Business organisational response to environmental challenges : performance measurement and reporting[1]

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Abstract

The measurement and reporting of environmental performance of business companies have been the subject of intense research efforts during the last few years. What appears from a survey of current literature is an obvious lack of standardisation of methods and procedures. Starting from the basic concepts and requirements of environmental performance measurement, we investigate how these can be put into practice, and we review and synthesize the recent trends and developments in the field. Particular attention is devoted to the various categories of methods allowing for aggregation of environmental information. Also, several existing categories of procedures are described and analysed in some detail, starting from impact categories, economic standardisation, to impact assessment, economic valuation and management indicators. The paper gives a summary of a recent reserach on indicators conducted at the European level, i.e., the MEPI project (Measuring Environmental Performance in Industry), and includes, as a second example, a short account of environmental indicators implemented at the Belgian cement company CBR. The text ends with some concluding remarks about the development of more general indicators of industrial ecology and sustainable development.

Outline

[1] This text is intended to be a chapter of the book prepared by the CEMS (Community of European Management Schools) Joint Teaching Group « Environmental Challenges of Business Management in Europe ». It was prepared using several published sources, among which Berkhout et al. (2001a, 2001b), Olsthoorn et al. (2001), Tyteca (1996), and Tyteca et al. (2001, 2002).

1. Introduction: the context of environmental performance measurement and reporting

Pressure is increasing on companies to report on the environmental impact of their activities. While in the previous two or three decades the behaviour of firms in this respect was mainly dictated by government, some companies have begun to recognise the potential benefits of behaving more consciously and proactively in this area. In parallel to this, there is an increasing need for tools that allow for a proper and objective measurement and benchmarking of the performance of firms with respect to the environment. As J. Ladd Greeno and S.Noble Robinson pointed out as far back as 1992: "Demands on companies to measure, document and disclose information about environmental performance will become more invasive – i.e., as the result of pressures from employees, neighbours, the general public, environmental groups and regulatory agencies. In the same way that public companies are measured by their financial results, environmental performance will increasingly become a critical factor to scrutinise".

Stakeholders use environmental performance indicators in different ways:

- Business managers use them as internal management tools and for external communication.
- Banks and insurers examine the environmental performance of firms to help assess longer-term economic risks.
- Fund managers use environmental criteria to respond to the demand for environmental and ethical concerns to be taken into account in investment decisions.
- Policy makers may evaluate the effectiveness of different policy instruments in improving a firm's overall environmental performance.
- Environmental groups compare the environmental profile of firms in order to put political pressure on poor performers.
- Neighbours observe to what extent companies damage their local environment.
- Researchers analyse patterns and trends to improve their understanding of the causes of good and poor environmental performance.

In all cases, indicators can provide only partial information that may need to be qualified with information from other sources. Indicators are deliberately simple measures that stand as proxies for complex and often diffuse phenomena. Indicators indicate: awareness of their specific limitations and biases is an important aspect of their interpretation.

Measuring the environmental performance of a company presents many challenges:

- Environmental issues are complex and often difficult to quantify.
- Comparing the environmental impacts of firms with different economic activities is problematic.
- There is no universally accepted approach to weighing different environmental impacts against each other, and any overall assessment will produce highly contested results.
- There is no standard approach to environmental reporting and measurement, although a range of guidelines has now been developed.
- The availability and quality of environmental data is often poor.

It is often argued that environmental performance cannot be compared because companies are different. However, the same could be said of corporate finance, yet the reporting of financial performance is routine. Distinctiveness should not stand in the way of comparison between competitors, be it in terms of profitability, market value or environmental performance.

Faced with these challenges, some researchers have decided to assess the 'greenness' of a company on the basis of qualitative criteria, such as whether they have adopted certified environmental management systems and environmental targets. These 'effort indicators' assume that management effort translates in a predictable way into environmental outcomes. There is little evidence as yet to support this assumption. In fact, the MEPI project has found that in some cases the reverse may be true (see section 4).

'Guideline-driven' initiatives towards environmental performance measurement, such as the Global Reporting Initiative (White 1999; Mullins 2000) or the eco-efficiency initiative led by the World Business Council for Sustainable Development (Verfaillie & Bidwell 2000), have concluded that quantitative assessment requires detailed environmental and technical data. Although this is a useful approach which may produce results over the longer term, it also has its drawbacks. Many firms are not willing or able to gather and disclose all the information required by these guidelines. Other voluntary schemes involving reporting, such as the European Eco-Management and Auditing Scheme (EMAS), also demonstrate that diffusion of guidelines into practice can be slow.

Environmental performance reporting and measurement has been a consistent theme in the literature on reporting. Many reports contain quantitative performance information, surveys and reviews have identified performance measures as being increasingly important through time, and much of the debate about standardisation has been over how standard sets of environmental indicators can be derived for firms. James (1994) suggested that six distinct frameworks for environmental performance measurement can be identified - production, auditing, ecological, accounting, economic and quality (see Table 1). James (1994) also argued that the diversity of environmental issues, organisational variables (size and management style), national circumstances and individual corporate strategies are likely to mean that performance measurement activities are likely to continue to vary between countries and industries. This prediction has been borne out in the many different reporting approaches and schemes adopted by companies (cf. van der Werf, 1998; Wright et al, 1998; NRTEE, 1997).

Table 1. - Frameworks for environmental performance measurement (adapted from James, 1994).

Approach	Orientation	Drivers	Measurement focus	Metrics
Production	Engineering	Efficiency	Mass/energy balance	Efficiency Resource use
Regulatory	Legal	Compliance	Management systems Risk; Non-compliance	Emissions/waste Risk
Ecological	Scientific	Impacts	Impact assessment Life cycle assessment	Emissions/waste Impacts Resource use
Accounting	Reporting	Costs Accountability	Liabilities	Emissions/waste Monetary
Economic	Welfare	Internalising externalities	Environmental valuation	Monetary
Quality	Management	Pollution prevention	Emissions/waste generation	Emissions/waste Monetary

In this paper we review and synthesize some of the advances made in the field of business environmental performance measurement and reporting over the last ten or fifteen years. As we will see, presently there is an obvious lack of standardisation among methods and procedures, especially as regards aggregation of environmental information. There is also an increasing need for more general indicators that would allow for assessing the contribution of business companies into the dynamics of sustainable development. The paper is organised as follows. In section 2 we will first review the objectives and definitions of environmental performance measurement and reporting. Then we will see how such concepts work in practice (§ 3), followed by two examples of full scale applications of environmental performance indicators (§ 4 and 5). The concluding section will contain remarks about the development of more general indicators of industrial ecology and sustainable development.

2. Requirements and definitions of environmental performance indicators (EPIs)

An **indicator** can be broadly defined as a measurable quantity or parameter established from observable or calculable quantities. An **environmental indicator** is one that is supposed to reflect in various ways the different impacts of an activity on the environment and the efforts made to reduce them. In their strictest sense, **environmental performance indicators** (EPIs) reflect the environmental efficiency of a production process involving quantities of inputs and outputs.

In order to accomplish their purpose in an appropriate way, EPIs have to possess several characteristics, that can be related to the structuring of objectives (see, e.g., Keeney & Raiffa 1993). For practical purposes, desirable EPI characteristics can be listed as follows (OECD 1993; Bartolomeo 1995; ISO 1997; Rauberger & Wagner 1997; Skillius & Wennberg 1998):

- **Relevance**: Indicators must provide information that responds to company's and stakeholders' needs. Every indicator contributes to fulfil one or several objective(s) with which it is linked. The relevance criterium implies **simplicity** in the interpretation and comprehension of indicators. In order to be relevant, an EPI should adequately reflect the relationship between a company and the environment, among others through input and output flows. Bartolomeo (1995) speaks in this case of **significant** measures that cover all important aspects. This also implies **comprehensiveness**. Finally, an EPI should result from an **agreement** among stakeholders (users), as to its validity and utility.

- **Accuracy of analysis**: This criterion means that indicators should be based on sound theoretical foundations, both in scientific and technical terms. This implies that they should be **objective** and **unambiguous**, in order to guarantee, on the one hand, a fair and synthetic representation of the situation or phenomenon under consideration, and on the other hand, the coherence of indicators in time and space, to allow for comparison, monitoring, and identification of trends. The accuracy of analysis also implies that there should exist a limit or **reference** value to which the indicator can be compared, in order to allow the users to assess the meaning of its value.

