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DIRECTORATE FOR SCIENCE, TECHNOLOGY AND INDUSTRY
COMMITTEE ON INDUSTRY, INNOVATION AND ENTREPRENEURSHIP

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EXISTING INDICATORS FOR SUSTAINABLE MANUFACTURING

Preliminary findings

Rochester, NY, 25 September 2008

This paper has been developed under the OECD/CIIE project on sustainable manufacturing and eco-innovation [DSTI/IND(2007)24]. It will be discussed by the Advisory Expert Group at its second meeting to be held on 25 September 2008 in Rochester, NY, United States.

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Summary

Measurements help manufacturing companies to understand environmental issues surrounding the existing production systems and then to define specific objectives and monitor progress towards sustainable production. This paper reviews the existing sets of indicators that assist industry and companies to track and benchmark different aspects of their environmental performance.

Among a multitude of indicator sets, the following nine categories have been identified: *1)* individual indicators; *2)* key performance indicators (KPIs); *3)* composite indices; *4)* material flow analysis (MFA); *5)* environmental accounting; *6)* eco-efficiency indicators; *7)* lifecycle assessment (LCA) indicators; *8)* sustainability reporting indicators; and *9)* socially responsible investment (SRI) indices. The effectiveness of these existing sets of indicators was then analysed according to the predefined criteria.

There is no ideal single set of indicators among the existing nine categories that can cover all aspects that manufacturing companies need to address to improve their production processes and products/services with a view to sustainable development. Rather, an appropriate combination of the existing indicator sets could help companies gain the most comprehensive picture of economic, environmental and social effects across the value chain and product lifecycle. For example, it could be valuable to consider combining MFA, LCA indicators and environmental accounting. Eco-efficiency indicators would be more valuable if concept and methodology are unified since they can be applied to managerial and operational purposes at the same time.

Lifecycle thinking has helped companies to consider environmental effects beyond their factory gates, but to date there is no indicator set which companies apply that takes into account system-level impacts beyond a single product lifecycle. In order to encourage system innovation, it is needed to develop a new set of system-level indicators. Meanwhile, SMEs need to start by collecting data such as a minimum set of individual indicators and to develop their indicators step by step.

It is recommended that the OECD could work with other stakeholders on developing a common understanding of the relative value of existing indicator sets. The OECD could also play a role in guiding and providing supportive measures for the increasing use of indicators by SMEs.

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1. Introduction

1. This paper constitutes part of the OECD/CIIE project on sustainable manufacturing and eco-innovation [DSTI/IND(2007)24].[1]

2. Since the publication of the Brundtland Report (WCED, 1987), sustainable development has become one of the major items on the global political and industrial agenda. Many manufacturers have not only had to deal with ever-increasing environmental regulatory measures but also realised economic benefits from reducing resource use and waste, operating their production processes more efficiently, and promoting environmentally sound products/services. *Sustainable production*, which emerged as a subset of sustainable development at the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992[2], has become one of the key components of business strategies in recent years. Under the so-called Marrakech Process, the UN Environmental Programme (UNEP) and the UN Department of Economic and Social Affairs (UN-DESA) have been co-ordinating since 2003 the development of a 10-year Framework of Programme on Sustainable Consumption and Production, which will be proposed at the 2010-11 cycle of the UN Commission on Sustainable Development (UNCSD).

3. In order to promote sustainable development, there is a need for measurements to assist companies in understanding the issues in the existing production systems and then defining specific objectives and measuring progress towards sustainable production. This desire for metrics is grounded on the proposition that in a business setting 'what you don't measure, you can't manage'. On the other hand, the measurement and monitoring of business activities is not necessarily easy at the practical level, especially in relation to sustainable development. This is partly because the sustainable development concept is too complex and multi-faceted to be dealt by quantitative measurements, and the emphasis on environmental and social aspects often contradicts with the conventional governmental and industry agenda of economic growth.

4. This paper focuses on reviewing the existing sets of indicators that assist industry and companies to track and benchmark different aspects of their performance in order to improve their production processes and products/services towards sustainable development. The objectives of this paper are three-fold:

- Introducing the existing sets of indicators for sustainable production that have been typically used by companies and business associations, especially in the manufacturing sectors;
- Analysing the existing typical sets of indicators in terms of their effectiveness in realising and advancing sustainable production based on the defined criteria; and
- Providing background information on what the OECD could contribute to improving indicators for sustainable production among OECD and non-OECD economies based on the analysis.

5. This paper is structured as follows. The next section firstly explains why indicators are necessary for companies' operations and management decision-making. The existing sets of indicators will be

1 This paper serves for the "[r]eview of current knowledge, of existing sustainable production indicators" (para. 11 and 12, DSTI/IND(2007)24). The review of "relevant country-level initiatives" that is also specified in para. 11 will be dealt by another paper.

2 Principle 8 of the Rio Declaration adopted at the UNCED states: "To achieve sustainable development and a higher quality of life for all people, States should reduce and eliminate unsustainable patterns of production and consumption and promote appropriate demographic policies."

categorised in Section 3 and each category's characteristics will be laid out and illustrated with appropriate examples. The effectiveness of the introduced existing sets of indicators will be analysed in Section 4 according to the predefined criteria. Lastly, some conclusions and recommendations on what the OECD could contribute to improving sustainable production indicators will be drawn based on the analysis.

