 employees. Manufactured products are mainly transported by ship from the company's own harbour. The company received the award for the best environmental report among Norwegian production industry and the international prize for the best report among small and medium sized companies last year. In their environmental policy they focus on the most important environmental aspects (dust, noise, waste and the efficiency of material and energy utilisation). They use EPIs in their reporting, e.g. emissions of climatic and acidifying gases. The amount of emissions from internal transport and combustion of oil is estimated from motor characteristics and oven specifications. The company uses this for eco-efficiency measures. The created value is expressed by yearly sale, see Fig. 4. This shows sales in proportions to emissions of climatic gases (here, CO_2) and acidic components (NO_x and SO_2). The eco-efficiency indicator shows a positive development over the past years. This does not include last year.

Other important EPIs are related to waste and waste treatment. By measuring the proportion of waste against the production volume, the efficiency of resource consumption can be evaluated. The waste indicators also give information regarding hazardous waste, waste for recycling and disposable waste. In addition, an indicator on costs per delivered ton of waste together with indicators on environmental investments are measured. These are further developed to eco-efficiency indicators, see Fig. 5.

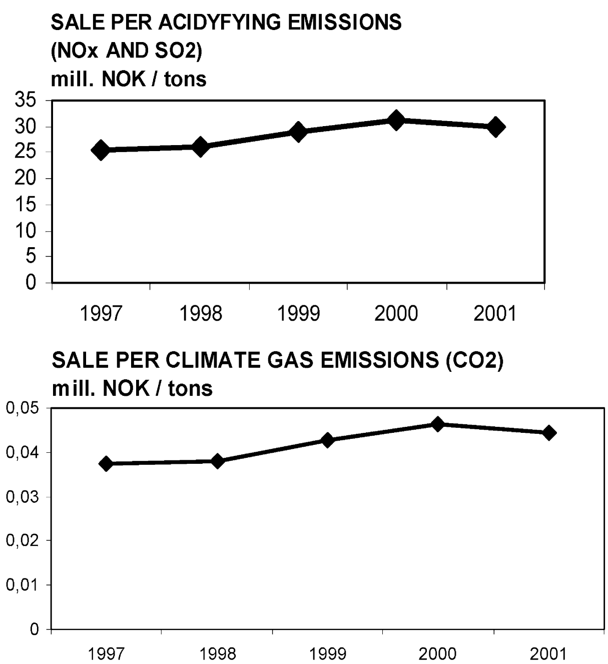

Fig. 4. Eco-efficiency indicators expressed as sale per climate gas emissions and sale per acidifying emissions

Case 2: reporting in local communities by means of systemic indicators

As part of the Local Agenda 21 project, the following goals were set:

- Establish comparable environmental accounting systems for a group of industrial companies in a community and for the community itself.
- Select a set of appropriate EPIs to meet the standards requested by interested parties.
- Establish reporting systems and the use of indicators in a local society.

The companies in this project wanted to use EPIs as shown in Table 2, and the waste indicators were of special interest to the community because the community wanted to secure a safe environmental treatment of the waste. A system for the reporting of waste streams and amounts of these from the companies to the community was established. Indicators such as "amount of each waste fraction delivered to the waste treatment plant" and "amount of waste delivered from the treatment plant for reusage, recycling, incineration, and landfill" were further established.

The community also developed a reporting system concerning their own activities, including the administration of the community, seven schools, and a nursery home. Examples of the use of EPIs for energy use and waste treatment are shown in Figs. 6 and 7. The most obvious systemic indicators are for energy use and waste. They are of interest both for each participant and for the

