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INDICATORS OF SUSTAINABLE DEVELOPMENT FOR INDUSTRY: A General Framework

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Despite numerous actions worldwide which call for adoption of more sustainable strategies, relatively little has been done on a practical level so far on the pretext that the issue is too complex and not fully understood. This paper follows the argument that it is important that today's decision-makers address the issue of sustainability, however imperfectly, as ignoring it may only exacerbate the problem for future generations. In particular, the paper concentrates on measuring the level of sustainability of industry with the aim of further informing the debate in this area. It proposes a general framework with a relatively simple, yet comprehensive set of indicators for identification of more sustainable practices for industry. The indicators cover the three aspects of sustainability—environmental, economic and social—and among others, include environmental impacts, financial and ethical indicators. The framework is applicable across industry; however, more specific indicators for different sectors have to be defined separately, on a case-by-case basis. It allows a modular approach for gradual incorporation of the framework into the organizational structure. The life cycle approach ensures that the most important stages in the life cycle and their impacts are identified and targeted for improvements. The framework also provides a link between micro- and macro-aspects of sustainable development through appropriate indicators. Thus, it serves as a tool which can assist companies in assessing their performance with regard to goals and objectives embedded in the idea of sustainable development.

Keywords: environment; indicators; industry; sustainable development; life cycle assessment.

INTRODUCTION

The publication of *Our Common Future*[1] in 1987 gave the most commonly used definition of sustainable development as that which 'meets the needs of the present without compromising the ability of future generations to meet their own needs'. This report prompted numerous actions on both international and national levels, which called on governments, local authorities, businesses and consumers to define and adopt strategies for sustainable development. One of the most conspicuous of these activities, instigated as a direct consequence of the emergence of the concept of sustainable development, was the Earth Summit held in Rio de Janeiro in June 1992. The Summit, attended by 120 world leaders and representatives from 150 countries, adopted a comprehensive action plan, known as Agenda 21[2], for the pursuit of sustainable development.

In response to Agenda 21, many governments and organizations started developing their own plans of action and setting out strategies for sustainable development. Many of these concentrate on sustainable development of industry. For instance, in its Declaration on the 'Role of Technology in Environmentally Sustainable Development' signed by fourteen countries world-wide, the Council of Academies of Engineering and Technological Sciences points out that achieving sustainable economic development will require changes in industrial processes, in the type and amount of resources used and in the products which are manufactured[3]. In particular, it recommends that industry should seek to balance the efficiency of its operations with its responsibilities for socially compatible environmental actions. The latter also underpins the UK Strategy for Sustainable Development[4] which encourages industry to take a proactive approach to environmental issues and to identify more sustainable practices for the future.

Although there is still much confusion and conflict about the exact meaning of sustainable development, many agree that sustainable development is about satisfying social, environmental and economic goals (Figure 1). This model implies both spatial and temporal dimensions as these three goals must be met locally and globally for both present and future generations. While this concept is generally accepted and relatively easy to comprehend, the difficulties arise in trying to apply the principles of sustainable development in practice. One of the difficulties is the need to measure the 'level of sustainability' of different sections of society, i.e. local and national governments, industry, local communities and individuals, to determine which directions of change are towards sustainability. Hence, as endorsed in Chapter 40 of Agenda 21[2], it is necessary to develop appropriate indicators of sustainable development that will enable this assessment. Thus far, a number of

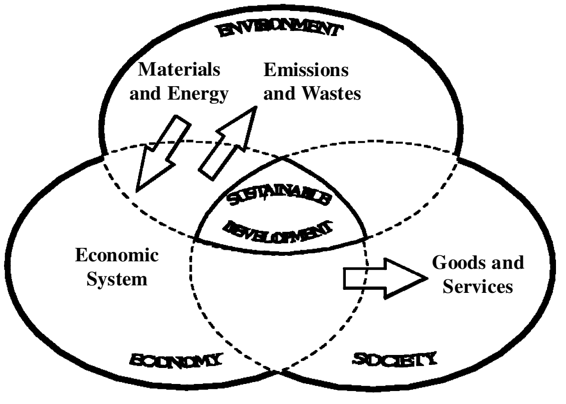

Figure 1. A model of sustainable development.

different approaches have been proposed to define the indicators for different parts of the community, including industry[5–7]. However, there is still no standardized methodology with a generic set of indicators to enable a consistent comparison and identification of more sustainable options.

This paper sets out to develop a comprehensive general framework for indicators of sustainable development for industry. It brings together in a novel way previous attempts to develop indicators with the aim of contributing towards standardization of the sustainability indicators. The framework combines environmental, economic and social indicators that are relatively simple, informative and relevant for industry. However, before such an approach can be developed and applied, it is important to identify and understand the main factors that drive industry towards sustainable development. These are briefly discussed below.

DRIVERS FOR SUSTAINABLE DEVELOPMENT OF INDUSTRY

Industry is one of the most important parts of the human economy. Industrial systems cause and determine flows of materials and energy through the human economy. Although industry is often seen as a source of environmental degradation and resource depletion, it is widely recognized that it is a vital part of development and wealth creation. Therefore, as an important social factor, industry must play a prominent role in identifying and implementing more sustainable options.

In the developed world, the business response to the then emerging environmental issues and later to the idea of sustainable development has gone through three phases. In the first, reactive phase, which ran from the early 1970s to mid-1980s, the main driver for improved environmental performance was regulation, and end-of-pipe solutions were almost the only options considered by industry at the time. However, as keeping pace with the ever-increasing magnitude and demands of the legislative systems and their enforcement was associated with higher costs, it soon became clear that the reactive approach was not viable in the longer term. For instance, the need for rapid implementation of clean-up measures for environmental protection in Japan pushed investment expenditures for environmental improvement up from 5% to almost 18% relative to total production costs[8].

Soon, many companies realized that pollution prevention and cleaner production, through reduction of waste at source and using resources more efficiently, were more beneficial options in comparison to the clean-up approach, not only in terms of environmental performance but also because they could reduce costs and increase profits. A typical example includes SC Johnson Wax which through various environmental improvements saved $125 million by eliminating over 200,000 t of waste in its processes[9]. The realization that better environmental performance could improve the ‘bottom line’ marked the beginning of the second phase, which ran from about the middle of the 1980s to the early 1990s, and slowly changed the business response to environmental problems from reactive to more proactive. This trend continues in the current, third phase, in which environmental performance is starting to be integrated into business strategy and development and increasingly communicated externally in the form of environmental reports. A recent survey of 1100 companies by KPMG[10] shows that the percentage of top companies worldwide producing an annual environmental report almost doubled from 13% in 1993 to 24% in 1999. The chemicals sector is leading in environmental reporting (59% of surveyed companies publish an environmental or HSE report), followed by forestry, pulp & paper (55%), utilities (55%), oil and gas (53%), and pharmaceuticals (50%).

Although the number of companies that have ‘entered’ the third phase is still relatively small, they nevertheless indicate a changing attitude in business. This change has resulted in a number of initiatives for more responsible environmental management, either by individual businesses or by consortiums of companies with similar interests. The examples of these initiatives range from ‘zero emission’ and ‘by-product synergy’ or ‘industrial ecology’ projects through ‘responsible care’ to ‘product stewardship’ and ‘take-back’ schemes. As a part of these activities, a number of companies have instituted voluntary environmental management systems, such as ISO 14001 and EU EMAS, which among other business benefits, enable them to track their environmental performance. For instance, in the 1997 in the UK only there were already over 200 companies that were ISO 14001 certified[11].

One of the important drivers for this change in attitude was a realization that, in addition to the more obvious costs, bad environmental practices bore other, at first less tangible costs—those associated with the social perception and image of the business. The increased public awareness of environmental problems and lobbying of various pressure groups has made some businesses more exposed and vulnerable, in some cases reflecting badly on their economic performance. The now classic example is the case of Shell and the controversy surrounding disposal of their Brent Spar oil platform in the North Sea. The public pressure and the resulting loss of 10% of its customers forced the company to reconsider its decision to dispose of the platform in the sea. Although controversial in many respects, this example is significant as it demonstrated that environmental performance of industry has become a matter of public interest and that the public can use their buying power to encourage business towards fulfilling its environmental and social responsibilities. As a direct consequence of this event, Shell has started to take sustainable development more seriously and has subsequently developed a sustainability strategy[12].

A more recent report by the World Business Council for Sustainable Development (WBCSD)[13] further confirms an increasing influence of the public on the way businesses are run, through a growing number of shareholders in companies with proven environmental and ethical credentials. This trend is also becoming apparent for some of the large lenders, e.g. the Co-operative Bank and Swiss Bank Corporation, which have started to invest preferentially in environmentally and ethically responsible companies.

Another example of the increasing importance of public perception of business has been provided lately by the Environment Agency in England and Wales. In its efforts to enforce the 'polluter pays' and 'producer responsibility' principles, in addition to fines, the Agency has taken the 'name and blame' approach, whereby the worst polluters are publicly identified on 'shame lists'. For example, ICI have been named the country's biggest polluter after they spilled over 400 t of chloroform, trichloroethylene and naphtha into the environment in 1997[14]. Waste disposal, water and energy companies also figure high up on the list. The fines by themselves are not sufficiently significant to make companies change their practices; however, being on this list means negative publicity and a potential loss of business which could cost much more than the mere financial penalty.

Therefore, the historical changes in the way industry has responded to the challenges of sustainable development represent a paradigm shift. It is a shift from a fractured view of the environment, with the emphasis on one stage of the life cycle, i.e. end-of-pipe solutions, to a more holistic life cycle approach which incorporates economic, environmental and social factors, leading towards more sustainable solutions. However, one of the main problems that industry faces in this context is how to measure its progress towards sustainable development. This is the subject of the rest of this paper.