- **Measurability**: This characteristic pertains to the **data** that are the basis for constructing an indicator. Such data should be immediately available or accessible with a reasonable cost/benefit ratio. An indicator should be **sensitive** to the data; i.e., for a slight variation of the observed process, the indicator must show a variation with acceptable response time and error margin. Measurability also pertains to the **form** of EPIs. These should be quantitative as much as possible, and qualititative only if this is not possible. One should be aware, however, that there almost always exists a gap between what should be measured in theory and what can be measured in practice.

- **Comparability**: This is an important objective in the use of EPIs. Namely, EPIs should allow one to fulfil one or several of the following functions: (1) monitoring the evolution of performances of a given unit (process, plant, company, sector …) over time; (2) comparing several plants of a given company that perform the same kind of production; (3) comparing several companies among a given industrial sector; (4) comparing different sectors among themslves; …

With these requirements in mind, Bartolomeo (1995) proposed a useful scheme for classifying and defining EPIs. It is given in Figure 1. As can be seen, two broad categories of indicators correspond to their scope: **performance** indicators sensu stricto pertain to what actually happens inside and around a company, a plant, or a process unit, whereas **impact** indicators tend to reflect what happens outside of the company, the plant, or the process unit, i.e., what actually happens to the environment as a result of the activities of such an entity. In both cases, indicators can be evaluated either (1) in *physical* terms, by relating the performance to physical quantities such as input materials used, waste flows, energy consumption, quality of the air and the water in terms of concentration of polluting substances (process performance indicators and physical impact indicators), (2) in *financial* or *monetary* terms, through monetary valuation of the physical impacts or processing activities of the entity considered. Finally, as mentioned above, performance indicators can incorporate *system* indicators, used to reflect the effort accomplished by a firm, a plant or a process unit to attenuate its impacts on the environment. Figure 2 gives a "zoom" on the sensu stricto performance indicators, by specifying which kind of information can be taken into account to evaluate these quantities. It should be understood that the list of components enumerated is not meant to be comprehensive and is only given here as an example.

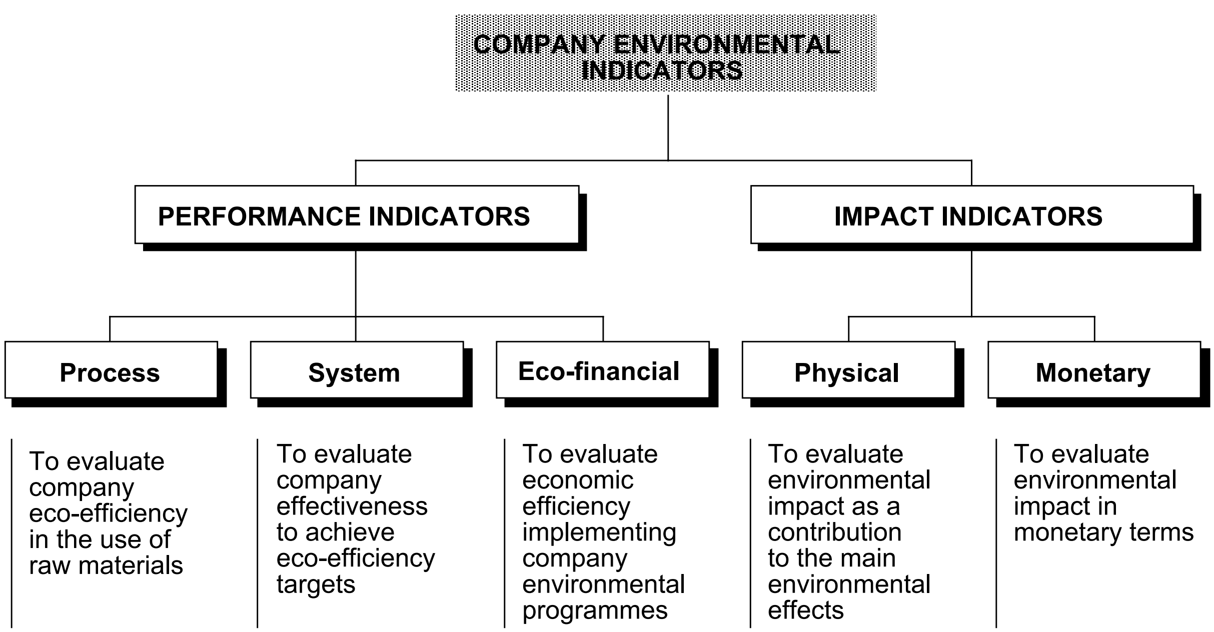

Figure 1. - Several categories of environmental performance indicators, stating their scope and goals (from Bartolomeo 1995).

A special case of physical impact indicator is the **Life Cycle Assessment** (LCA - SETAC 1997). This can be defined as "the process of evaluating the effects that a product has on the environment over the entire period of its life cycle" (UNEP 1996). The expression "from cradle to grave" is often used. This implies that all impacts at the production and consumption stages, from the extraction of raw materials to final disposal, be enumerated and evaluated, including the numerous waste, effluent, emission and recycling flows during all intermediate stages (incorporating, e.g., transport activities), as Fig. 3 illustrates. By contrast, process environmental performance indicators concentrate on a given industrial process, taking into account the inputs flowing in and outputs flowing out - including effluents, emissions, wastes - of the process.

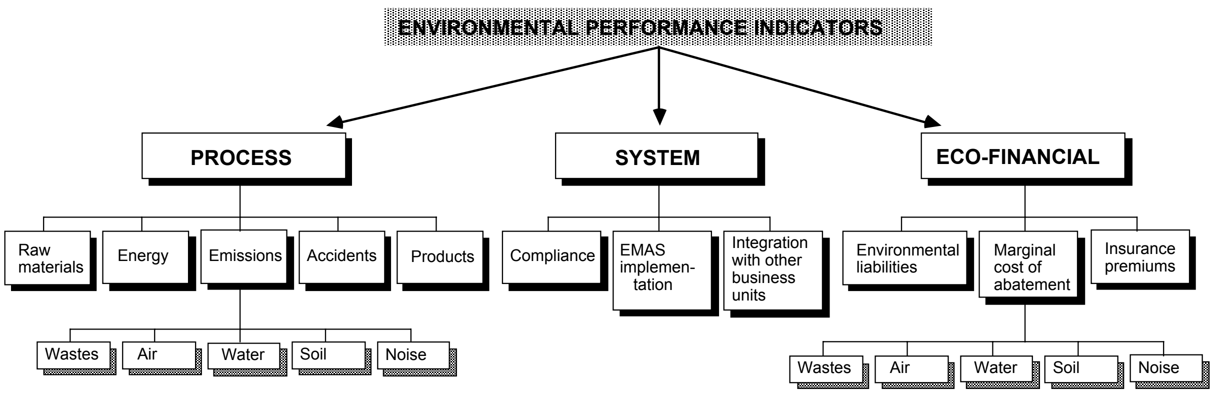

Figure 2. - Environmental performance indicators sensu stricto, with examples of information that has to be taken into account (from Bartolomeo 1995).