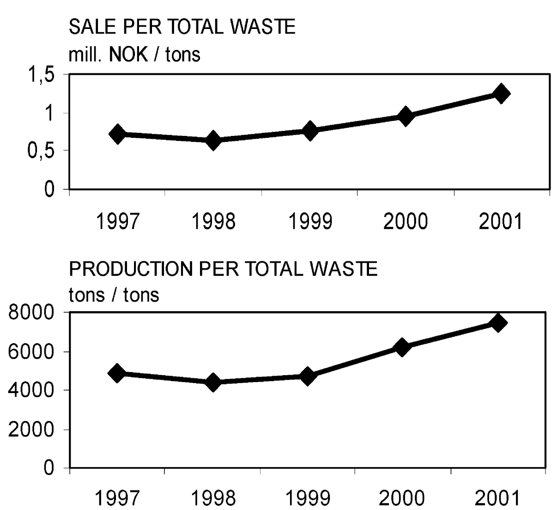

Fig. 5. Eco-efficiency indicators for waste

Table 2. EPIs for small companies

Group	EPI
Purchase	· Proportion of products with environmental declaration (%) · Number of suppliers with an environmental management system
Energy usage	· Electrical energy use per year (kWh) · Energy use based on fossil fuel (kWh) · Total energy use per area (kWh/m^2) · Total energy use per turn-over (kWh/NOK)
Waste	· Yearly amount in total (ton) · Yearly amount per production volume (ton/ton) · Yearly amount per turnover (ton/NOK) · Yearly amount to recycling per total waste (%) · Yearly amount to disposal (ton)

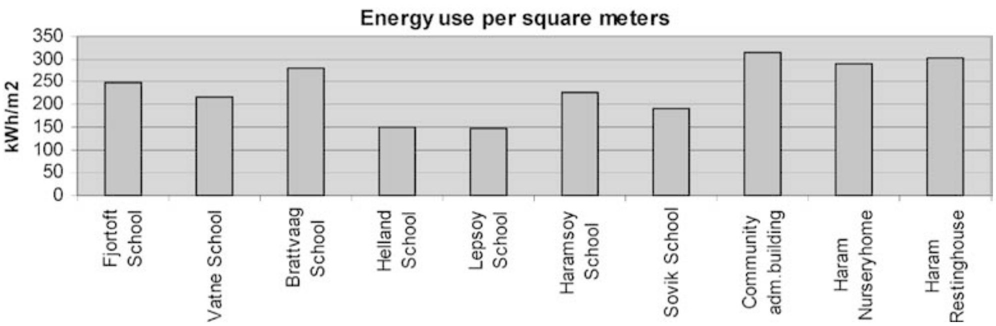

Fig. 6. Yearly energy use per m^2 in the building owned by the community

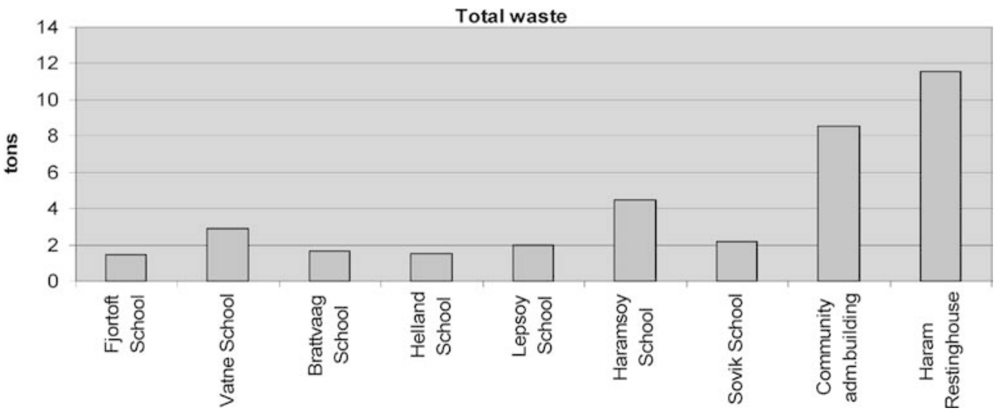

Fig. 7. Total waste delivered from schools and other activities in the community

community, and they are of great value for further planning and improvements.