INDICATORS OF SUSTAINABLE DEVELOPMENT FOR INDUSTRY

The paradigm shift was accompanied by considerable efforts by industry to take part in defining sustainable strategies for business. Companies, including major multinationals such as Royal Dutch/Shell Group, are now working towards a balance between their financial, environmental and social or ethical performance, and are starting to report progress in all three areas. This trend is also notable in the KPMG report[10] which shows an increase from 12% in 1996 to 36% in 1999 in the number of corporate reports that mention sustainable development. The emergence of the Global Reporting Initiative (GRI)[15] and attention being given to its draft Sustainability Reporting Guidelines also confirm this trend. A recent survey[12] of large multinational chemical companies, summarized in Figure 2, indicates that sustainability is also becoming an increasingly important topic for this sector and that a number of companies are starting to develop and implement strategies for sustainable development (e.g., DuPont, Shell and P&G).

The increasing interest of industry in sustainable development has resulted in a number of approaches being developed by various companies and business associations. At present, most of these approaches put the emphasis on the environment only[10] and are therefore more indicators of environmental performance than of sustainable development. For instance, ICI's Environmental Burden[16] (EB) approach and Unilever's Overall Business Impact Assessment (OBIA)[17] method identify a set of environmental impacts usually reported in LCA (e.g., Acidification, Global Warming, Ozone Depletion) to assess and report environmental impacts of their operations. A related approach, developed by the World Resource Institute (WRI)[18], concentrates more on the use of resources and emissions rather than the impacts. It proposes the use of four key environmental performance indicators for a manufacturing process or industrial activity: material use, energy consumed, pollutant releases, and non-product output. The Factor 10 Club, which advocates an increase of materials and energy efficiency by a factor 10 over today's utilization, proposes measures of environmental performance similar to the WRI's, which also include indices such as hazardous chemicals and net use of natural capital[19].

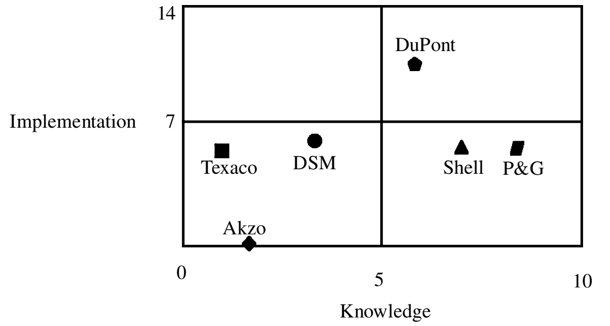

Figure 2. The position of chemical companies in the sustainable development matrix[12]. The x-axis represents the extent to which the company understands sustainable development, includes it in its policies and recognizes it throughout the company; the y-axis represents the extent to which sustainable development is implemented within the company.

Other approaches, alongside the environmental, try to include additional factors, mainly economic. One such example is the eco-efficiency[20] approach, developed by WBCSD, a coalition of 120 international companies from more than 20 major industrial sectors, which since Rio has been involved actively in activities aimed at identifying and defining sustainable pathways for businesses. The eco-efficiency tool is designed to promote improving both environmental and economic performance at a company level by addressing the whole life cycle of a product or process. The seven measures of eco-efficiency are: material intensity of goods and services; energy intensity of goods and services; toxic dispersions; material recyclability; sustainable use of renewable resources; product durability; and service intensity of goods and services. Similar to the OBIA method[17], these measures of environmental performance are normalized with respect to an economic indicator, taken to be value added. Although the importance of social factors is recognized, at present they are not integrated in the eco-efficiency approach.

There are a number of approaches similar to eco-efficiency, including the AIChE/CWRT[21] and UNEP's Cleaner Production[22] methods and CERES Global Reporting Initiative (GRI)[15]; for a more detailed review of different approaches see Lehni[23]. However, many of the methods are still being developed and there are few quantitative examples of their application in real case studies. Furthermore, none of these approaches, with the exception of the GRI, goes beyond environmental and economic indicators to include social aspects of sustainable development. Environmental indicators are often oversimplified and include mainly material and energy consumption and some emissions. For instance, the chemical industry usually uses energy consumed, waste reduction and recycling percentage of waste as environmental indicators. Furthermore, although most of the methods supposedly recognize the importance of life cycle considerations, often the boundaries of the study are the boundaries of a particular manufacturing site which means that the upstream or downstream effects of the firm's activities are ignored. Other approaches[15] are, on the other hand, too complicated as they include a large number of indicators which may be difficult to quantify or understand. This increases the difficulty of their implementation in practice and consequently does not guide the decision-making process effectively.

These and other differences in the indicators of sustainable development do not help companies to monitor their performance consistently and compare it to that of their competitors. This is not helpful to external stakeholders either, particularly in the financial sector, who may use benchmarking to evaluate companies in the sector in which they want to invest. Furthermore, inconsistencies in the indicators at the micro-level do not help policymakers in formulating and implementing sustainable strategy at the macro-level. Therefore, standardization of indicators is the next step that may aid identification and comparison of options for more sustainable development of industry.

Standardization of Indicators

The general methodological framework proposed in this paper is an attempt to contribute towards standardization of the indicators of sustainable development for industry. The standardized indicators would enable identification of more sustainable options through:

- comparison of similar products made by different companies;
- comparison of different processes producing the same product;
- benchmarking of units within corporations;
- rating of a company against other companies in the (sub-)sector; and
- assessing progress towards sustainable development of a (sub-)sector.

In developing this methodological framework, the aim was to use simple and informative indicators, relevant to environmental, economic and social aspects of sustainable development. A modular approach, which allows gradual incorporation of both industry-generic and sector-specific indicators, has been adopted. Life cycle thinking is embedded in the methodology and the indicators are based on the function that the system delivers. Some of these elements of the framework are discussed in the text below.

Industry-generic and sector-specific indicators

There are two steps in the standardization of indicators. Firstly, the indicators that underlie the principles of sustainable development must be identified. They must include indicators generic for all industry and sector-specific indicators. The methodology developed here proposes a set of indicators that can be applied across industry. Although some elements of the framework draw on the approaches proposed in different contexts by other authors[20,24,25], the indicators have been adapted to reflect the properties of industry in general. The sector-specific indicators will vary from sector to sector, and they are best identified on a case-by-case basis. Therefore, they are not included in this paper, although some examples are given later in the text.

Metrics

The second step in the standardization is related to identifying appropriate metrics that would enable performance tracking and comparison of different options. It has often been advocated that the indicators should be normalized to a unique measure of performance across different sectors. Some of the examples include normalization to the physical flows in the system (e.g., tonne of product output), or to a measure of economic performance (e.g., turnover, value added etc.)[20]. It is argued here that it is not possible to fix a single measure of normalization that would apply uniquely in all cases and for all industrial sectors. There are a number of observations that support this argument. For instance, consider the case of the extractive industry and two sub-sectors within it: production of coal and diamonds. Because of the much higher annual product output in the coal industry, normalization of the indicators per tonne of product would favour coal production although diamond production may contribute more to wealth creation. On the other hand, normalization to value added, for instance, would identify diamond production as a more sustainable sub-sector, although it could be argued that coal production provides a more fundamental service to society.

This indeed is the point of departure for the methodology proposed here. It is argued that economic systems exist because they provide a certain service to society (see Figure 1). Therefore, it is only logical to express the indicators of sustainable development per unit of service that the system delivers. This implies that comparisons of the level of sustainability can only be made between systems that deliver the same function. This approach would, for instance, enable a cross-sectoral comparison of different companies providing the same service, but would exclude comparison of companies or sectors with completely different functions. Although this may appear to limit the usefulness of this approach, at least it avoids the heavily criticized bias of other approaches towards the economic aspect of sustainable development by normalizing the indicators to GDP[5] or value added[20]. Levett[26] proposes a similar approach at the policy level with indicators standardized to 'quality of life benefits' produced, which is very different from any standard economic measure such as GDP or value added. Linking the indicators with the function of the system is analogous to the approach taken in Life Cycle Assessment (LCA), where the environmental impacts are expressed per 'functional unit', which is a measure of the service provided. Examples of functional unit include 'unit surface area covered by paint for a defined period of time', 'the amount of packaging used to contain a given volume of beverage' or 'the amount of detergent necessary to clean a standard household wash'[24].

The function or service delivered by an industrial system will normally remain unchanged over its lifetime. However, depending on the context and purpose of the analysis, the indicators may have to be expressed in terms of different functional units. As listed at the beginning of this section, the purpose of the indicators may be to inform customers on the levels of sustainability of consumer products delivering the same function but made by different competitors. For example, consider two different detergents whose service or function is to clean clothes to a pre-specified level of cleanliness. The functional unit in this case can be defined as the amount of detergent needed to clean one wash-load of clothes and the indicators can then be normalized per this amount of detergent.

This kind of analysis is here referred to as product-oriented (see Table 1). Two other types of analysis are also distinguished in this work: process- and company-oriented. In a process-oriented analysis, the indicators can be used to compare different processes producing the same product. For instance, consider the example of one type of detergent made by two different processes to the same cleaning specification. The service that these two systems deliver is production of the detergent so that the functional unit in this case may (arbitrarily) be set to 1000 kg of the detergent. The indicators are then expressed per 1000 kg of the detergent. Another example of process-oriented analysis may be that the company wants to assess the level of sustainability of its process so that it can track improvements over time. The function of the system is still production of detergent; however, the functional unit in this case is different and can be defined as 'operation of the system over a certain period of time' and expressed, for instance, as the total output over the conventional reporting time interval.

The third type of analysis focuses on the performance of a company or its constituent parts. This kind of analysis is, for instance, relevant for benchmarking of units within corporations. In cases like these, where the results of the assessment are going to be used for internal purposes, perhaps to identify the options for improvement of the least sustainable parts, the appropriate functional unit for the overall system can be defined by agreement within the company. All units within the company are then assessed in relation to that functional unit.

Company-oriented analysis can also be used for rating a company against other companies delivering the same service in the same or a different sector. This could for instance include comparison of companies producing the same product, using either the same or a different manufacturing process. An example would be two companies making two different detergents. The functional unit could be defined as the amount of the detergent necessary to deliver the same level of cleanliness of a specified amount of clothes and could be expressed e.g. in tonnes equivalent per year. This application of the indicators is closely related to the product-oriented analysis.