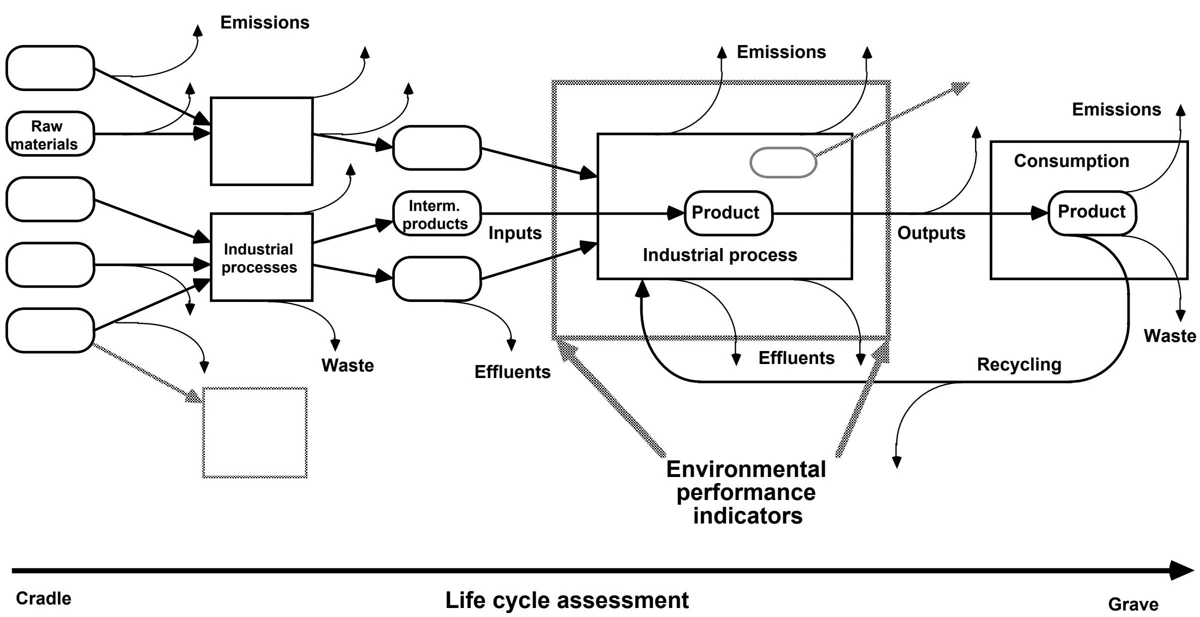

Figure 3. - Illustration of the components taken into account in a life cycle assessment process, in comparison with simple process environmental performance indicators.

3. Building EPIs: from concept to practice

3.1. Basic Concepts

The literature and practice review (as in Olsthoorn et al. 2001) shows that there is a great diversity of individual approaches to gather, make sense of and publish environmental information caused by and attributed to corporate activities. However, at the moment little comparability exists and environmental data is often displayed without known standardisation or conversion factors, and with limited information as to what the data refers to or includes. This makes comparability for external users difficult and external information users may find it difficult to make sense of such data. To increase transparency of performance and to increase credibility, it is preferable that all environmental data be normalised after which step the data can be standardised and / or aggregated to suit particular information needs (Figure 4). This sequence should improve comparability of data (through standardisation), as well as reduce data complexity and increase the usability and suitability of data (aggregation).

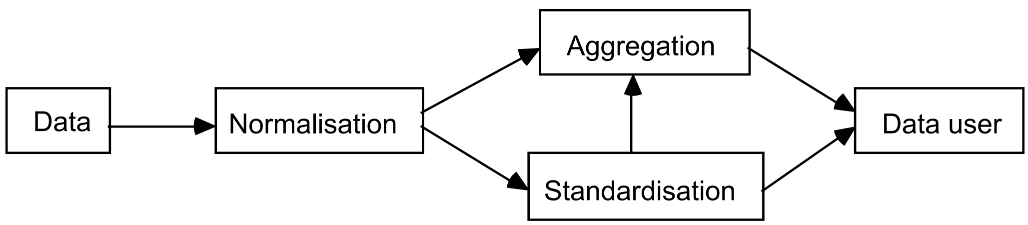

Figure 4. - Stepwise approach to development of Environmental Indicators.

Standardisation refers to efforts to increase the comparability of environmental data, between years, sites, functional units, products or resource uses. The most common activity to standardise is normalisation, which transforms data into compatible or comparable forms. **Normalisation** ensures that data is converted to units or to a form which relates it to a chosen standard or baseline or that it has common units (see section 3.3). By contrast, aggregation refers to the transformation of data into different forms or formats to allow a better understanding or interpretation of the data. **Aggregation** of information aims to produce simple, but meaningful indicators that reflect a firm's overall environmental performance (Tyteca 1996), i.e., indicators should be as simple as possible but as complex as necessary. To convert large amounts of data into managerially useful information appropriate metrics is necessary (James & Bennett 1996).

Aggregated physical indicators serve as summary indicators and give an overview of total resource use, emissions and waste without being relative to production. Higher aggregation allows the presentation of larger or more complex production units into an overall picture, thus allowing for the interaction and interdependency of environmental effects. However, greater data aggregation also implies less relevance for local or highly specific environmental issues. We suggest that data aggregation is guided by the subsidiarity principle, namely that data is to be aggregated to the lowest level of the organisational hierarchy where the decision (about production and/or data gathering) can be made appropriately.

A special aspect of data aggregation is the use of Potency factors, such as Ozone Depletion Potential, or Global Warming Potential. Conversion or potency factors become relevant in intra-impact assessment that aims to aggregate emissions of different physical/chemical nature into physical indicators for pressures on various environmental endpoints. Common measurement units for physical EIs are physical, chemical and biological units. Attempts to aggregate several indicators will result in dimensionless measures (Tyteca 1996) and these will be outlined below in sections 3.3 - 3.5.

3.2. Impact Categories and Indicators

In policy making, the issue of changes in the environment is conceptualised as an ensemble of environmental problems of more or less different nature, that can be addressed more or less mutually independently. The impact of an emission (environmental pressure) relates then to such environmental problem (e.g., the climate problem, waste production). Following the practice in Life Cycle Assessment of products (SETAC-LCA 1997) we call these problems **impact categories**. In the ISO terminology one speaks of "environmental categories" (ISO 14042).

The concept of "an environmental problem or impact category" is a social construct, and listings of environmental problems, therefore, differ with the contexts within which impact categories have been identified. For instance, Table 2, first column, lists impact categories that are often used in product LCA. The second column shows impact categories as they are perceived in the wide European context of environmental (quality) policy making. These indicators refer to environmental condition in countries, and not to impacts of firms. The third column lists impact categories as distinguished in a paper on corporate environmental policy. This list shows that from a firm management point of view there can be several topics that are relevant for constructing indicators for corporate environmental policy making.

An environmental impact may be the result of different environmental pressures. For instance, the change in the condition of the ozone layer is the result of the emissions of different substances. Similarly, the acidity of soils and surface water can be changed by different pollutants. In those cases there are possibilities to normalise the impacts of these environmental pressures (e.g., emissions) with respect to their impacts (e.g., impacts per kg emission).

3.3. Economic Standardisation (Business Activity Indicators)

A particular category of indicators are labelled here economic indicators as they link the information provided by physical and impact indicators with relevant information on the activity of the production or business units under investigation. Economic, financial and/or monetary quantities can be used to normalise or scale the information contained in other kinds of indicators, i.e., physical and/or environmental, or even impact indicators. Thus the indicators derived from such a normalisation will generally take the form of ratios, in which the numerator contains the physical information, and the denominator, the economic or financial information:

$$Indicator = \frac{\text{Physical and/or environmental quantity}}{\text{Economic and/or financial quantity}}$$

The quantities that can be used at the denominator should reflect adequately the size and/or the activity of the production unit. Table 3 provides a (non-exhaustive) list of possible quantities.

Table 2: Topics in environmental policies in different decisions contexts.

Product policy. LCA-community SETAC (Udo de Haes, 1996)	EU-environmental quality policy (EUROSTAT 1998; Lammers et al. 1999)	Corporate environmental policy indicators (Brophy, 1995 in Azzone et al. 1996).
Depletion and competition of abiotic resources Depletion and competition of biotic resources Depletion and competition of land Global warming Depletion of stratospheric ozone Human toxicological impacts Ecotoxicological impacts Photo-oxidant formation Acidification Eutrophication Odour Radiation casualties Noise	Air pollution Biodiversity loss Climate Change Marine environment and coastal zones Ozone layer depletion Resource depletion Dispersion of toxic substances Urban environmental problems Waste Water pollution and water resources	Waste minimisation, reduce consumption of non-renewable resources, energy efficient Shared responsibility Environmental training Targets and objectives set beyond minimum compliance Public disclosure Sustainable development Habitat conservation Research and development BS7750, EMAS World-wide standard Compensation for environmental damage Legislative compliance, liability on environmental issues

Table 3. Possible proxies of economic activity used as denominators in Environmental Indicators defined as ratios.