Case 3: eco-efficiency indicators for the purpose of comparing alternative fuel types

This study was conducted focusing on biodiesel (rapeseed oil) production and on the recreational boat market in the U.K. (Fet 2000). Biodiesel has been considered as an environmentally friendly fuel which offers advantages of cleaner emissions, less pollution, less toxicity, biodegradability, less odour, ease of handling, high lubricity, smoother operation, and complete combustion. These facts make biodiesel an attractive fuel for recreational boats, where a clean environment is desired. It was concluded in the study that the biodiesel production rate in the U.K. would be about 430,000 tons per year if all U.K. set aside land were used for growing rapeseed crops. For fuelling all sailing yachts in the U.K., only 4.5% of this is needed. Table 3 presents the emissions from the sailing yachts in the U.K., fuelled by either fossil diesel or biodiesel (BABFO 2002; Statistics UK 2002). Column 5 shows the characterisation values (Fet et al. 2000). It indicates that the contribution of NO_x emissions to acidification is only 70% of that of SO_2. Column 6 shows the normalisation factors based on total emissions per year in the U.K. The yearly emissions are divided among these factors. This makes the figures comparable (see last two columns in Table 3). Figure 8 shows the characterised and normalised EPIs from sailing yachts in the U.K.

In order to calculate the eco-efficiency, it is necessary to evaluate the economic values created by sailing activity (see Eq. 1). However, it is difficult to obtain values/incomes on recreational activities, although one solution is to measure the value as the inverse of costs based on the fuel prices and yearly costs shown in Table 4 (BABFO 2002).

The environmental influence can be expressed by the impact categories as shown in Table 3. The eco-efficiency

Table 3. Life cycle emissions of fuel from sailing yachts operation in UK (Zhou et al. 2002)

Impact category	Substances	Fuelled by Fos-D[a] (kg/year)	Fuelled by Bio-D (kg/year)	Charac-terisation	Normalisation factors	Normalised values fossil diesel	Normalised values biodiesel
Climate change	CO_2	1.4×10^{8}	3.4×10^{7}	1	4.16×10^{11}	3.46×10^{-4}	8.17×10^{-5}
Acidification	SO_x	1.5×10^{5}	2.9×10^{4}	1.0	1.62×10^{9}	3.40×10^{-4}	3.45×10^{-4}
	NO_x	6.2×10^{5}	8.2×10^{5}	0.7	1.75×10^{9}		
Local air pollution	Particulates/ soot	5.2×10^{5}	3.1×10^{5}	1	0.44×10^{9}	1.28×10^{-3}	8.26×10^{-4}
	CO	4.8×10^{5}	5.8×10^{5}	1	4.76×10^{9}		
Photo oxidant formation	NMVOC	2.9×10^{5}	1.5×10^{5}	1	1.96×10^{9}	1.48×10^{-4}	7.66×10^{-5}
Eutrophication	NO_x	6.2×10^{5}	8.2×10^{5}	1	1.75×10^{9}	3.54×10^{-4}	4.68×10^{-4}

[a]Fos-D represents fossil diesel fuel; Bio-D represents biodiesel

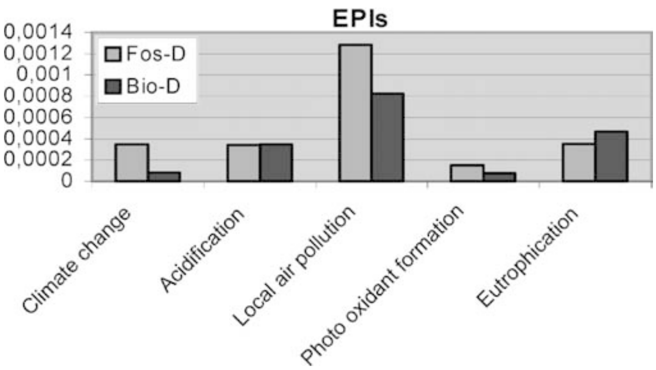

Fig. 8. Characterised and normalised inventory results presented by EPIs

Table 4. Fuel cost per year by sail yacht. Sensitivity study of fuel costs

	A[a]	*B*	*C*	*D*
Bio-D	40,632	90.2	874	32,032,156
Red diesel	40,632	34.79	852	12,043,764
Fos-D	40,632	77.9	852	26,967,783
Bio-D, no tax	40,632	50.56	874	17,955,053