The standardized indicators could be used to assess progress towards sustainable development of a sub-sector or sector within which all the companies deliver a comparable function. For instance, all companies making detergents could be assessed in this way and the functional unit could be defined in terms of tonnes equivalent per year.

Furthermore, this type of analysis could also include cross-sectoral comparison of businesses as disparate as the one making a detergent and the other providing a dry-cleaning service. As in the previous case, both systems exist to provide the same service, i.e. cleaning of certain

Table 1. Different metrics in relation to the type and purpose of analysis.

Type of analysis	Purpose of indicators	An example: detergents	
		Service or function of the system	Functional unit
Product-oriented	To compare different products delivering an equivalent service or function	To clean clothes to a pre-specified level of cleanliness	The amount of detergent to clean a certain amount of clothes (e.g. one wash-load)
Process-oriented	(i) To compare different processes producing the same product(s) (ii) To assess the level of sustainability of a process and track improvements over time	(i) Production of detergent (ii) Production of detergent	(i) An (arbitrary) amount of detergent (e.g. 1000 kg) (ii) Operation of the system over a certain period of time (e.g. total annual output for one year)
Company-oriented	*Internal use:* For benchmarking of units within a company	*Internal use:* e.g. Production of detergent	*Internal use:* By agreement within the company
	External use: (i) To compare companies producing the same product or delivering an equivalent service (ii) To assess a (sub-) sector within which all companies deliver an equivalent function (iii) To compare different sectors delivering an equivalent function	*External use:* (i) Production of detergent (ii) Production of detergent (iii) Cleaning of clothes to a pre-specified level of cleanliness (e.g. by detergent or dry-cleaning services)	*External use:* (i) The amount of detergent to deliver a pre-specified level of cleanliness (ii) The amount of the detergent (e.g. tonnes equivalent per year) (iii) The amount of cleaning agent to clean a certain amount of clothes

amount of clothes; the only difference is that they do it in a rather different way.

This approach could be taken even further to provide a link between the micro- and macro-level analysis of sustainable development by broadening the 'service' definition from cleaning of clothes to the ultimate 'quality of life service' which should be 'people feeling comfortably (and socially acceptably) clean in their clothing'[27]. So there would be an even wider range of possible 'products' (and industrial sectors) to be compared, including:

- commercial/communal laundries with high levels of water, detergent and energy cascading/reuse/recovery;
- clothing made of different fabrics, or better adapted to climate so it stays equally fresh with less frequent washing;
- antiperspirants, etc.

To summarize, it is proposed to express the indicators in different ways, depending on the goal of the assessment. For product-oriented analyses, the indicators can be expressed per unit mass of the product, while in process-oriented assessments, total (annual) output may be a more appropriate unit of measure. In company-oriented analyses both measures can be used, depending on the context. Although the introduction of different metrics may appear to further complicate an already complex problem, it should be borne in mind that, once the framework is in place, converting from one unit of measure to another is a trivial task.

However, not all the indicators will be quantitative and some will have to be expressed qualitatively. In these cases, normalization to a unit of measure is not possible, nor meaningful. There is always a slight degree of discomfort associated with the mention of qualitative indicators, particularly in the quantitatively minded industrial environment. Although in every-day life situations we all rely on highly subjective and qualitative indicators, such as aesthetic or ethical values, in formal decision-making situations we still find it difficult to make decisions without using quantitative measures, regardless of their true meaning and reliability (e.g., the much criticized use of cost-benefit analysis to express the quality of the environment or ethical values[28]). Both qualitative and quantitative elements of the methodological framework proposed in this paper are presented next.

Indicators of Sustainable Development: A Modular Approach

As shown in Figure 3, the proposed framework is based on the three components of sustainable development: environmental, economic and social. Although a number of indicators have been included in the framework, it is recognized that not all of them will be appropriate for all companies and types of analysis. Which indicators will be chosen will depend on a number of factors, of which data availability and simplicity of analysis are two. For that purpose, the approach is designed to be modular to allow gradual implementation of the framework. For instance, a company could start with the environmental indicators module and gradually introduce the other two modules, i.e. economic and social.

As well as being able to compare the levels of sustainability of different systems, the indicators proposed here can also measure relative progress towards (or away from) sustainable development. Realistically, we can only aim to measure progress (or deterioration) towards sustainable development rather then strive to describe the absolute state of sustainability of industrial systems, particularly as we are not able at present to define what the latter means. Therefore, relative indicators that measure progress regularly, for instance in one-year intervals, are much more useful at this stage. They enable companies and consumers to track improvements (or departures from the sustainable course) from year to year and to identify more sustainable options and practices.

Environmental indicators

This framework is based on a life cycle approach which considers the full supply chains of materials and energy. This is particularly relevant for the environmental module of the framework, some of which follows the LCA methodology[24,29]. As discussed earlier, the need to consider

ENVIRONMENTAL INDICATORS

- Environmental impacts
  - Resource use
  - Global warming
  - Ozone depletion
  - Acidification
  - Eutrophication
  - Photochemical smog
  - Human toxicity
  - Ecotoxicity
  - Solid waste
- Environmental efficiency
  - Material and energy intensity
  - Material recyclability
  - Product durability
  - Service intensity
- Voluntary actions
  - Environmental management systems
  - Environmental improvements above the compliance levels
  - Assessment of suppliers

ECONOMIC INDICATORS

- Financial indicators
  - Value added
  - Contribution to GDP
  - Expenditure on environmental protection
  - Environmental liabilities
  - Ethical investments
- Human-capital indicators
  - Employment contribution
  - Staff turnover
  - Expenditure on health and safety
  - Investment in staff development

SOCIAL INDICATORS

- Ethics indicators
  - Preservation of cultural values
    - -stakeholder inclusion
    - -involvement in community projects
  - International standards of conduct
    - -business dealings
    - -child labour
    - -fair prices
    - -collaboration with corrupt regimes
  - Intergenerational equity
- Welfare indicators
  - Income distribution
  - Work satisfaction
  - Satisfaction of social needs

Figure 3. Indicators of sustainable development for industry: a general framework.

the life cycle implications of economic activities in the context of sustainable development is now widely recognized and accepted. The life cycle approach provides a full picture of the interactions of human activities with the environment and identifies 'hot spots' in the system, which can be targeted for improvements. The latter is particularly important as it enables concentration on the important stages and impacts in the life cycle. Electrolux, for example, found that 80 to 90% of its impacts were located at the product use stage and not at the production stage[30]. This allowed the company to re-define its environmental strategy in order to focus on the previously unknown major source of impact. There are numerous other examples of the usefulness of the life cycle approach and many companies are already using LCA to assess and improve their environmental performance[31].

As shown in Figure 3, the environmental indicators have been classified into three general categories:

- environmental impacts;
- environmental efficiency; and
- voluntary actions.

The environmental impact indicators include the usual categories considered in LCA (for definitions see the Appendix). Some of the impacts have a local effect on the environment (e.g., photochemical smog and eutrophication) while the others are of a more global nature (e.g., global warming and ozone depletion). The impacts are divided into two categories: those from planned emissions and those from unintentional or accidental releases. The list is fairly comprehensive but it can be reduced or expanded as appropriate for a specific system and type of analysis.

Although the LCA impacts are calculated using the available scientific data which relate emissions to their impacts, it should be recognized that there is a scientific uncertainty in calculating some of the impacts (e.g., global warming and human toxicity). The other problem may be that the fate of pollutants is usually not considered, so that the calculated impacts are potential rather than actual. Although different fate models exist and it is possible to incorporate them into this framework, this level of complexity may at present be unsuitable for industrial applications. In any case, the 'potential' impacts should be analysed in context and as long as the comparisons are made on an equivalent basis this should not pose a major problem.

To enable a gradual implementation of the framework, it is possible to divide the system under consideration into foreground and background (see Figure 4). The foreground is defined as the set of processes of direct interest for the study, while the background supplies energy and materials to the foreground system[32]. For instance, in a company-oriented analysis, the foreground could be a detergent manufacturing plant, so that the environmental impact indicators would be related to the direct impacts from the plant. This 'gate-to-gate' analysis can then be broadened to include other stages in the life cycle, e.g., manufacture of raw materials and their transportation. Distinction between foreground and background can also be useful for identifying the direct contributions to the impacts of the activities of the company, compared to the impacts along the whole supply chain. There are a number of examples of application of this approach to real case studies, e.g. in the mineral[33], water[34] and other industries[31].

In addition to the environmental impacts, further information on the level of sustainability of an activity can be provided by determining its environmental efficiency. The set of indicators proposed here includes five of the seven categories specified by the WBCSD in their eco-efficiency[20] approach (see Figure 3). The other two categories, toxic dispersion and sustainable use of renewable resources, are included here in the environmental impacts indicators. Material and energy intensity determine the total amount of materials and energy used in the production of a product. Therefore, the smaller the amounts, the more sustainable the product. The material intensity category is equivalent to the MIPS (Material Input per Service Unit) approach[35], which also estimates the overall material inputs over the life cycle of a product or service.