Denominator	Units	Availability	Drawbacks
Output (less input use)	Physical	Good	Comparison across sectors; product diversity; relative weights to outputs and inputs
Turnover or sales	Financial	Good	May be over-rated
Shipment value	Financial	?	
Value added	Financial	Fair or difficult	Problems of definition
Operating profit	Financial	Good	
Number of employees	Number	Good	Differences in labour intensities across sectors
Total investments	Financial	Good	Reflect only a part of the activity

- *Physical production* is well suited in situations characterised by one unique physical production output, e.g., tons of pulp in the pulp and paper sector, or kWh in the electricity sector; which makes it suitable to compare plants or companies within the same sector.

- *Turnover* or *sales* are often promoted in studies on the measurement of environmental performance, because they are simple and readily available in most situations. However, when considering production chains, there may be problems of double accounting and therefore overrating. Looking at environmental performance within a sector, a better measurement may therefore be the *shipment value* (Martin et al. 1991).

- *Value added* is often advocated as a good candidate because it is supposed to reflect the contribution of manufacturing activity to the global welfare, as measured, e.g., by the national GDP. However, while its definition at a macroeconomic level does not pose particular problems, definitions at the corporate level may vary, depending upon the assumptions and standpoints adopted, and in some cases upon the context (Huizing & Dekker 1992). Economic value added used at corporate level refers to above “normal” return on capital. This concept is not easily observable and usually not reported by firms. Additionally, a particular problem regarding economic comparisons across sectors/nations is the different degree of internalisation of environmental costs by the price mechanism. Firms in an economy with few environmental taxes will be economically favoured compared to firms operating in economies with “green taxes”. Indicators normalising with value added or profit would thus favour firms in economies with low degree of internalisation (see also § 3.5).

- The *number of employees* may be another proxy for the manufacturing activity; it is readily available and does not entail the problems linked with financial quantities (Bartolomeo 1995; Templet 1993). There may be additional problems using that quantity, due, e.g., to different labour intensities in different sectors and/or different countries.

- Finally, *total investments* may be taken as a substitute to either turnover or value added.

3.4. Aggregation

Taken globally, one important issue with environmental indicators is that we come up with a large multiplicity of data and measurement units. Therefore, to allow for proper comparisons, one has to consider methods to **integrate** or **aggregate** various parameters from different levels of analysis. This is the issue raised in the more general problematics of objectives structuring, that makes part of multiattribute decision analysis (see, e.g., Keeney & Raiffa 1993). Hereafter we review some of the existing procedures that are relevant in the assessment of business environmental performance, and were either elaborated on the basis of empirical standpoints, or constructed starting from theoretical multiattribute analysis.

One very simple example of aggregation has been proposed at the World Bank for comparing the environmental performances of entire industrial sectors (Martin et al. 1991; Beede et al. 1993). These authors defined an index that reflects the toxic intensity of pollutants selected according to the US TRI (Toxics Release Inventory) scheme (EPA, 1989, 1992). For a given plant or firm,

$$\text{Pollutant risk} = \Sigma \text{ pollutant x toxicity weight}$$

Then they computed the pollutant intensity index of a given plant or company (or even a whole industrial sector) by dividing by the total manufacturing activity, which yields an example of a normalized aggregated indicator:

$$\text{Pollutant intensity index} = \text{Total pollutant risk}/\text{Total manufacturing activity}$$

The quantity supposed to reflect the manufacturing activity was taken as the shipment value. Martin et al. (1991) and Beede et al. (1993) used this index to assess the variation in the generation and management of industrial waste (which appeared quite significant, especially accross firms of a given industrial sector !), or to rank the U.S. industrial sectors according to their pollutant intensities.

Other methods of aggregation have been developped in business companies and published in their environmental reports. Examples include Belgian initiatives such as Solvay (1993 - indicators were defined as sums of impacts within different categories - air pollution, water pollution, wastes -, weighted by relative toxicity coefficients reflecting the gravity of impacts) or Obourg (1993 - indicator taken as the surface of a multidimensional figure, i.e., a radar, whose axes are the individual pollutant concentrations divided by corresponding standards).

A further class of aggregate indicators may be derived from the productive efficiency framework. This methodology is based on quantities and information that are readily available, i.e., physical and economic/financial quantities. A detailed discussion of the approach can be found in Tyteca (1996 and 1997).

Essentially, the principles of the productive efficiency analysis are based on the premise that a production unit that produces more of output with the same level of inputs, or releases less of undesirable outputs (i.e., pollutants) for a given level of output production, is more efficient. Based on that standpoint, for a given set of similar observed production units, the method then constructs a so-called production frontier, such that observations lying on the frontier are declared "efficient", while observations lying inside the frontier are declared "non-efficient", implying that the latter have productivity slacks and that they can improve either their output production or their release of undesirable outputs. The method is an aggregation method in the sense that all relevant information taken into account (i.e., production inputs and outputs, pollutants, financial quantities) are aggregated using self-defined weighting coefficients, to produce an aggregate quantity, conventionally taken as 1 for units that are efficient, and less than 1 for non-efficient units. For each producing unit, the method (based on linear programming techniques) seeks a weight combination that will yield the maximum value of the efficiency. If the unit is efficient, that value will be 1; if no weight combination exists such that efficiency takes the value 1, the unit is non-efficient. The prodution frontier may be paralleled with the concept of best available technology, since points lying on the frontier reflect best practice, relative to the observed data set.

The frequently advocated advantages of productive efficiency methods include standardisation, flexibility (since various ratio alternatives can be formulated right away), robustness of the associated linear programming methods, and "objectivity", because the weights are self-defined. However, we should also be aware of one other potential drawback of productive efficiency, i.e., the high sensitivity of the results with respect to the number of factors and units considered; one should therefore be aware that a given result can only be considered with reference to the associated data set. However, this is no longer a drawback if we recall that best practice, or best available technology, is always a relative concept that heavily depends on what actually exists. In general, the higher the number of observations, and/or the lower the number of variables, the better the discriminating power of productive efficiency methods. The productive efficiency methods such as described can provide us with aggregate environmental indicators, that can be termed "economic", because they are grounded into a theory that is basically economic.

A simplified variant of the productive efficiciency (PE) analysis can be found in Jaggi & Freedman's (JF) methodology (see Jaggi & Freedman 1992; Tyteca 1996). In brief, the principles of JF indicators are as follows. Their philosophy is quite comparable to PE methods, in the sense that for a given set of analogous units devoted to a given type of production, and characterised by a few variables reflecting inputs and (un-) desirable outputs, reference is made to the units that perform best. The essential difference is that here, the variables are compared one by one to their best possible value among the observed set, instead of being taken together; afterwards, the individual scores are summed using an arbitrary weight of 1. Dividing the value obtained by the number of variables will yield a standardised indicator whose value will be less than or equal to 1. Details about the method and formulations can be found in other references (e.g., Tyteca 1997). It should be noted here that, because the chance that a given plant be the best in all criteria is low, JF indicators will usually take values strictly less than 1, whereas this is not the case with PE models, where the score 1 corresponds to points located on the frontier.

3.5. Impact assessment and economic valuation

The final step of a LCA type of impact assessment results in an appraisal that contains subjectivity since in the final judgement the opinion of (a group of) individuals is decisive. Economics offers a methodology to avoid such subjectivity. The economic approach attempts, at least conceptually, to apply societal judgement as it is revealed by market prices. In practice, this methodology is difficult to follow since there is no market for the type of economic goods (e.g., environmental quality) that impacts ‘constitute’.

Activities that cause environmental concerns are also beneficial to individuals. From a welfare economics perspective, a firm’s activities pose an (environmental) problem if the valued concerns are larger than the valued benefits (optimal welfare is defined here as a Pareto optimum). In a world which is ideal according to neo-classical economics, concerns and benefits are priced by the market mechanism and in such world there is no problem; that is from a societal point of view (individuals may still have problems). However, in the real world there are concerns that are not adequately priced. These are called externalities of economic activities (e.g. safety in transport, environmental externalities). Taking this view, the impact categories that should be taken into account should relate to environmental externalities. So, in a way, impact categories refer to a type of environmental externalities.