6. This paper presents some preliminary findings. It will be complimented at a later stage with insights of companies' application of different indicator sets for sustainable production. For that purpose, the OECD is conducting a questionnaire survey and focus group meetings of corporate practitioners during the summer and the autumn of 2008.

7. As the first stage of this project, the paper puts its emphasis on environmental aspects of sustainable development. It should also be noted that the paper's scope is limited to the application of sustainable production indicators in the manufacturing sectors, even though the overall categorisation and analysis of the existing indicator sets may largely be applicable to other sectors.

2. The need for indicators for sustainable production

Functions of indicators

8. The management of complex issues in organisations requires methods for representing the issues by simple units of measurement in order to make timely decision-making possible. These are called indicators – condensed information for decision-making (Olsthoom, *et al.*, 2001). Our body temperature is an example of indicators we regularly use as it provides critical information on our physical condition. Likewise, indicators provide information about phenomena that are regarded typical for and/or critical to the quality of target issues.

9. Companies can use indicators to set targets and monitor consequent success and under-achievement. Interpretation becomes easier if targets can be set for the indicators themselves. These targets help the decision-maker visualise what actions they will need to focus on in the future. Indicators can go beyond simple data collection and illustrate trends or cause-and-effect relationships between different phenomena. Typically, indicators have the following three key objectives:

- **To raise awareness and understanding**: Indicators are useful in describing baseline and current conditions (*e.g.* the amount or magnitude of something) and performance of a system. They can provide the common language for describing a particular system that is necessary for effective and clear communication among interested parties (McCool and Stankey, 2004). Bossel (1999: 9) explains that "[l]earning to handle a complex system means learning to recognize a specific set of indicators, and to assess what their current state means for the health, or viability, of the system".

- **To inform decision-making**: Indicators help make decisions and move analysis into a new diagnostic mode, as they can be a source of real-time feedback on their performance. The value of such indicators is that they reveal what additional analysis might be needed to gain an improved understanding of a phenomenon, just as an increase in a person's temperature leads to more testing and diagnosis (involving new indicators) to determine underlying causes. The observed changes might be an aberration or derived from systemic change. In either case, more monitoring and research is needed to understand underlying causes of the observed changes; such understanding is a necessary condition for enhancing the possibilities of effective intervention.

- **To measure progress towards established goals**: Indicators offer a measure of the effectiveness of actions in moving a system towards a more desirable state. Such indicators are not so much concerned with describing the state of a system as in depicting its response to a treatment or intervention in relation to a given objective (McCool and Stankey, 2004). For example, if body temperature decreases after taking a medicine, we conclude that the medicine has been effective in combating the disease. Thus, to accomplish this third objective, indicators should provide an ability to assess cause-and-effect relations.

Indicators for sustainable production

10. In the past decades, sustainable development indicators have been developed mainly at the global, regional, country and local levels. Such indicators help policy makers and the public to understand the linkages and trade-offs between economic, environmental and social values, in order to evaluate the long-term implications of current decisions and behaviours as well as to monitor progress towards sustainable development goals by establishing baseline conditions and trends.

11. While the behaviour of companies with respect to the goal of sustainable development was mainly directed by government in the past, some companies have recently begun to recognise the potential competitive advantages and other business benefits of adopting a more conscious and proactive approach to sustainable development. The understanding and management of its environmental and social performance is a prerequisite for realising sustainable development and should therefore be a basic asset for competitiveness of any company. In the meantime, in the wake of a series of corporate scandals such as spill-over of oil and sweatshop labour, there has been significant pressure from the public on businesses to be more accountable and transparent in their activities. Shareholders are also becoming increasingly vocal in their demands for non-financial information on business activities aside from financial performance. The idea that organisations should be held accountable for their economic, environmental and social impacts is often referred to as "corporate social responsibility" (CSR).

12. There is an increasing need for the means that allows objective measurement and benchmarking of companies' performance with respect to the environment, or more recently to sustainable development. Once companies recognise the need to embrace sustainable development, the next step is understanding how to implement it. The development of sustainability indicators related to products/services and production processes is an excellent way for companies to incorporate the goal of sustainability into management decision-making (Schwarz, *et al.*, 2002). An improved understanding of the linkages between sustainability performance, competitiveness and business success could enable profit-oriented organisations to realise the 'win-win-win' potentials in the current market system (Schaltegger and Wagner, 2006).

3. A review of the existing sets of indicators

13. A number of manufacturing companies have already started to use certain sets of indicators to measure and monitor the state and progress of their operations (sites/facilities, products/services) as well as their management (company as a whole) towards realising and advancing sustainable production. Those indicator sets have been developed by various organisations including public authorities, industry associations and non-governmental organisations (NGOs), while many companies have also developed their own indicator sets according to their needs. As a result, there exist a multitude of indicator sets for sustainable manufacturing around the world with diverse nature[3]. Furthermore, no literature that comprehensively categorises those existing indicators has been found so far.