The product is also credited for its recyclability and durability. Linked to these indicators is increased service intensity, which indicates whether the material loops have been closed, for instance, by shifting from traditional selling of the product to leasing it. A now well-known example of this shift in the market mechanisms is that of Xerox, which does not sell but leases photocopiers to the customers. Other, more recent examples include solvent, carpet

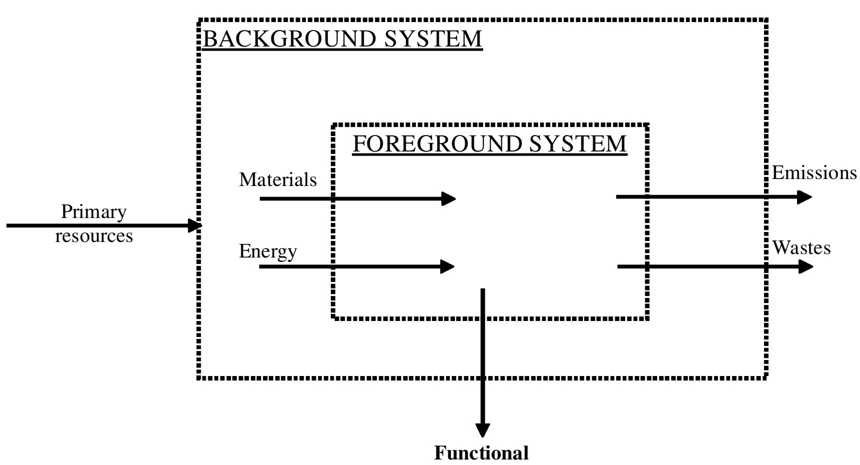

Figure 4. Foreground and background systems.

and car manufacturers. This change in practice comes as a result of realizing that in many cases there is no need to own an artefact in order to obtain the service. It can therefore be argued that the service intensity of such products is increased because they provide a service that society needs but at least cost to the environment. At the end of its life, they are recovered by companies who still own it to be either remanufactured and recycled in the same use or cascaded into different life cycles, thus closing the loop completely.

However, although quite simple to use as a tool, the WBCSD's eco-efficiency has its limitations. It is mainly product-oriented and it concentrates on a limited number of indicators. For instance, eco-efficiency includes (unspecified) toxic dispersions, but not impacts such as global warming and ozone depletion. Thus, the framework proposed here broadens the approach by incorporating a number of environmental impact indicators that are important but not considered within eco-efficiency. Further criticism of this and related approaches (e.g., OBIA[17]) is that it tries to combine both environmental and economic performance in one set of indicators thus implying that quality of the environment and therefore life can be measured in monetary terms. The approach proposed here, on the other hand, avoids this bias on the economic component of sustainable development by adopting a function of the system as a basis for measuring sustainability. In addition, as discussed later in the paper, this framework also proposes a set of different economic as well as social indicators, which are not included in eco-efficiency at present.

Both environmental impacts and environmental efficiency indicators proposed here are calculated routinely through LCA and, by analogy, are expressed per functional unit. The widely available LCA software packages, which usually come with extensive databases, enable relatively quick and reliable assessments. Therefore, there is no benefit in restricting the number of categories for environmental indicators, as there is little time or resource saving and some important categories could be missed out in this way. Instead, it is better to start the analysis with as many indicators as possible to identify those of greatest concern; less significant indicators can then be dropped in the subsequent analysis.

The third set of environmental indicators proposed in this framework is related to a proactive response of business to environmental problems. These indicators are designed to help companies measure their contribution to the environment and therefore to society which in turn may help to improve their external image and gain competitive advantage. A proactive approach also enables companies to anticipate regulatory shifts and reduce costs associated with catching up with legislation.

Three such indicators have been included here: implementation of environmental management systems (e.g., ISO 14001 or EU EMAS), performance beyond minimum compliance and preferential choice of suppliers based on their environmental performance. As discussed above, there are already a large number of companies which subscribe to some kind of voluntary environmental management system. However, it should be pointed out that the value of this indicator is in the improvements that the EMSs bring about as just having an EMS in place is not necessarily an indication of more sustainable operations.

As far as improvements beyond minimum compliance levels are concerned, some companies have already cut their emissions beyond the minimum levels prescribed by legislation or ahead of the targets set by government or international organizations. For instance, the Chemical Industries Association and the UK Government have reached an agreement with its members that they undertake to reduce specific energy consumption by 20% of the 1990 level by 2005, a full five years ahead of the Government's climate change target[36]. The agreement should lead to savings in annual CO_2 emissions of between 550,000 and 900,000 tonnes per year.

In a similar vein, more progressive companies (e.g., some detergent, car and cosmetics manufacturers) go further than site-specific considerations and look at the whole supply chain relevant to their activities[31]. They assess the environmental performance of their suppliers and make appropriate choices on that basis. In the context of life cycle thinking, the right choice of suppliers is directly linked to the company's performance as environmentally better suppliers mean lower impacts overall.

Information on voluntary actions can be used to further inform the decision-making process when comparing progress of different systems towards sustainable development. Other indicators can also be included, depending on the particular activities in which a company is engaged. As for the metrics of these indicators, they can be treated as either qualitative or quantitative. For instance, if a company reduced its air or water emissions by a certain amount below the levels prescribed by the Environment Agency, it could express it in terms of percentage decrease per functional unit. The EMS or assessment of suppliers indicators may be more difficult to express in quantitative terms. They may be included as descriptive statements; the quantitative improvements will in any case be reflected in the reduction of environmental impacts and increase of efficiency, as expressed by the relevant quantitative indicators.

The flexibility of the approach proposed here enables inclusion of more specific indicators as necessary; it also allows for a reduced set of categories, if the assessment shows that some are insignificant. The categories included are relatively well defined and many companies and organizations are already using them routinely to indicate their environmental performance[16,30,31]. The latter provides a further justification for using the proposed indicators, as this may bring us a step closer to their standardization. However, while there may be a general agreement on the environmental indicators to be considered in the context of sustainable development, the situation is much less clear with the economic and social indicators. These are discussed in the following sections.

Economic indicators

Economists look at the world in terms of stocks and flows of capital. This covers not only monetary or economic capital but also 'capital' of other types, including natural, human and social (which most neo-classical economists reduce to monetary terms[28,37]). In this module of the framework, two types of capital and related indicators have been included: financial and human (for definitions see the Appendix); natural and social factors are considered in the other two modules, i.e. environmental and social. Financial indicators measure the economic performance in conventional monetary terms—for instance, value added or contribution to GDP. Human-capital indicators assess economic aspects related to the workforce—for instance, expenditure on health and safety and investment in staff development. While some companies may favour financial portfolio management as a measure of sustainability, it is also necessary to connect sustainable development of industry to employment and investment in human-capital. Recent findings by the World Bank[38] that the bulk of wealth is in human resources and social capital confirm the importance of human-capital for sustainable development. Produced assets, seen as the main determinant of wealth in much applied economics, account for barely a fifth of wealth in most countries, rich or poor[39].

One of the primary aims of each business is to create Value Added (VA) and through that wealth. VA is a value that economists refer to as residual income, which means a residue left over after all costs have been covered. There are different ways to estimate VA. In terms of the value added to a company, it represents the net income of the company, calculated by deducting from the value of sales, the cost of all raw materials and other bought-out purchases[40]. In terms of the value added to a product (which is what VAT taxes), the more the skills and expertise applied to the product, the higher the VA.

Value added analysis has long been used by national statisticians and since relatively recently it also started to be used for taxation purposes (VAT was introduced in 1970). However, it is only lately that companies rediscovered this indicator of economic performance and started to integrate it into their management accounting system. At present, one of the most widely applied approaches for determining VA of a company appears to be Economic Value Added (EVA)[41] which represents the net operating profit minus a charge for the capital invested. The inventors of EVA[41] claim that it comes closer than any other measure of financial performance to capturing the true economic profit of an enterprise and that it is also directly linked to the creation of shareholder wealth over time. More than 300 companies, including Coca-Cola and Monsanto, have implemented an EVA framework for financial management. However, although EVA appears to be a useful indicator, not the least because it is simple to calculate and easy to understand, its shortcomings include a too simplistic approach, distortion of value and subjectivity. For instance, EVA has been criticized for being a snapshot of a company's capital efficiency taken over a one year time frame, which cannot take into account significant investments, acquisitions or disposals during the year or the speed with which prior acquisitions contribute to earnings[42]. Furthermore, the results are also sensitive to the assumptions made in the calculation of EVA (e.g., how much of R&D is written back) and often consultants cannot agree on the assumptions. Moreover, EVA does not take account of the perceived value of brands or corporate alliances, as there is no cash implication until a sale takes place. To correct these flaws, some companies, including Monsanto, are in addition to EVA using other measures of financial performance, such as Cash Flow Return on Investments (CFROI).

Nevertheless, value added as a measure of sustainable development can be useful if used in conjunction with other indicators. Value added also represents the contribution of a business to the Gross Domestic Product (GDP). As already discussed, GDP is one of the indicators most often used to measure economic performance and welfare of a country. Despite its limited and often criticized usefulness*, it is an easily available indicator and in combination with other indicators can still provide an indication of the level of sustainability as a part of the bigger picture. The contribution to GDP is particularly relevant to the manufacturing sector and its potential for growth. For instance, if measured by the ratio of trade volume over GDP, it can provide information on the degree of integration of business into the national and international economy. It therefore establishes a link between micro-economic and macro-economic considerations. Furthermore, if this share of the GDP is due to Value Added, then it serves a dual purpose[43]. On the one hand, it serves as a measure of industrial advancement, which is crucial from a sustainability point of view. On the other hand, this share can be interpreted as an environmental indicator. Depending on the sector, the share may have a different meaning. Compared, for instance, to the agricultural sector, the higher share of GDP for the manufacturing sector may mean a reduced drain on natural resources. However, it may also mean a relatively large consumption of energy and materials in that sector.

To correct the flaws of GDP, a number of alternative indices for measuring the level of sustainability at the macro-level have been proposed. They include an Index of Sustainable Economic Welfare (ISEW)[44], a measure of Net Economic Welfare (NEW)[45] and the ISEW-based Genuine Progress Indicator (GPI)[46]. These indices represent an improvement over the GDP-based indicators of economic welfare as they make allowance for, among other items, household production, leisure, environmental services, longer-term environmental damage and the depreciation of natural capital and thus show how sustainable welfare changes over time. Recently, an ISEW for the UK was published which showed a striking difference between the growth from 1950 to 1996 expressed in terms of GDP and ISEW: while the former amounted to 250%, the latter showed only a modest increase of 31%[47]. Although ISEW or a related approach will ideally replace GDP in the future, it is still not widely available and may be difficult to calculate due to the lack of data. Therefore, for practical reasons, GDP is suggested in this framework instead.