A method based on the economic valuation of environmental impacts is known as the "value added - value lost" method. It uses the following definitions (Huizing & Dekker 1992):

Cost of environmental effects = Environmental costs relating to the processing
or treatment of emissions + costs of residual effects

Cost of residual effects = Residual effects expressed in monetary terms

Environmental expenditure = Payments to third parties + environmental taxes - environmental grants

Value lost = Costs of the environmental effects caused by a company's operations, less the company's expenditure on mitigating these effects

Net value added = *Value added - value lost*

The value lost may be taken as an overall assessment of the environmental burden of a company, provided all relevant information on the use of resources and the discharge of waste and pollutants is available, and provided appropriate cost equivalents have been quantified using adequate methods. However, in situations where the emphasis is on comparison, a more meaningful environmental indicator would be a ratio defined as

Environmental Indicator = value lost/value added

There are various methods with which the aforementioned quantities may be evaluated (see, e.g., Turner et al. 1993; Gray et al. 1993). However, the effort required for data collection and economic assessment is still high and may turn out to be prohibitive in many practical situations. As an example, Table 4 compares the results obtained in three situations, the first of which has been largely developped and commented in the literature (the Dutch software company, BSO/Origin - see, e.g., Huizing & Dekker 1992, Gray et al. 1993), while the other two are rough, approximate, unpublished applications based on two Belgian cases from manufacturing sectors (Graceffa 1991; Leclef 1991). As can be seen, even if those cases implied rough evaluations and crude approximations, the magnitudes obtained for the value lost/value added ratio come in a quite logical gradation, while the value lost can be of the same order (and even exceed in some cases, not shown) as the value added, which would imply that, globally speaking, the company is doing more harm than it produces goods !

Table 4. - Compared green accounts between one service company and two manufacturing companies

	BSO/Origin (MNLG)	**Belgian food company (MBEF)**	**Belgian fertilizer company (MBEF)**
Total environ^{tal} costs **- total envir. expenditures**	3.613 - 0.254	95.4 - 0.133	934.1 - 41.0
Value lost	3.359	95.3	893.1
Vale added	377.3	1365.6	1254.7
Net value added	373.9	1270.3	361.6
Value lost / Value added	0.89 %	6.98 %	71.2 %

As an alternative to methods based on financial evaluation, it can be suggested to group information on emissions of stressors, using types of environmental impacts caused by pollution as a criterion for aggregation. This step includes assigning the data on environmental interventions (emissions, environment pressures, and stressors) to impact categories. In both SETAC-LCA circles (Heijungs and Hofstetter, 1996) and ISO proposals this step is called classification. The calculation of the physical indicators is carried out by multiplying emissions with a factor. Such factor is called a characterisation factor (Udo de Haes, 1996), potency factor (Wright et al., 1998) or equivalency factor (Hauschild and Wenzel, 1998). Udo de Haes (1996) distinguishes three broad groups of impact categories, namely (a) resources' and related impact categories; (b) human and eco-toxicity; and (c) non-toxic pollution.

Some studies have applied a broader approach, with the indicators 'energy consumption' or 'tonnes of materials consumption'. These are aggregate measures. However, these indicators should preferably not be used in combination with impact categories discussed above since double counting may occur.

3.6. Management indicators

Management indicators (MIs) do not per se belong to the categories of standardised or aggregate indicators. They are mentioned here because they yield complementary information that is often used as explanatory of the environmental performance as quantified by the physical, economic or impact indicators.

MIs should provide information on the organisation's capability and efforts in managing matters such as training, legal requirements, resource allocation, documentation, and corrective action which have or can have an influence on the organisation's environmental performance. These MIs should assist evaluation of efforts undertaken by management and actions to improve environmental performance. Two broad classes can be identified, which (caricaturally) are referred to as "qualitative, subjective" and "quantitative, objective".

The first class of MIs corresponds to those described in the Business Environment Barometer (e.g., Belz & Strannegård 1997). They are designed for the measurement of perceptions, attitudes, and strategies towards the environment. They also need global surveys to allow for the assessment of the influence of various factors on perceptions and attitudes, or for cross sectoral comparisons. Since there is no standardisation as to what is a "good" or "bad" attitude or perception, even if we translate such information on Likert scales, there may be little relationship between these and physical or impact indicators, especially if we want to compare results from different surveys.

The second broad class of management indicators have the same goals as the previous ones, i.e., assess the efforts made, but here the information is based on quantified, verifiable information. For instance, the European Green Table (1997) highlights examples of MIs as: Environmental investments; Running costs pertaining to environmental protection (fees, personnel expenses, fines, energy, maintenance); Number of employees with specific environmental tasks; Number of reported incidents; Degree of compliance with regulation. Some of the categories may be hard to distinguish and/or assess. As a traditional example, what is the part of total investments that is devoted to the environment? This may be easy to answer in the case of end-of-pipe treatment investments, but much harder in the case of new (cleaner) production technologies.

4. Example 1: the MEPI project (Measuring Environmental Performance of Industry)

4.1. Scope of the project

The MEPI project, funded by the European Commission, grouped researchers from six EU countries around the problematics of evaluating and comparing the environmental performance of business companies within six industrial sectors. The project, which lasted from 1998 through 2000, was pioneering in the sense that it was one of the first attempts to collect and standardise existing data from these sectors, and starting from these, to build and evaluate indicators that would allow for performance evaluation and help decision makers in taking adequate actions, both at the public and corporate levels. The MEPI project aimed to demonstrate that robust quantitative analysis of industrial environmental performance can be carried out on the basis of publicly available information. To achieve this, a balance had to be found between doing justice to complexity on the one hand, and pragmatism about data availability and quality on the other hand.

Environmental performance indicators should aim to compare the comparable. In most cases, this means comparing companies and sites within the same economic sector on an annual basis. For example, benchmarking the energy use of an insurance company with the energy use of a chemical firm may not generate useful results to either. Sometimes, if companies within the same sector use processes with very different environmental profiles, it may be necessary to define sub-sectors.

The MEPI approach distinguishes between variables and indicators. Through literature reviews that identified the environmental profiles of different industry sectors, and following consultation with representatives from industry, policymaking and financial organisations, indicator sets for each of the sectors studied were generated. These presented identifiable data requirements. Data is collected for this set of variables - for example CO_2 emissions or profits - providing the information necessary to measure environmental performance. In a second step, indicators are constructed from these variables (Figure 5). In most cases indicators are simple ratios of two variables (e.g. water consumption per tonne of paper produced).

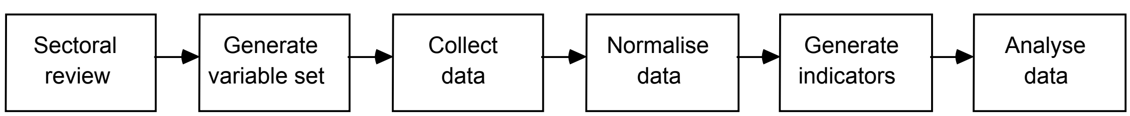

Figure 5: the process of data collection, indicator development and data analysis.

When comparing indicator sets across sectors, it is clear that many environmental issues are generally applicable, for example energy use, greenhouse gas emissions and water consumption. Other problems are specific to certain production processes, for example nuclear fuel discharges and copper emissions. Therefore, MEPI uses a combination of generic and sector-specific variables. This approach reduces complexity while also providing some flexibility. Details are given in Berkhout et al. (2001a) and Tyteca et al. (2001); see also the web site http://www.environmental-performance.org.

The MEPI approach also has some limitations:

- The approach is based on economic sectors and their different environmental characteristics. However, an increasing number of large companies operate in a wide range of sectors. The sectoral frame and the comparisons that flow from it may therefore need to be treated with caution.
- The MEPI approach assumes that companies within a sector or sub-sector face similar environmental challenges. It is less suitable for sectors with more diverse products and processes.
- Environmental data is usually focused on production processes. Currently, it does not provide a means for assessing the environmental performance of goods and services provided by a firm over their entire life cycle.