of sailing yachts in the UK on a yearly basis could then be calculated by:

$$\text{Eco}-\text{efficiency} = (1/\text{yearly costs})/\text{environmental impact} \tag{3}$$

The values in Table 4 are used to calculate eco-efficiency. The results from the different scenarios are presented in Fig. 9. They show that non-taxed biodiesel has the best eco-efficiency for climate change and photo-oxidant formation. For acidification, normal priced biodiesel has the worst eco-efficiency. This is due to NO_x emissions. However, for other impact categories, fossil diesel shows a good eco-efficiency. For red diesel the environmental performance of fossil diesel is used, which is partly incorrect. By comparing and analysing Figs. 8 and 9, the influence of costs on the eco-efficiency can be derived. However, the use of cost factors is just for the purpose of demonstration. Other pricing mechanisms and taxation systems could be included here. This is a subject for further studies.

Case 4: eco-efficiency of products

To determine the eco-efficiency of products, the total value chain has to be evaluated. Appropriate EPIs can be found in LCA data. Different measures of value creation can be used even though monetary terms are found most useful. Eco-efficiency indicators can thus be used to track changes in eco-efficiency over time in different parts of the value chain (Michelsen and Fet 2002). An example is shown in Fig. 10. Here both an eco-efficiency measure (net sale in NOK per megajoule energy consumed) and the total environmental pressure (total energy consumed) are shown.

Another set of eco-efficiency indicators is visualised graphically, see Fig. 11. They are found to be useful for comparing different models of a product. The values are given a relative value based on arithmetic mean values. The measure of environmental impact can either be a single EPI (i.e. energy consumption) or aggregated values where different impact categories are weighted and added. Figure 11 shows the value as the sale value for a product and the environmental impact is the normalised value for aggregated impact categories. This is based upon the method used by BASF (Saling et al. 2002), and the values represent five different models of an office chair. It is possible to start with only a few important environmental aspects, i.e. energy and material consumption, and includes more aspects when more data are available. This makes it easier for small and medium sized enterprises to evaluate eco-efficiency for their products when resources to identify all environmental aspects, e.g. to do a complete LCA, are limited. It is also possible to use different measures of value creation. In this example the monetary terms are used, but function fulfilment can also be used (Michelsen et al. 2003).

The method for the establishment of eco-efficiency indicators presented earlier in this paper can be expanded to yield products by including the two next steps:

1. Develop a weighting model for the environmental aspects so the environmental performance can be aggregated to one single indicator (this step is controversial).
2. Implement the eco-efficiency indicators in the value chain to help decision makers track the performance and changes in performance of products.

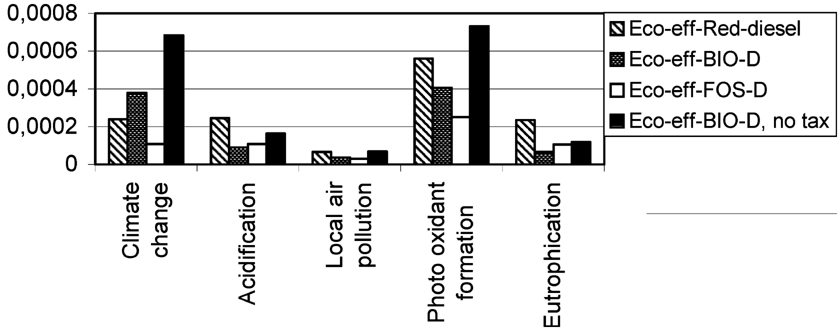

Fig. 9. Eco-efficiency for different alternatives, see Table 4 (Zhou et al. 2002)