Other, less common, measures of economic performance listed in Figure 3 include expenditure on environmental protection, environmental liability and ethical investments. Expenditure on environmental protection is one of the measures that shows commitment of the company to improving environmental performance. However, this indicator alone does not necessarily reflect the real environmental improvements. For example, a company might be investing large sums of money in clean-up technologies, which from the life

* One of the criticisms of GDP is that it does not reflect the true welfare of society. For example, the nation could constantly be falling ill and buying medicines which would increase GDP and therefore indicate a more prosperous society. Similarly, exploitation of forests and fossil fuels would show an increased GDP, without taking into account environmental degradation and the resulting decrease in the real welfare of society in the longer term.

cycle point of view may only shift the burdens from one life cycle stage to another, bringing little overall improvement. On the other hand, companies that invest little in money terms in environmental performance may be better achievers, as often better housekeeping and management practices can result in substantial improvements. Therefore, this indicator should only be considered in conjunction with other indicators of environmental performance.

Environmental liability is increasingly becoming one of the most important issues for business. In the EU, some aspects of environmental liability are reinforced by the Polluter Pays Principle which is enshrined in Art 130R(2) of the Maastricht Treaty as part of Community policy to enhance the environment. The same principle is applied in the proposed EU Directive on Civil Liability for Environmental Damage which allows any citizen in the EU to claim damages from the people and organizations responsible for degrading the environment anywhere in the Community[48]. Furthermore, the European Programme of Policy and Action in Relation to the Environment and Sustainable Development (the Fifth Environmental Programme)[49] calls for financial institutions to contribute to sustainable development through the appraisal of the potential environmental liabilities of their clients. The Fifth Environmental Programme also encourages industry to develop a more sustainable strategy for development.

Environmental liability has already had a seriously adverse effect on industry, particularly in the US, and has led to a more cautious approach to environmental issues. Demonstration of this is found in some of the large multinationals who are either abandoning activities that might accrue high liabilities in the future or attempting to put together a strategy to reduce these liabilities. Examples of the former include some of the chemical companies (e.g., ICI[50,51]) which are selling off parts of their business which are more environmentally intensive and moving into more specialist markets with smaller business units and higher ability to adapt to future changes in the market and environmental policy. Other companies, for example gas and oil, are starting to admit their responsibilities and clean up polluted land[52]; or mining companies which are now trying to address the problem of mine closures and site restoration[53,54]. Although this indicator may be more difficult to calculate, particularly for future liabilities, it represents one of the important indicators of sustainable development and should not be disregarded because it is hard to quantify. If quantification is possible, then liability could be expressed as total costs per functional unit for restoring the quality of the environment to the level before the activity started. Alternatively, it could be expressed as a ratio of environmental over total liabilities per functional unit as an indication of the scale of the problem in relation to the business. Some of the methods used, for instance, by insurance companies may assist in estimating environmental liabilities[55].

The final financial indicator proposed in this work is related to ethical investments. Although still an emerging market, there are already a few companies who invest in ethical funds and businesses (e.g., Co-operative bank). The Ethical Investment Research Service (EIRIS) provides information to investors on companies that invest ethically. Although there is no exact definition of what may be ethical investments, some examples could include developing alternative energy sources or investing in a business that contributes to the development of local communities. A further elaboration of ethical indicators is given in the section on social indicators.

Human-capital indicators enable assessment of the level of sustainability of a business with respect to the workforce employed. Employment contribution per unit of service delivered by the system is one of the human-capital indicators. However, this indicator can have different meanings at the micro- and macro-levels and therefore has to be interpreted carefully. While from a macro-economic point of view of sustainable development, it is desirable for this indicator to have a higher value, from the environmental or even social-welfare point of view this may have different implications. Higher employment rate does not necessarily mean the most efficient processes. In fact, the more efficient they are, the fewer people they tend to employ. Higher process efficiency is usually linked to a better environmental performance. Therefore, this implies that a higher employment rate per functional unit may be associated with higher environmental burdens. Furthermore, a company may have a higher employment rate, but may not be paying the employees as much (in a developing country) as a company which employs a smaller number of staff (in a developed country). This implies that better employment indicators are not a sufficient condition for better social welfare. On the other hand, at the micro-economic level, one way companies try to maximize their ‘efficiency’ is by reducing expensive inputs, including labour. Therefore, from a company’s point of view, it is desirable that the employment indicator has a lower value. This is sometimes achieved at the expense of using more of other cheaper inputs—for example environmental resources, particularly where they are not charged (i.e., environmental ‘externalities’). In this case the lower employment rate is associated with higher environmental burdens.

Thus, this is an example where it may be difficult to ensure that commercial efficiency simultaneously contributes to the macro-efficiency of the economy. One of the possible means to do this is ecological tax reform, which in the current context can be understood as reducing the unit cost of labour and increasing the unit cost of environmental resources so companies can increase commercial efficiency by increasing the amount of labour they use relative to environmental resources[27].

In an attempt to reduce the shortcomings in the employment contribution indicator, an additional indicator is introduced that measures staff turnover as the ratio of new employees over the workforce made redundant. However, like employment, this indicator has its own deficiencies and should be used with caution. In any case, both indicators should be considered in conjunction with other indicators of sustainable development.

There is little dispute that health and safety of employees are of paramount importance for any business. Many companies invest a substantial amount of money to ensure a healthy and safe working environment. They report on their efforts in this respect regularly, and also often include indicators such as numbers of injuries and fatalities and days of lost work. Expenditure on health and safety may be expressed per employee or per functional unit of the system. However, as with environmental improvements, some aspects of health and safety may be improved without any investment, for instance through better management practices. Therefore, like the other economic indicators, this should only be taken as one indication of performance and analysed in parallel with other indicators.

The fourth indicator in the human-capital set of indicators, i.e. staff development, can also be expressed as investment per member of staff per functional unit. Examples of staff development include training and continuing professional and personal development. This indicator is closely related to the welfare indicators discussed in the next section.

Social indicators

This set of indicators focuses on corporate social responsibility by relating human well-being to the activities of business. Several of the social aspects of sustainability could be measured in an industry specific way. In this framework, two generic types of indicators are considered: ethics and welfare indicators.

Without addressing issues concerning human rights, cultural values, equity and disparity within the current population and between current and future generation, the assessment of sustainability would not be complete. Therefore there is a need to develop indicators of sustainable development that would reflect these wider responsibilities that business has to communities in which it operates, to society in general, including both present and future generations. Yet, measuring the social impact and ethical behaviour of a company is not an easy task. There are currently no widely agreed standards for measuring ethical performance as there are, for instance, for measuring environmental performance. In social and ethical dimensions of the company's activity, many of the variables such as protection of cultural values or equity are hardly quantifiable, and cannot even be defined in physical terms. However, it remains a realistic goal to measure them consistently and in a comparable manner across organizations by using qualitative ethical indicators. Thus, three sets of descriptive ethical indicators are proposed as tools which will enable companies to assess their performance with regard to ethical goals and objectives embedded in the idea of sustainable development.

The first set of ethical indicators refers to preservation of cultural values. Preservation of cultural values means the continuation of the way of life of a people, and protection of their values, beliefs, arts, modes of perception, habits of thought and activity, in their natural and cultural conditions. The idea of preservation of cultural values follows 'regulative principles' such as autonomy, freedom, communication, participation and fairness. To measure the achievement of this aim, two indicators are suggested:

- stakeholder inclusion; and
- involvement in community projects.

Stakeholder inclusion is proposed as an ethical performance indicator because it is believed that broad participation is crucial for the implementation of the underlying values of sustainable development and preservation of cultural values[56]. This approach calls for each organization to think carefully about the many different constituencies upon which its activities and performance have an impact. Wheeler and Sillanpaa[57] of The Body Shop suggest a very comprehensive list of stakeholders that include primary social stakeholders (local community, suppliers and business partners, customers, investors, employees and managers), secondary social stakeholders (such as civil society, business at large and various interest groups), and non-social stakeholders (which are also divided into primary and secondary categories: the natural environment, non-human species, future generations and their defenders in pressure groups). They argue that there is a strong business case for actively involving stakeholders in corporate strategy, since failure to do so will reduce competitiveness and increase risk of corporate demise. Yet, there is also a strong ethical case for stakeholder inclusion: sustainable development is a concern for all, and it requires that people be given the opportunity to be informed about issues and conditions that affect them. For a company which aims to contribute to the goal of sustainable development, it means that it needs to listen and respond appropriately to the values and beliefs of individuals or groups who are affected by its activities. Broad representation of key stakeholders and their participation in decision-making ensures recognition of diverse values, and secures their rights to be informed about issues and conditions that influence their lives[56].

The indicator relating to Involvement in Community Projects is intended to show the level of partnership that an organization develops with the community in which it operates. Partnership with the local community is complementary to stakeholder inclusion. It reflects the wider responsibilities of a business to communities in which it operates, and indicates the reconciliation of the organization's needs with those of the community. This indicator is related to satisfaction of social needs which is discussed further below in the context of welfare indicators.

The second set of ethical indicators addresses the international aspect of business activities. The process of globalization has changed the way in which many organizations operate. Products are designed in one country, manufactured in another using components from many other countries, and sold worldwide. Companies are operating in different countries, bringing together people from different cultural backgrounds. At the same time, the general public is more aware of what is happening in other parts of the world, which means that the activities of business organizations that once were invisible are now considerably more exposed to the public scrutiny. Whether one looks at the allegations of the use of child labour by some companies operating in developing countries, or of the use of timbers from the Amazon rain forests, or selling arms to political regimes that violate human rights, it becomes clear that the general public (consumers, pressure groups) is increasingly taking ethical performance at the global level into account. As experience of some of the multinationals shows (e.g., the case of Shell in Nigeria[58,59]), no company can be confident any longer of hiding misbehaviour behind the mask of distance.

Thus, a simple set of ethical indicators which measures a discrepancy between operating principles in developed and developing countries is proposed for measuring company's performance at the international level. They include the following ethical principles:

- avoidance of improper inducements in business dealings;
- abolition of child labour;

- payment of fair prices to local suppliers; and
- avoidance of collaboration with corrupt political regimes.