4.2. Overview of results

The results obtained in the scope of the MEPI project are described fully in a report to the European Commission (Berkhout et al. 2001a; http://www.environmental-performance.org) ; some details are also given in Tyteca et al. (2001) and Wehrmeyer et al. (2001). Below we give an overview of the general results. Table 5 gives an idea of the data coverage, by country and sector. It must be said that although the global coverage appears rather good in several sectors, there were many blanks in the data, due to the unavailability of values for many of the variables that make part of the MEPI database. In order to account for this, and to identify the most significant variables that influence the companies' environmental performance, statistical analyses (i.e., principal component analyses) were conducted (see details in the references given above).

Table 5: distribution of firm-years* across countries and sectors.

Sector / Country	Pulp & paper	Fertiliser	Textile finishing	Printing	Electricity generation	Computer manufacturing	Total
Austria	23		1	4	2		30
Belgium	24	19	14		15		72
Finland	3						3
Germany	78	6	30	52	31	16	213
Italy	38	16	26	19	73	16	188
Netherlands	70	20	43		7		140
Sweden	11						11
UK	22	20			17		59
Total	269	81	114	75	145	32	716

* A firm-year is a firm observed over one year ; this is the unit used for gathering the data (one firm can be observed over several years, which yields data for several firm-years).

Analysis confirmed that aggregate environmental performance can be adequately reflected by a subset of the variables incorporated in the database. These results have important implications for the statistical analysis carried out. Construction of performance indicators, benchmarking and analysis of explanatory factors were based on those variables that appeared to be both sufficiently available within the dataset and were found to be significantly influential on environmental performance. Also, the analyses that could be performed depended on the sector analysed.

One aim of the MEPI study was to understand better underlying patterns in business environmental performance. In particular, it was important to understand whether there are relationships between aspects of business and management performance and environmental performance (for instance, do more profitable firms perform better environmentally?). Regression analyses were carried out, using the reduced core variable sets only. All regressions were conducted using environmental indicators normalised by 'functional unit (FU)'.

Rankings of firms have been obtained with different sets of indicators, for five MEPI sectors (book and magazine printing, electricity generation, fertiliser production, pulp and paper manufacture and textile finishing - see details in Berkhout et al. 2001a). Company rankings are a powerful way of using greater transparency in corporate environmental performance to influence management decisions. However, rankings of performance must be treated with caution. A lower rank does not necessarily indicate poor environmental management. It may be explained by the technological, market or regulatory constraints the firm operates within. For example, its products may require a particularly energy-intensive production process. Besides the company level, results were also obtained at the site level, with some particular methodological issues regarding, among other, aggregate indicators (Tyteca et al. 2001). An example showing water use by printing firms is shown in Table 6.

Table 6. - Ranking table - Printing Firms on Water Use (Energy Input per Employee).

Rank	Firm or Business Unit	GJ/employee*
1	Georg Kohl GmbH & CO	39.82
2	Ludwig Auer GmbH	48.16
3	Monti n.v.	91.33
4	Enschede-Van Muysewinkel n.v.	98.52
5	Alfred Wall AG	172.78
6	Bischof & Klein GmbH & Co	186.67
7	Stark Druck GmbH	275.08
8	MFF519	281.67
9	MFF521	307.23
10	Schlott Tiefdruck GmbH	308.66
11	MFF504	355.24
12	MFF520	2053.98

* Mean value for all available years.

4.3. Methodological results

The MEPI project generated methodological and analytical results leading to a number of policy conclusions, the most salient of which are discussed here. Evidence supporting these conclusions can be found at the project website (http://www.environmental-performance.org).

- Although measuring environmental performance poses many challenges, the MEPI study has demonstrated well-founded analysis of performance on the basis of publicly available data that can be conducted in some industrial sectors.
- After several years of experimentation and fragmentation, there is evidence of methodological convergence between different approaches to environmental performance measurement proposed by the Global Reporting Initiative (GRI), World Business Council for Sustainable Development (WBCSD), MEPI and others. All stress the need for a consolidated core set of indicators, as well as sector-specific indicators. MEPI provides the most comprehensive piloting of this approach across several industries.
- Because the environmental impact of businesses can be analysed at multiple levels (process, production site, business unit, and firm) and has multiple dimensions (energy use, resource use, emissions, and environmental management), data needs are potentially large. It is crucial to focus on the most relevant elements of corporate environmental performance. The MEPI study developed an approach to focusing analysis on indicators with high explanatory value, so reducing data collection and analytical effort.
- There is frequently a mismatch between the functional units which are most appropriate (value added and profits) and those for which data is available (employees and production output). Variables for which data availability is better were frequently used in the MEPI analysis.

4.4. Analytical results

- Core indicators: analysis of the MEPI performance data suggests that a small number of indicators give a relatively good representation of the overall environmental performance of a firm.
- Performance variability: performance between firms tends to vary widely for most sectors and indicators analysed. Frequently the range of performance spans orders of magnitude. The main explanation appears to be the production technology used, but significant variability in performance was also revealed between companies using similar technologies.
- Performance trends: in cases for which time series data was available, change in environmental performance did not occur progressively over time. This is because performance is dependent on two factors, one environmental the other related to business performance.
- Size effect: the size of the production site appears not to be related to environmental performance. The relationship between firm size and environmental performance seems from our data to be mixed, depending on the sector and variable concerned. This is an interesting result since large firms are generally held to have both greater internal capabilities to manage environmental performance, and to be under more sustained regulatory pressure. However, the result appears not to confirm that smaller-scale niche operators use technologies with distinct environmental advantages.

- Profit effect: there is little evidence, on the basis of the MEPI data, of a link between high profitability and high levels of environmental performance, but neither is there evidence of a negative correlation.
- Environmental management effect: firms with a certified environmental management system do not appear to perform better than those without, although at both the site and firm levels the statistical significance of this result was low. In some cases, firms with certified environmental management systems performed worse. At the firm level, the only exception was found in fertiliser production (lower nitrogen emissions to water among ISO/EMAS registered firms). At the site level there is some more evidence of a positive influence of environmental management systems. The thinness of the evidence for an ‘environmental management effect’ is somewhat surprising, given the expectations that voluntary schemes would have a positive impact on performance.
- Technology effect: perhaps not surprisingly, the environmental performance on the site-level is strongly related to the sub-sector in which the site is operating, and the process technology being used.

4.5. Policy issues

There are a number of reasons why **transparency** is becoming a key principle in environmental policy:

- Citizens demand the right to know whether companies are behaving responsibly
- Environmental competition between companies (competition on environmental performance, as well as on price and quality) requires a common information, reporting and analytical basis.
- New voluntary and market-based policy instruments are more information-intensive. Markets for environmental services cannot operate without transparency.
- Evaluation of environmental policy impact needs to be based on empirical evidence. Without evidence of benefit commensurate with costs, the legitimacy of a policy is undermined.

The MEPI project has demonstrated that an information base for conducting integrated analysis of the environmental performance of European industry is becoming available. It has also demonstrated the major weaknesses and gaps that still exist in this information base. The level of performance reporting varies widely between countries, sectors and firms.

EU and national-level policy can play a critical role in encouraging and mandating an extension of performance reporting by more firms in more sectors. While governments are beginning to encourage more measurement and reporting, the commitment to these transparency measures remains weak. Widespread benchmarking will enable firms to set targets for improving eco-efficiency, as well as providing incentives for doing so by informing shareholders, customers and regulators about sites' and firms' relative performance.

The process of standardising environmental data collection, reporting and performance measurement needs to be supported by policy measures. Many voluntary standardisation initiatives have produced conceptual frameworks, but few practical tools. Sector-based voluntary and mandatory schemes also need to be considered.

The MEPI project also confirmed the wide intra-sectoral **variability** in measured environmental performance (across both regulated and unregulated performance measures) in EU industry. Some of this variability can be explained by technological differences within sectors and some by differing regulatory standards and enforcement. However, these preliminary results suggest that there remains much potential for improving the eco-efficiency and for reducing the environmental impact of European industry.

The results of the project also show that many assumptions about environmental performance need to be revised. In particular we have been unable to detect clear links between firm size and environmental performance, and between a firm's location and environmental performance. Small southern European firms seem equally likely, on this evidence, to be as good performers as large northern European firms.