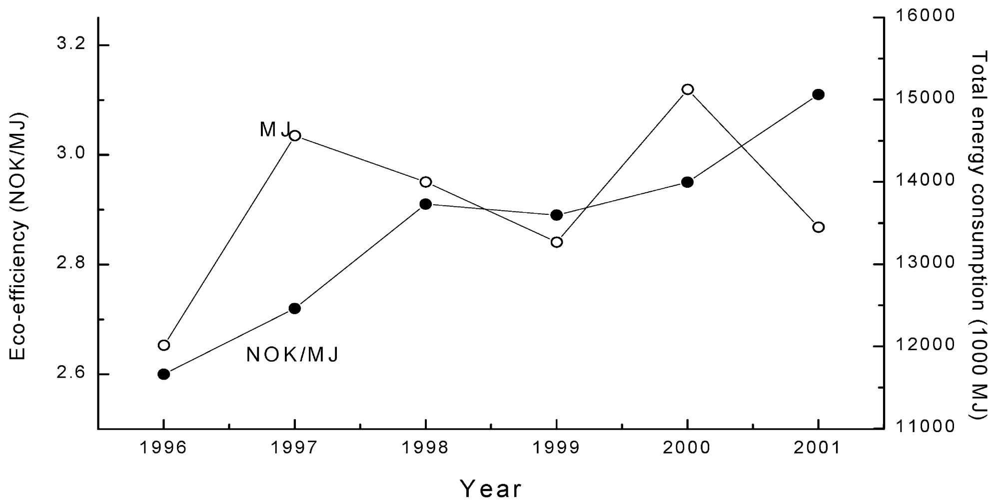

Fig. 10. Eco-efficiency for value chain calculated by energy use (Michelsen 2003)

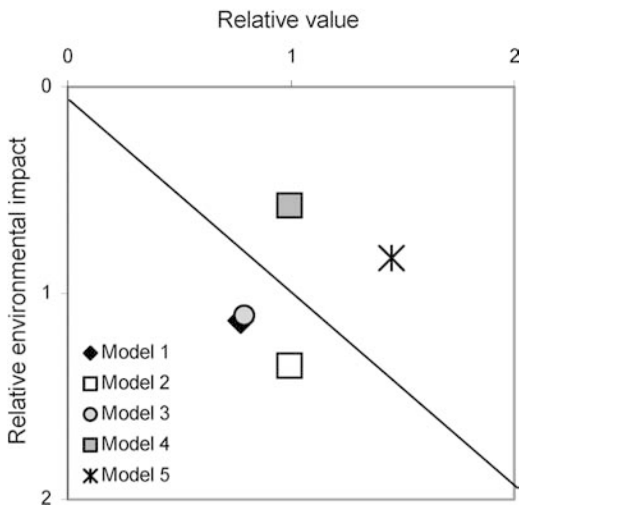

Fig. 11. Eco-efficiency for product value chains presented for different models of a product

Hopefully in the near future eco-efficiency indicators will also be of great use for environmental product declarations (EPD).

Corporate social responsibility (CSR)

In line with the introduction in this paper, the term corporate social responsibility (CSR) is often used to identify the business role in this context. However, CSR has no clear definition, and to discuss what it exactly embraces is a point in it itself. Growing public awareness, and demands for greater transparency, add a new requirement to communication and reporting. WBCSD has given the following description of CSR: "Corporate social responsibility is the commitment of business to contribute to sustainable economic development, working with employees, their families, the local community and society at large to improve quality of life". This means that the balance between a company's social responsibility and the corresponding responsibility for the efficient utilisation of key resources, including labour and capital, must be addressed. CSR requires open dialogue and constructive partnerships with the authorities at various levels, inter-governmental and non-governmental organisations and other elements of civil society, in particular, local communities; CSR is sometimes explained as "corporate citizenship". In addition to the economic and environmental performance indicators already mentioned, GRI also provides a list of social performance indicators. See Table 1 for the grouping and aspects of social performance indicators.