These ethical principles and related indicators reveal whether international standards of conduct of a company deviate from the standards used at home. The aim of these indicators is to make operating principles at the international level more transparent and ultimately more ethical.

The third set of indicators addresses the issue of intergenerational equity. The widely accepted definition of sustainable development strongly emphasizes that needs of future generations must not be neglected. In ethical terms, this request is expressed as the recognition of legitimate interests and rights of future generations to live in a physically secure and healthy environment and, consequently, as the recognition of our moral duties and obligations to protect the natural environment to such an extent that the survival and well-being of future generations are not jeopardized.

Yet, micro-scale considerations, such as measuring company performance, cannot cover all the complex issues regarding intergenerational equity. Thus, the ethical indicators to measure this aspect of sustainability suggested here narrow down the task to two key areas. They are limited to a descriptive indication of the observance of the following ethical norms:

- does the company's activity leave the environment in a condition that we cannot expect to be accepted by the next generation?; and
- does the company's activity create any problems for which solutions are not known to us today?

If, for instance, nuclear waste is stored in a way that ensures that no leakage occurs in the life time of just one or two generations, trusting the next generation to ensure by its own means that there is no leakage in the more distant future, the problem is bequeathed to posterity. Or, if genetically modified virus-resistant plants are released without knowing their effect on biodiversity, an additional source of risk is introduced into the environment potentially creating a problem requiring future remedy. The intergenerational equity indicators are therefore developed to indicate whether a company is involved in such activities. Their aim is to denote whether a company's behaviour exemplifies long-term thinking or whether it supports short-term horizons, with little thought given to problems created for future generations.

Similar to the ethical indicators, human welfare is not an easily defined concept. Wealth and income are often mentioned as measures of welfare, but that is only part of the whole story. For instance, UNDP in its Human Development Index (HDI)[60] uses a 'standard of living' category to measure welfare and indicate human progress. This is combined with longevity and education in an attempt to include other dimensions of social welfare. Some elements of the social welfare indicators proposed in this framework are based on HDI. Income distribution is one such indicator which is related to 'standard of living' and describes social welfare through economic benefits. Income distribution could for instance be expressed in terms of income of the top 10% of employees per income of the bottom 10%. Alternatively, it could be expressed as a ratio of the income of a CEO/board member and an average income in the company[61]. This indicator is also related to social equity, as it shows distribution of wealth among people. The closer to unity this indicator is, the higher the level of social sustainability of the company.

Another important parameter in this respect is the level of work satisfaction of the employees. Many companies, particularly in labour-intensive sectors, include this factor in their mission statement, recognizing that staff morale may prove the critical indicator of a company's health. Although even more difficult to capture adequately by any means of quantitative measure, some indication of work satisfaction can be provided through the number of sick days per employee, perhaps in relation to the national average. Number of people retiring on health grounds per total number of employees could also be included here. This indicator is directly linked to the economic performance of the company; therefore it is in its own interest to reduce absence from work through improved welfare. For instance, Anglo American of South Africa has had to invest significantly in fighting HIV and AIDS because the disease is attacking its workforce[62]. Another indication of work satisfaction could be a ratio of people that are 'happy' with their job over the total number of employees. Although these indicators are admittedly simplistic and depend on a number of factors over which a company may have no direct control, if monitored over time they may at least indicate progress towards sustainable development.

Both income distribution and work satisfaction are internal indicators, which describe the level of social sustainability of a company in relation to its employees. The third welfare indicator included in this framework establishes a link between the company and the welfare of the rest of society. This link is made through the company's contributions to satisfying societal needs. Apart from contributing to employment and wealth creation, industry has often contributed to other areas of social life, such as education, health, public service and recreation. Some of these contributions are financial and they are relatively easy to measure—for instance, financing an education programme (including education in sustainable development); the others are less tangible and include various interactions with the local community and skills transfer.

Social indicators enable assessment of the course of social policy in a company which should help stimulate interactions of the company and population, reduce mistrust and raise individual and collective moral and ethical standards. They would also contribute to the establishment of social action programmes that guarantee the implementation of a development model with a social content[63]. In this way they provide an essential link between micro- and macro-aspects of sustainable development.

FINAL CONSIDERATIONS: THE DECISION-MAKING CONTEXT

The main purpose of the indicators of sustainable development is to provide information to decision-makers on the overall level of sustainability of a system. This information can then be used to devise a strategy for more sustainable development by comparing different options. However, given the number of indicators that need to be considered and the number of decision-makers or stakeholders that can potentially be involved in the decision-making process, the problem of identifying the best options in a given situation is not trivial. This type of situation, where there are a number of often conflicting objectives to be satisfied simultaneously, is known as multiobjective decision-making.

Multiobjective decision-making can be classified into two general groups: single decision-maker and multiple decision-maker problems[64]. The first group relates to those situations in which there is a single decision-maker or a group of decision-makers that share the same interests and preferences about the conflicting objectives of a multiobjective problem. In the context of sustainable development for industry, this would be a situation in which the employees of one company, which normally share the same interests with respect to that company, are deciding on the best options for improvements. The second group involves situations in which there are many decision-makers and interest groups or stakeholders, each of which has different or conflicting preferences and objectives. Applied to the industrial context, this would be the case of a wider involvement of stakeholders in the decision-making process, i.e. employees, consumers, local community, etc., who have to identify the best compromise solution for a given situation.

A number of techniques and tools have been developed to facilitate multiobjective decision-making[64]. All these methods recognize that, in order to choose the best compromise solution, some articulation of preferences by decision-makers is necessary. This implies that it is not possible to avoid subjective value judgement in problems with conflicting objectives: if the best compromise solution is to be identified and agreed upon by all interested parties, some kind of subjective valuation has to be carried out.

However, the crucial difference between different decision-making techniques is in the way the valuation is carried out. One type of method advocates elicitation of preferences for different objectives very early in the decision-making process, even before the objectives have been quantified. The objectives are then aggregated into a single utility function, based on the importance the decision-makers put on each of the objectives. For the case of sustainability indicators, this would mean deciding on the importance of each indicator in relation to the others prior to their quantification. The main problem associated with these techniques, which include for instance the multiattribute utility function method[65], is that they assume that the decision-makers will always have the same preferences with respect to certain objectives, regardless of their 'quantity' and trade-offs.

The other type of multiobjective decision-making technique enables elicitation of preferences and valuation after all objectives have been identified and analysed. In this type of analysis, the decision-makers are asked to examine the trade-offs among different objectives and then to decide on their preferences. It is argued here that this approach is more appropriate in the context of sustainable development for two main reasons. Firstly, it can be applied in a wider range of decision-making contexts. In the case of single decision-makers, it provides information on the trade-offs between different objectives, to show explicitly what can be gained and what lost by choosing each alternative. Where there are multiple decision-makers with conflicting interests, this technique can help to resolve disputes by providing different alternative solutions. Decision-makers who understand the trade-offs and the alternatives are more likely to understand the interests of other parties and, therefore, to compromise.

Secondly, using multiobjective analysis avoids the well-known problems encountered, for instance, in cost-benefit analysis, which attempts to reduce individual preferences to a market value or to express quality of the environment in monetary terms[28,37]. These controversial techniques of pricing non-monetary objectives, such as environmental quality, and aggregating non-commensurables into a single utility function, have been widely criticized. The critics point out that not only is monetary valuation unsound, it is also unnecessary (see, e.g., O'Neill[66]). On the other hand, multiobjective analysis is able to trade-off incommensurable objectives, e.g. environmental impacts and socio-economic requirements, and therefore appears to be more appropriate for decision-making in the context of sustainable development.

However, whatever the approach, it is certain that identification of sustainable options and decision-making in this context are not an easy problem and we cannot pretend that we have ready-made solutions for it. Nevertheless, it is important that today's decision-makers address and discuss the issue of sustainability, however imperfectly, as it would be hard to imagine that future generations would accept the difficulty of the problem as an excuse for ignoring it.

CONCLUSIONS

The issue of sustainability is becoming increasingly important for industry. To respond to the challenge, industry must be able to measure its progress towards sustainable development. The generic framework for indicators of sustainable development proposed in this work could be used as a strategic tool for assessing the level of sustainability of industry and for identifying more sustainable options for the future. Most of the indicators included in the framework can be applied across industry; however, the framework does not pretend to be uniformly applicable to all sectors nor does it include sector-specific indicators. The latter have to be considered on a case-by-case basis to reflect specific characteristics of different businesses.

In developing the methodological framework, the aim was to use relatively simple, informative and easily available indicators with relevance to all three aspects of sustainable development, i.e. environmental, economic and social. The framework proposes a methodology to define and determine a number of indicators, including environmental impacts and efficiency, financial, human-capital, ethics and welfare indicators. A life cycle approach has been taken in this work and, as in Life Cycle Assessment, it is proposed that the indicators be standardized according to the function the system delivers. This unit of measure avoids a bias towards either environmental or economic measures of sustainable development, often found in some other methods. A modular structure is proposed to enable gradual incorporation of the indicators, also allowing for addition of sector-specific indicators. It also enables the use of a restricted set of the proposed indicators to suit a particular type of analysis. Where appropriate, the indicators also provide a link between micro- and macro-aspects of sustainable development.

APPENDIX: DEFINITION OF THE INDICATORS

All indicators defined here are expressed per functional unit, related to the function the system delivers. Some of the indicators are suitable for all three types of analysis identified in this work, i.e. company-, process- and product-oriented; however, others are more appropriate for one type of assessment. The suitability of the indicators for different analyses is specified below for each type of the indicator. Subscripts c and l in the formulae correspond to company c and life cycle stage l of the system. In a company-oriented analysis, c will normally be 1. For process- and product-oriented analysis, c will normally assume a number of companies involved in the supply chain. Depending on the number of life cycle stages included in the analysis, l can range from 1 to the total number of stages L from 'cradle to grave'.