Policy has a role in both widening the scope of environmental performance benchmarking between firms on an EU basis and for using this information in the development of new policy and the implementation of existing policy.

Over the last ten years many companies have adopted **environmental management systems**, whether registered or certified or neither. There has been a widespread expectation that these new management approaches would lead to tangible benefits in terms of improved environmental performance. Many companies have argued that 'regulatory relief' should be given to firms with environmental management systems.

The link between environmental management and performance was analysed statistically in the MEPI project. In general, we do not find that those companies with a registered/certified EMS perform significantly better than those without. Indeed, in some cases they appear to perform worse than those without an EMS. This is an unexpected result for which there may be a number of possible explanations:

- a 'lag effect' in which companies with an EMS do not immediately experience an environmental performance benefit; or
- a 'catching-up effect' in which companies that perceive themselves to be poor performers are those that seek to implement a system as a way of reaching the best practice frontier.

This result suggests that more evidence is needed before environmental arguments are made in favour of regulatory relief for certified firms. It also underscores the need for a better information base for evaluating the impacts of voluntary and market-based environmental policy instruments.

5. Example 2: simple indicators implemented at the Belgian cement company, CBR

CBR's 2000 environmental report included a study on environmental performance indicators (Tyteca et al. 2001). Some of the principles and results will be briefly reviewed here.

An important aspect was that, contrary to the examples reviewed in the MEPI project, the emphasis was not on comparing the performances of CBR with any of its competitors, but rather on benchmarking CBR against itself, by assessing the performances year after year. As a first task, it was important to identify the steps in cement production that were significant in terms of environmental (negative or positive) impacts. Table 7 gives such a list. It can be seen that for the four types of products - clinker, white cement, Portland cement, blast furnace cement - important elements are the use of substitution fuels and substitution materials, as well as the specific energy consumption. Indeed, the cement industry provides one of the best examples of **industrial ecology**, in which the wastes from one industrial sector (e.g., the steel industry) can be used as a useful and valuable input to another sector (the cement industry). More examples can be found in the environmental report (CBR 2001).

In order to allow for proper comparisons, ratios were defined as indicated in the table, namely, the product amounts per energy inputs, and the uses of substitution materials and fuels, as proportions of total materials and fuels. Another significant aspect, from a similar standpoint, was the proportion of blast furnace cement in the total amount of cement produced, since indeed the cement incorporating the residues from steel works contributes to a better overall management of industrial wastes.

Finally, other significant impacts are those linked with air pollution. These, however, were not incorporated in the aggrgate indicators, mainly because in strictly scientific terms spot measurements cannot be extrapolated to the whole of the unit of time (one year) used in the comparisons, without inducing significant biases.

Table 7. - Definition of ratios used as basic indicators for building the aggregate CBR environmental performance indicator.

Product / Effluent	Ratio
Clinker	Use of substitution fuels Specific energy consumption → Product per energy unit Use of substitution materials
White cement	Specific energy consumption → Product per energy unit Use of substitution materials in cement production
Portland cement	Specific energy consumption → Product per energy unit Use of substitution materials in cement production
Blast furnace cement	Specific energy consumption → Product per energy unit Use of substitution materials in cement production
All cements	Proportion of blast furnace cement in total cement production
Air pollution	Specific SO2, NOx, CO2, dust emission

The construction of aggregate indicators based on those components was performed using Jaggi & Freedman's methodology (see see Section 3.4). Using the Jaggi & Freedman indicator, we obtained the results illustrated in Fig. 6, showing that the overall environmental performance is in progress over the whole period investigated - except for a slight decrease between 1997 and 1998. Although the process went through several normalisation and aggregation phases, the meaning implied by this indicator is intuitively understandable by a varied audience, covering members of the public, scientific researchers, the staff of the company, its shareholders, the public authorities, industrial federations, etc. The hypothetical value of 100 % would be achieved if all the incorporated ratios achieved their best possible value in a given year. This value of 100 % is itself only relative, however, as any improvement during subsequent years will cause the limit of best performance to be increased.

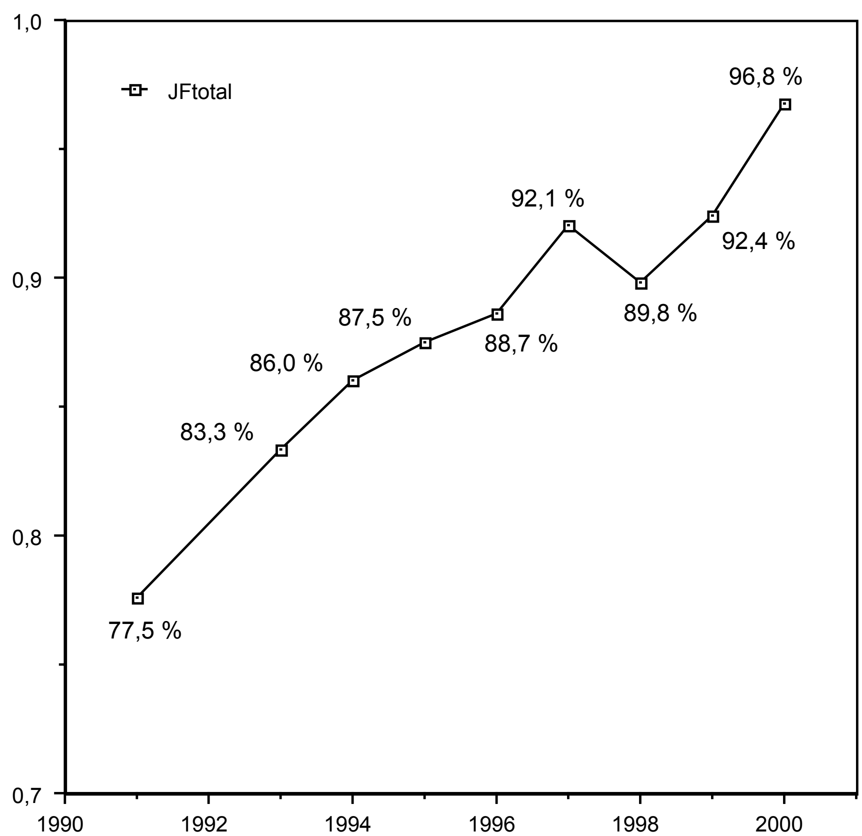

Figure 6. - Evolution of the aggregate Jaggi & Freedman indicator for CBR over years 1991 to 2000.

6. Conclusions: towards indicators of industrial ecology and sustainable development

Although there has been significant progress in building, implementing and exploiting environmental performance indicators over the last few years, we are still far from complete standardisation and universal use by private companies and public decision makers. This paper has presented some of the present trends in a field within which research is still very active and new developments are most likely to appear, before we reach a consensus as to which methods to use, how to collect data, which aggregation framework and extent has to be adopted, etc. At least the MEPI project has shown the feasibility of an approach which started from the information actually available within business companies.

As the last example has shown, even if many methodological developments need to be pursued, we will soon have to proceed one step further, and extend environmental performance indicators (EPIs) towards sustainable development indicators (SDIs). While EPIs strictly look at the performances of processes or products for themselves, SDIs view this in a more global and systemic context, where a company or a process is part of a system in which other kinds of human activities come into play, and even additional dimensions, such as human well-being, long term preoccupations, the biosphere, have to be accounted for. The indicators developed for CBR, even if they are simple in their principles, put the emphasis on the enlarged scope of industrial ecology, which indeed is one step further towards sustainable development of our society. Indeed, industrial ecology indicators, as they have been termed, explicitly refer to the saving of natural resources (through seeking to use substitution materials and fuels, as well as implementating responsible management of energy through the promotion of products - blast furnace cements - that are more respectful of the environment), which constitutes an essential challenge for future generations.

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8. References

Azzone, G., Noci, G., Manzini, R., Welford, R. & Young, W., 1996. Defining environmental performance indicators: an integrated framework, *Business Strategy and the Environment* **5**: 69-80.

Bartolomeo, M., 1995. Environmental performance indicators in industry. Fondazione Eni Enrico Matei, nota di lavoro 41.95, Milano (Italy).