The Norwegian Research Foundation has established a research group on CSR. The mandate for this group is to plan the need for research within CSR seen from the industry's point of view as well as from the governmental and researchers'/universities' point of view. Given a clear statement of the need for further research, the planning group will come up with a program plan for future research programs. One area of concern will most likely be the development of appropriate social performance indicators (SPI) and cross-cutting indicators, see Fig. 1.

Conclusion

The function of GRI's performance indicators is to provide information about the economic, environmental, and _social impacts of the reporting organisation in a manner that enhances comparability between reports and reporting organisations. In the case of GRI, the indicators are designed to inform both the reporting organisation and any stakeholders seeking to assess the organisation's performance. To achieve these goals, performance must not only be defined in terms of internal management targets and intentions, but must also reflect the broader external context within which the reporting organisation operates. In the end, it speaks to how an organisation contributes to sustainable development by virtue of its economic, environmental, and social interactions with its diverse stakeholders. The combination of better methods (both for selecting indicators and for analysing them), and rising stakeholder demands for richer disclosure is likely to continue this movement toward a new generation of performance reporting. Full integration in the form of single reports that communicate performance along the three dimensions is already practised by a handful of leading companies. National and local efforts should focus on the development of appropriate indicators and testing of reporting systems. This presentation has shown that EPIs and economic indicators can be used on a small scale. However, it does not include social aspects or cross cutting indicators in the areas of socio-economic and socio-environmental. This is an area for further studies.

References

BABFO (2002) British Association for Bio Fuels and Oils, http://www.biodiesel.co.uk, May

DeSimone LD, Popoff F (1997) Eco-efficiency: the business link to sustainable development. MIT Press, Cambridge, Mass.

Fet K. (2000) The use of biodiesel in recreational boats. Final Year Project for BEng in Marine Technology, the University of Newcastle upon Tyne, UK, May

Fet AM, Michelsen O, Johnsen T, Sørgård E (2000) Environmental performance of transport—a comparative study. Norwegian University of Science and Technology (NTNU), Norway

ISO (1996) Life cycle analysis—general framework. ISO 14040, The International Standardisation Organisation

ISO (1998) Environmental performance evaluation. ISO 14031, The International Standardisation Organisation

Michelsen O, Fet AM (2002) Eco-efficiency along value chains—towards a methodology. Conference Paper, International Society of Industrial Ecology, Barcelona, Spain, December

Michelsen O, Fet AM, Dahlsrud A (2003) Eco-efficient value chains—status for research questions. Norwegian University of Science and Technology (NTNU), Norway, in preparation

OECD (2001) Policies to enhance sustainable development, OECD

Olivin A/S (2001) Environmental report

Saling P, Kicherer A, Dittrich-Krämer B, Wittlinger R, Zombik W, Schmidt I, Schrott W, Schmidt S (2002) Eco-efficiency analysis by BASF: the method. Int J LCA 7(4):203–218

Statistics UK (2000) Digest of United Kingdom energy statistics. Department of Trade and Industry, London

UNEP (2002) Sustainable reporting guidelines on economic, environmental, and social performance, August, UNEP's Global Reporting Initiative (GRI), see www.globalreporting.org

WBCSD (2000) Verfaille HA, Bidwell R (eds) Measuring eco-efficiency, a guide to reporting company performance, June

Zhou PL, Fet AM, Michelsen O, Fet K (2002) A feasibility study of using biodiesel in recreational boats in the UK, submitted to J Eng Mar Environ, May