Environmental Indicators

Environmental impacts:

The environmental impacts are defined according to the problem-oriented approach[67] to Impact Assessment in LCA. Similar indicators are used for instance in the ICI Environmental Burden (EB) approach[16] and Unilever's OBIA method[17]. They can be calculated either for the foreground only (e.g., as in the EB approach) or for the whole life cycle of the system (e.g., as in OBIA). Both planned and accidental releases and their respective impacts are calculated using the formulae presented below, but are reported separately in the interest of transparency. These indicators are applicable to all three types of analysis identified in this paper, i.e. company-, process- and product-oriented.

- Resource use: abiotic, biotic depletion and land use

Abiotic resource depletion (ARD) includes depletion of non-renewable resources, i.e. fossil fuels, metals and minerals. The effect score is calculated by:

$$EI_{ard} = \sum_{j=1}^{J}\sum_{l=1}^{L}\frac{B_{i,j}}{e_{ard,j}} \qquad (-) \tag{A1a}$$

where $B_{l,j}$ is quantity of resource j used in life cycle stage l; $e_{ard,j}$ represents total estimated world reserves of that resource[68].

Biotic resource depletion (BRD) is related to the use of species threatened with extinction for instance, black rhino and sperm whale. It is calculated as:

$$EI_{brd} = \sum_{j=1}^{J}\sum_{l=1}^{L}\frac{B_{l,j}}{e_{brd,j}} \qquad (\mathrm{yr}^{-1}) \tag{A1b}$$

where $B_{l,j}$ is the use of species j in a life cycle stage l and $e_{brd,j}$ is the biotic depletion factor for that species. For instance, $e_{brd,j}$ for black rhino is 4×10^{-5}/yr[68].

Land use is expressed in square metres of land occupied for the delivery of the functional unit:

$$EI_{land} = \sum_{l=1}^{L} B_l \qquad (\mathrm{m}^2) \tag{A1c}$$

where B_l is the land area used in different stages of the life cycle.

- Global warming potential (GWP)

GWP represents total emissions of the greenhouse gases, $B_{l,j}$ (i.e., CO_2, N_2O, CH_4 and other VOCs) multiplied by their respective GWP factors, $e_{gwp,j}$:

$$EI_{gwp} = \sum_{j=1}^{J}\sum_{l=1}^{L} e_{gwp,j}\, B_{l,j} \qquad (\mathrm{kg}) \tag{A2}$$

GWP factors, $e_{gwp,j}$, are for different greenhouse gases expressed relative to the global warming potential of CO_2, which is therefore defined to be unity. The values of GWP depend on the time horizon over which the global warming effect is assessed. GWP factors for shorter times (20 and 50 years) provide an indication of the short-term effects of greenhouse gases on the climate, while GWP for longer periods (100 and 500 years) are used to predict the cumulative effects of these gases on the global climate.

- Ozone depletion potential (ODP)

The ODP category indicates the potential of emissions of chlorofluorohydrocarbons (CFCs) and chlorinated HCs for depleting the ozone layer and is expressed by:

$$EI_{odp} = \sum_{j=1}^{J}\sum_{l=1}^{L} e_{odp,j} B_{l,j} \qquad (\mathrm{kg}) \tag{A3}$$

where $B_{l,j}$ is emission of ozone depleting gas j. The ODP factors $e_{odp,j}$ represent depletion potential of the emissions relative to the ozone depletion potential of CFC-11.

- Acidification potential (AP)

AP is based on the contributions of SO_2, NOx, HCl, NH_3, and HF to potential acid deposition, i.e. on their potential to form H^+ ions. AP is calculated according to the formula:

$$EI_{ap} = \sum_{j=1}^{J}\sum_{l=1}^{L} e_{ap,j}\, B_{l,j} \qquad (\mathrm{kg}) \tag{A4}$$

where $e_{ap,j}$ represents acidification potential of gas j expressed relative to the AP of SO_2, and $B_{l,j}$ is emission of burden j per functional unit.

- Eutrophication potential (EP)

EP is defined as the potential to cause over-fertilization of water and soil, which can result in increased growth of biomass. It is calculated as:

$$EI_{ep} = \sum_{j=1}^{J}\sum_{l=1}^{L} e_{ep,j}\, B_{l,j} \qquad (\mathrm{kg}) \tag{A5}$$

where $B_{l,j}$ is emission of species such as NOx, NH_4^+, N, PO_4^{3-} and P, and $e_{ep,j}$ represents their respective eutrophication potentials. EP is expressed relative to PO_4^{3-}.

- Photochemical smog (PS)

Photochemical smog or photochemical oxidants creation potential, is expressed relative to the *PS* of ethylene and is calculated by:

$$EI_{ps} = \sum_{j=1}^{J}\sum_{l=1}^{L} e_{ps,j} B_{l,j} \qquad \text{(kg)} \tag{A6}$$

$B_{l,j}$ is emission of different contributory species, primarily VOCs, classified into the following categories: alkanes, halogenated HCs, alcohols, ketones, esters, ethers, olefins, acetylenes, aromatics and aldehydes; $e_{ps,j}$ are their respective classification factors for photochemical smog formation.

- Human toxicity potential (*HTP*)

HTP is calculated by adding human toxic releases to three different media, i.e. air, water and soil:

$$EI_{htp} = \sum_{j=1}^{J}\sum_{l=1}^{L} e_{htp,jA} B_{l,jA} + \sum_{j=1}^{J}\sum_{l=1}^{L} e_{htp,jW} B_{l\,jW} + \sum_{j=1}^{J}\sum_{l=1}^{L} e_{htp,jS} B_{l,jS} \qquad \text{(kg)} \tag{A7}$$

where $e_{htp,jA}$, $e_{htp,jW}$ and $e_{htp,jS}$ are human toxicological classification factors for the effects of the toxic emission to air, water and soil, respectively. $B_{l,jA}$, $B_{l,jW}$ and $B_{l,jS}$ represent the respective emissions of different toxic substances into the three media. The toxicological factors are calculated using the acceptable daily intake or the tolerable daily intake of the toxic substances. The human toxicological factors are still at an early stage of development so that HTP can only be taken as an indication and not as an absolute measure of the toxicity potential.

- Ecotoxicity potential (*ETP*)

ETP is divided into aquatic and terrestrial ecotoxicity, which are calculated as:

$$EI_{etp_A} = \sum_{j=1}^{J}\sum_{l=1}^{L} e_{etp,jA} B_{l,jA} \qquad (\text{m}^3) \tag{A8}$$

$$EI_{etp_T} = \sum_{j=1}^{J}\sum_{l=1}^{L} e_{etp,jT} B_{l,jT} \qquad \text{(kg)} \tag{A9}$$

where $e_{etp,jA}$ and $e_{etp,jT}$ represent ecotoxicity classification factors of different toxic substances and $B_{l,jA}$ and $B_{l,jT}$ are their respective emissions to the aquatic and terrestrial ecosystems. *ETP* is based on the maximum tolerable concentrations of different toxic substances in water and soil. Similar to the *HTP*, classification factors for *ETP* are still developing, so that *EP* can only be used as an indication of potential ecotoxicity.

- Solid waste (*SW*)

SW is expressed in kg per functional unit:

$$EI_{sw} = \sum_{l=1}^{L} B_l \qquad \text{(kg)} \tag{A10}$$

where B_l is the amount of solid waste generated in the life cycle of the system.

Environmental efficiency

This set of indicators is appropriate for a product-oriented analysis.

- Material intensity (*MI*)

MI represents the sum of all materials used in the system and can be calculated as:

$$EE_{mi} = \sum_{j=1}^{J}\sum_{l=1}^{L} M_{l,j} \qquad \text{(kg)} \tag{A11}$$

where $M_{l,j}$ is the amount of material j used in life cycle stage l.

- Energy intensity (*EN*)

EN is the total amount of energy and is determined as:

$$EE_{en} = \sum_{j=1}^{J}\sum_{l=1}^{L} EN_{l,j} \qquad \text{(MJ)} \tag{A12}$$

where $EN_{l,j}$ is the amount of energy type j used in the life cycle.

- Material recyclability (*MR*)

This indicator shows a potential for the product to be recycled, either in the same or a different life cycle. It can be expressed as a percentage of the material that can potentially be recycled relative to the total amount of the material:

$$EE_{mr} = \frac{\sum_{j=1}^{J} R_j}{M_p} \cdot 100 \qquad (\%) \tag{A13}$$

with R_j equal to the amount of material j that can be recycled and M_p equal to the total amount of materials contained in the product (note that EE_{mi} and M_p are not necessarily the same, as EE_{mi} includes both materials that form part of the product and materials used in the life cycle). Recycling could include different techniques, such as reuse, mechanical recycling and energy recovery. This indicator should be interpreted with care, as it only shows the potential for recycling and not the actual amount of material that will be recycled. This is particularly true for multiple-material products for which material separation may present difficulties. An additional indicator could be included to show what proportion of the product has been made from the recycled materials.

- Product durability (*PD*)

PD is an indicator that will not be applicable to all products, as some of them may be delivering a function that necessitates a shorter life cycle. Examples of such products can be found in the food and drinks industry, for instance. *PD* can be expressed in terms of days or years per functional unit.

- Service intensity (*SI*)

An increased *SI* shows that society is obtaining a better service from the system at lower environmental costs. This indicator can be measured as the degree to which the company has closed the loop in providing the service as opposed to only selling the product. Within that, the number of use-cycles that the product goes through before it reaches the end of its life cycle could also be included. For instance, one photocopier can be leased to one or more different customers during its useful life. At the end, it will be reclaimed by the company and remanufactured into a 'new' photocopier or perhaps its materials will be recycled. The product managed in this way provides much higher benefit than one used by just one customer and then scrapped. *SI* could either be measured quantitatively or expressed qualitatively, depending on a particular system. Service intensity is also considered in the MIPS approach[35] whereby *SI* is enhanced through the reduced material input.

Voluntary actions

These indicators are more appropriate for a company-oriented analysis, particularly the indicators related to environmental management systems and assessment of suppliers. Improvements above compliance levels could be used for all three types of analysis.

• Environmental Management Systems (*EMS*)
This is a qualitative indicator which is included as a statement; the quantitative benefits of incorporation of the *EMS* are reflected in reduced environmental impacts and increased environmental efficiency.