Beede, D.N., Bloom, D.E. & Wheeler, D., 1993. Measuring and explaining cross-establishment variation in the generation and management of industrial waste. World Bank, Discussion paper. Presented to the American Economic Association, Anaheim, California, January 1993.

Belz, F. & Strannegård, L. (eds.), 1997. *International Business Environmental Barometer*. Cappelen Akademisk Forlag, Oslo.

Berkhout, F. (coord.), Azzone, G., Carlens, J., Hertin, J., Jasch, C., Noci, G., Olsthoorn, X., Tyteca, D., Van der Woerd, F., Van Drunen, M., Wagner, M., Wehrmeyer, W., & Wolf, O., 2001a. - MEPI – Measuring the Environmental Performance of Industry. Final report, EC Environment and Climate Research Programme: Research Theme 4 - Human Dimensions of Environmental Change - Contract No: ENV4-CT97-0655. February 2001. Web site http://www.environmental-performance.org.

Berkhout, F., Hertin, J., Carlens, J., Tyteca, D., Olsthoorn, X., Wagner, M. & Wehrmeyer, W., 2001b. 'Green-ness' can be measured. *European Business Forum*, Issue 6, Summer 2001: 42-47.

CBR, 2001. Environmental Report 2000, Cimenteries CBR S.A., Brussels. Edited in French, English and Dutch.

Ciments d'Obourg, 1997. Rapport environnemental 1997. Obourg (Belgium).

EPA - U.S. Environmental Protection Agency, 1989. The toxics release inventory, a national perspective. Washington, DC, EPA-560/4-8-005.

EPA - U.S. Environmental Protection Agency, 1992. Toxics in the community, national and local perspectives, the 1990 toxics release inventory national report. Washington, DC, EPA-700-S-92-002.

European Green Table, 1997. Environmental Performance Indicators in Industry. Report 5: Practical experiences with developing EPIs in 12 companies. Oslo, March 1997.

EUROSTAT 1998. www.telcom.es/tau/indicat.htm.

Graceffa, S., 1997. Unpublished MS thesis, IAG School of Management, Université catholique de Louvain, Louvain-la-Neuve (Belgium).

Gray, R., with Bebbington, J. & Walters, D., 1993. Accounting for the environment. Paul Chapman Publishing Ltd., London.

Greeno, J.L. & Robinson, S.N., 1992. Rethinking corporate environmental management. *Columbia Journal of World Business* Fall & Winter 1992, 222-232.

Hauschild, M. & Wenzel, H., 1998, Environmental Assessment of Products. Volume 2: Scientific background, Chapman & Hall, London

Heijungs, R. & Hofstetter, P., 1996. Definitions of terms and symbols, In: Udo de Haes Ed.: Towards a methododolgy for Life Cycle Impact Assessment, p. 31-39, SETAC Europe, Brussels.

Huizing, A. & Dekker, H.C., 1992. Helping to pull our planet out of the red: an environmental report of BSO/Origin. *Accounting, Organizations and Society* **17**: 449-458.

ISO, 1997, Certified ISO14000 US Companies/Facilities, http:/www.iso4000.net/

Jaggi, B. & Freedman, M., 1992. An examination of the impact of pollution performace on economic and market performance: pulp and paper firms. *Journal of Business Finance and Accounting* **19**, 697-713.

James, P., 1994. Business Environmental Performance Measurement. *Business Strategy and the Environment* **3** (2), 59-67.

James, P. & Bennett, M., 1996. Environment-related Performance Measurement in Business - From Emissions to Profit and Sustainability? Ashridge: Ashridge Management Research Group.

Keeney, R.L. & Raiffa, H., 1993. Decisions with multiple objectives - Preferences and value tradeoffs. Cambridge University Press, Cambridge.

Lammers, P.E.M., & Gilbert, A.J. (Eds.), 1999. Handbook of Environmental Pressure Indices, Institute for Environmental Studies, IVM-VU E-99/07, Amsterdam.

Leclef, L., 1999. Unpublished MS thesis, IAG School of Management, Université catholique de Louvain, Louvain-la-Neuve (Belgium).

Martin, P., Wheeler, D., Hettige, M. & Stengren, R., 1991. The industrial pollution projection system: concept, initial development and critical assessment. World Bank, Discussion paper, October 1991.

Mullins, J.M., 2000. - Public Accountability: Disclosure in a Competitive Environment. prepared for the Environmental, Health and Safety Auditing Roundtable newsletter. http://www.globalreporting.org.

NRTEE (National Round Table on the Environment and the Economy), (1997), Measuring Eco-Efficiency in Business: backgrounder, (NRTEE- www.nrtee-trnee.can), Renouf, Ottowa

OECD, 1993. Corps central d'indicateurs de l'OCDE pour les examens des performances environnementales - Rapport de synthèse du Groupe sur l'Etat de l'Environnement, Organisation de Coopération et de Développement Economiques - Monographies sur l'Environnement n° 83, Paris.

Olsthoorn, X., Tyteca, D., Wagner, M. & Wehrmeyer, W., 2001. Environmental indicators for business: A review of the literature and standardisation methods. *Journal of Cleaner Production* **9**: 453-463.

Rauberger, R. & Wagner, B., 1997. A guide to corporate environmental indicators, Federal Environmental Agency, Berlin/Bonn.

SETAC. Life-cycle assessment. Brussels: Society of Environmental Toxicology and Chemistry - Europe (SETAC); 1992.

Skillius, Å & Wennberg, U., 1998. Continuity, credibility and comparability - Key challenges for corporate environmental performance measurement and communication, Report of the European Environmental Agency, February 1998.

Solvay, 1994. Rapport Environnement 1993-1994. Groupe Solvay, Brussels.

Templet, P.H., 1993. The emissions-to-job ratio. *Environmental Science & Technology* **27**: 810-812.

Turner, R.K., Pearce, D. & Bateman, I., 1993. Environmental economics - An elementary introduction. Johns Hopkins University Press, Baltimore, Maryland.

Tyteca, D., 1996. On the measurement of the environmental performance of firms - a literature review and a productive efficiency perspective. *Journal of Environmental Management* **46**: 281-308.

Tyteca, D., 1997. Linear programming models for the measurement of environmental performance of firms - Concepts and empirical results. *Journal of Productivity Analysis* **8** (2): 183-197.

Tyteca, D., 1999. Sustainability indicators at the firm level: pollution and resource efficiency as a necessary condition towards sustainability. *Journal of Industrial Ecology* **2** (4): 61-77.

Tyteca, D., Carlens, J. & Thiry, J., 2001. Environmental performance indicators. Report in CBR Environmental Report 2000, Cimenteries CBR S.A., Brussels, pp. 46-57. Edited in French, English and Dutch.

Tyteca, D., Carlens, J., Berkhout, F., Hertin, J., Wehrmeyer, W. & Wagner, W., 2002. - Corporate environmental performance evaluation: evidence from the MEPI project. *Business Strategy and the Environment* **11** (1): 1-13.

Udo de Haes, H.A., Ed., (1996), Towards a methodology for life cycle impact assessment, SETAC-Europe, Brussels

UNEP, 1996. Life Cycle Assessment: What it is and how to do it. United Nations Environment Programme - Industry and Environment, Paris.

van der Werf, W., 1999. A weighted environmental indicator at Unox: an advance towards sustainable development? Greenleaf, Sheffield.

Verfaillie, H.A. & Bidwell, R., 2000. - Measuring eco-efficiency - a guide to reporting company performance. World Business Council for Sustainable Development.

Wehrmeyer, W., Tyteca, D. & Wagner, M., 2001. - How many (and which) Indicators are necessary to compare the Environmental Performance of Companies? A sectoral and statistical answer. Paper for The 7th European Roundtable on Cleaner Production, 2-4 May 2001, Lund, Sweden.

White, A.L., 1999. - Sustainability and the accountable corporation: society's rising expectations of business. *Environment* **41** (8), 30-43.

Wright, M., Allen, D., Clift, R. & Sas, H., 1998, Measuring Corporate Environmental Performance. The ICI Environmental Burden System. *Journal of Industrial Ecology* **1** (4): 117-127.