• Environmental improvements above the compliance levels (*ICL*)
This indicator can be expressed as an average percentage decrease in environmental burdens for either prescribed substances, or substances that are of general environmental concern but are not legislated. For instance, a company would be credited for a voluntary reduction of emissions of CO_2 below the target levels set by the Government or an international organization. *ICL* could be calculated as:

$$EE_{icl,j} = \frac{\displaystyle\sum_{c=1}^{C} \frac{AL_j - B_{c,j}}{AL_j}}{C} \cdot 100 \qquad (\%) \qquad \text{(A14)}$$

where $B_{c,j}$ is a level of burden *j* from company *c* and AL_j is a prescribed local or national level, or accepted target for that burden. In company- or process-oriented analysis, *C* is normally equal to 1; in product-oriented analysis, *C* could theoretically include all companies involved in the life cycle of the product. However, on a practical level, these data would be very difficult to obtain. For companies that do not have environmental improvements above the compliance levels, this indicator is zero.

• Assessment of suppliers (*AS*)
Like *EMS*, *AS* is also a qualitative indicator and can consist of a statement which describes the procedure of the assessment; for instance if the company requires their suppliers to have an *EMS* in place or perhaps if they use LCA for their activities.

Economic Indicators

In principle, these indicators can be used for all three types of analysis, although some are more suited for one type than the other, as specified below.

Financial indicators

• Value added (*VA*)
The conventional *VA* is expressed as net operating profit of the company[40]:

$$EC_{va} = \sum_{l=1}^{L} \sum_{c=1}^{C} [S_{c,l} - (RM_{c,l} + OP_{c,l})] \qquad (£) \qquad \text{(A15)}$$

where $S_{c,l}$ represent total sales, $RM_{c,l}$ is total raw materials and $OP_{c,l}$ is the outside purchase by company *c* in life cycle stage *l*.

Another way to calculate *VA* is to account for the use of capital in addition to the operating costs. One of the approaches, known as Economic Value Added (*EVA*™) calculates *VA* as[41]:

$$EC_{eva} = \sum_{l=1}^{L} \sum_{c=1}^{C} [NOPAT_{c,l} - (C_{c,l} \cdot CA_{c,l})] \qquad (£) \qquad \text{(A16)}$$

where *NOPAT* is net operating profit before interest but after tax, *C* is the cost of capital in the organisation and *CA* is capital employed in the organization. *EVA* has been shown to give identical results to Discounted Cash Flow (*DCF*) when all the assumptions are the same and after all adjustments have been made[42].

Although this indicator is more company-oriented, it can also be used in the other two types of analysis. If the analysis is company- or process-oriented, *VA* can be calculated as that which the company or process generates; in that case $C = 1$ and $L = 1$. However, if the analysis is product-oriented, than *VA* can be calculated over the whole life cycle of the system so that *C* and *L* are equal to the total number of companies and life cycle stages, respectively. In this case, *VA* will generally be equal to the total value of sales of the product[69], as for instance given by (A15).

• Contribution to the gross domestic product (*CGDP*)
One of the ways to express *CGDP* is in terms of value added per functional unit:

$$EC_{cgdp} = \frac{\displaystyle\sum_{l=1}^{L} \sum_{c=1}^{C} VA_{c,l}}{\dfrac{\displaystyle\sum_{n=1}^{N} GDP_n}{N}} \cdot 100 \qquad (\%) \qquad \text{(A17)}$$

where *VA* is calculated either by equation (A15) or (A16), and *GDP* is gross national product per capita with a total of *N* countries involved in the life cycle of the functional unit. If the analysis is process- or company-oriented, then *L* and *N* will normally be 1; if it is product-oriented, then *L* can be equal to the total number of stages in the life cycle and EC_{cgdp} represents the contribution to average *GDP* of the *N* countries involved in the different life cycle stages.

• Expenditure on environmental protection (*EP*)
EP represents an investment in the protection of the environment and can be expressed per functional unit as:

$$EC_{ep} = \sum_{l=1}^{L} \sum_{c=1}^{C} EP_{c,l} \qquad (£) \qquad \text{(A18)}$$

where $EP_{c,l}$ is investment by company c in the life cycle stage l. This indicator can be used for all three types of analysis.

• Environmental liability (EL)
EL is often expressed as costs that a company may have to pay if it is found liable for causing an environmental hazard. At present there is no consensus on how to calculate environmental liabilities, particularly those that may be accrued in the future. Because of the uncertainty involved, surrogate measures are often used, such as fines and costs of clean-up.

Some of the methods used, for instance, by insurance companies may assist in estimating EL, as they put a price on the probability of being exposed to such liability charges[54]. The insurance cost can then be used for evaluating EL. This indicator could also be expressed as a ratio of environmental over total liabilities per functional unit as an indication of the scale of the problem in relation to the business. EL is primarily a company- and process-oriented indicator, although it could also be used in a product-oriented analysis.

• Ethical investments (ETI)
ETI represents assets invested in business activities that are considered to be ethical. Expressed per functional unit it is equal to:

$$EC_{eti} = \sum_{l=1}^{L} \sum_{c=1}^{C} ET_{c,l} \qquad (£) \tag{A19}$$

where $ET_{c,l}$ is the ethical investment per functional unit by company c in life cycle stage l. For examples of ethical investments see the main text.

Human-capital indicators
• Employment contribution (EM)
This indicator can be calculated as a number of employees PE per functional unit:

$$EC_{em} = \sum_{l=1}^{L} \sum_{c=1}^{C} PE_{c,l} \qquad (-) \tag{A20a}$$

and can be used for all types of analysis identified here. Alternatively, EM can be defined as a ratio of the number of employees per functional unit over an average number of people P employed in the countries involved in the life cycle of an activity:

$$EC_{em} = \frac{\sum_{l=1}^{L} \sum_{c=1}^{C} PE_{c,l}}{\dfrac{\sum_{n=1}^{N} P_n}{N}} \cdot 100 \qquad (\%) \tag{A20b}$$

In that case, EC_{em} represents an average contribution per functional unit to employment in N countries involved in different life cycle stages of the system.

• Staff turnover (ST)
ST can be expressed as the ratio of new employees (NE) to workforce made redundant (RE) by company c in the life cycle stage l as follows:

$$EC_{st} = \frac{\sum_{l=1}^{L} \sum_{c=1}^{C} NE_{c,l}}{\sum_{l=1}^{L} \sum_{c=1}^{C} RE_{c,l}} \cdot 100 \qquad (\%) \tag{A21}$$

Although ST is more suited for company-oriented analyses, it can also be used in the other two types of assessments.

• Expenditure on health and safety (EHS)
EHS can be expressed as total expenditure on health and safety, HS, over the total number of employees, E, to give an investment in health and safety per employee (and per functional unit):

$$EC_{ehs} = \frac{\sum_{l=1}^{L} \sum_{c=1}^{C} HS_{c,l}}{\sum_{l=1}^{L} \sum_{c=1}^{C} E_{c,l}} \qquad (£/\text{employee}) \tag{A22}$$

This indicator can be used for all three types of analysis.

• Investment in staff development (ISD)
This indicator can be expressed as an investment, SD, in training and continuing professional and personal development per employee (and functional unit):

$$EC_{isd} = \frac{\sum_{l=1}^{L} \sum_{c=1}^{C} SD_{c,l}}{\sum_{l=1}^{L} \sum_{c=1}^{C} E_{c\,l}} \qquad (£/\text{employee}) \tag{A23}$$

ISD is suited for all three type of analysis discussed in this work.

Social Indicators

Social indicators are also suitable for all types of analysis, as shown below.

Ethical indicators
These indicators include preservation of cultural values, international standards of conduct and intergenerational equity. Although they can be related to a process or product, they are more suited for the assessment of a company. These indicators are qualitative in nature and are reported as descriptive statements. Their definition is given in the main text and is not repeated here.

Welfare indicators
• Income distribution (ID)
ID shows an average distribution of wealth and could be expressed in terms of income of the top 10% of employees per income of the bottom 10%:

$$SI_{id} = \frac{\sum_{c=1}^{C} \dfrac{IT_c}{IB_c}}{C} \qquad (-) \tag{A24}$$

where IT and IB represent income of the top and bottom 10%, respectively. In company-oriented analysis, $C = 1$; for process- and product-analysis, C includes all major suppliers in the life cycle. Alternatively, in product-oriented analysis, IT and IB can be related to the distribution of income of people in different countries in the life cycle, as it may be easier to obtain data for national than for company income distribution.

- Work satisfaction (WS)

WS is suited for all three type of analysis and, as discussed in the paper, can be expressed in many different ways. Two measures of WS proposed here are respectively number of sick days (SC) and number of people 'happy' with their job (HP) per employee (and functional unit):

$$SI_{ws} = \frac{\sum_{l=1}^{L}\sum_{c=1}^{C} SC_{c,l}}{\sum_{l=1}^{L}\sum_{c=1}^{C} E_{c,l}} \quad (-) \qquad \text{(A25a)}$$

or

$$SI_{ws} = \frac{\sum_{l=1}^{L}\sum_{c=1}^{C} HP_{c,l}}{\sum_{l=1}^{L}\sum_{c=1}^{C} E_{c\,l}} \quad (-) \qquad \text{(A25b)}$$

- Satisfaction of social needs (SN)

SN can be expressed as both quantitative and qualitative indicators. If it is measured in terms of financial contributions of business to satisfying social needs, then it can be expressed as a sum of these investments per functional unit:

$$SI_{sn} = \sum_{l=1}^{L}\sum_{c=1}^{C}\sum_{i=1}^{L} IS_{i,c,l} \quad (\pounds) \qquad \text{(A26)}$$

where $IS_{i,c,l}$ is an investment in social need i (e.g., education) by company c in life cycle stage l. Contributions that cannot be measured in monetary terms can be included as a statement which describes the activity that contributed to satisfying a particular need and puts it in the context of the society to which the contribution has been made. SN can be used for all three types of analysis.

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