14. The OECD (2005) provides a definition of environmental indicators by distinguishing between parameter, indicator and index as presented in Box 1. However, in reality, most companies combine

3 For example, Singh (2008: 98) indicates that "[t]here are more than 600 initiatives working on indicators and frameworks for sustainable development of societies".

various parameters and indicators and apply them as a set in order to understand the state and progress of their sustainability performance rather than use only a single parameter or indicator separately. To analyse the actual application of different metrics used by companies, this paper embraces all types of metrics application and refers as "sets of indicators" (or indicator sets).

Box 1. Definitions of environmental indicators

Parameter: A property that is measured or observed.

Indicator: A parameter, or a value derived from parameters, which points to, provides information about, describes the state of a phenomenon/environment/area, with a significance extending beyond that directly associated with a parameter value.

Index: A set of aggregated or weighted parameters or indicators.

Source: OECD, 2005

15. Among a multitude of indicator sets, the following categories have been identified based on publicly available information such as academic literature and corporate reports (see also Table 1):

- Individual indicators
- Key performance indicators (KPIs)
- Composite indices
- Material flow analysis (MFA)
- Environmental accounting
- Eco-efficiency indicators
- Lifecycle assessment (LCA) indicators
- Sustainability reporting indicators
- Socially responsible investment (SRI) indices

16. The above categories were selected as: *i)* focused on sustainable production in the private sector; *ii)* applied by many companies in practice; and *iii)* not strongly based on another set of indicators. This categorisation is mainly based on the way that companies call different indicator sets and distinguish from other sets of indicators with different characteristics, though it may not necessarily be scientifically robust. In the following sections, the definition, scope of application and methodology of each category of indicator sets are introduced, along with examples of their application in boxes.

Table 1. A list of categories of indicator sets for sustainable manufacturing

Category	Description	Similar indicators or examples
Individual indicators	Measure single aspects individually	Core set of indicators Minimum set of indicators
Key performance indicators (KPIs)	A limited number of indicators for measuring key aspects that are defined according to organisational goals	
Composite indices	Synthesis of groups of individual indicators that is expressed by only a few indices	
Material flow analysis (MFA)	A quantitative measure of the flows of materials and energy through a production process	Material balance Input-output analysis Material flow accounting Exergy; MIPS
Environmental accounting	Calculate environment-related costs and benefits in a similar way to financial accounting system	Environmental management accounting Cost-benefit analysis Material flow cost accounting
Eco-efficiency indicators	Ratio of environmental impacts to economic value created	Factor
Lifecycle assessment (LCA) indicators	Measure environmental impacts from all stages of production and consumption of a product/service	Ecological footprint Carbon footprint
Sustainability reporting indicators	A range of indicators for corporate non-financial performance to stakeholders	GRI Guidelines Carbon Disclosure Project
Socially responsible investment (SRI) indices	Indices set and used by the financial community to benchmark corporate sustainability performance	Dow Jones Sustainability Indexes FTSE4Good

Individual indicators

17. A set of individual indicators means a simple compilation of single indicators, which measure diverse aspects of sustainable development with standard units, such as dollar/euro, gram/tonne and litre/cubic metre, or rates (percentage). Those indicators focus on measuring single aspects of the phenomenon of the systems such as amounts of water use, energy consumption and waste generation as well as a rate of recycling. Each indicator is basically independent and benchmarked separately. This set of indicators is the most commonly used among companies as the first step of developing and applying sustainability indicators for each facility and/or a whole company, while sectors, countries and the globe can also be subject of a set of individual indicators.

18. ISO 14031, an international standard for environmental performance evaluation (EPE), provides a standardised process for measuring an organisation's environmental performance against its environmental policy, objectives, targets and other criteria, in line with the ISO 14001 environmental management system standard. This standard also provides the categorisation of different types of individual indicators. It distinguishes between environmental condition indicators (ECIs) and environmental performance indicators (EPIs), and subdivides the latter into management performance indicators (MPIs) and operational performance indicators (OPIs) (Putnam, 2002). Table 2 shows examples of those indicators.

19. There is no limitation to the number of individual indicators to be used so far as the applying companies consider this appropriate to obtain an overview of their performance with respect to sustainable development. However, since it can be resource-intensive to measure a large number of aspects of

phenomena and difficult to make a balanced and timely judgement, a small number of individual indicators may be selected as a core or minimum set of indicators (see Box 2).

Table 2. Examples of individual indicators

Operating Performance Indicator (OPI)	Management Performance Indicator (MPI)	Environmental Condition Indicator (ECI)
Raw material used per unit of product (kg/unit)	Environmental costs or budget ($/year)	Contaminant concentrations in ambient air (µg/m^3)
Energy used annually per unit of product (MJ/1000 L product)	Percentage of environmental targets achieved (%)	Frequency of photochemical smog events (#/year)
Energy conserved (MJ)	Number employees trained (% #trained/to be trained)	Contaminant concentration in ground- or surface water (mg/L)
Number of emergency events or unplanned shutdowns (#/year)	Number of audit findings (#)	Change in groundwater level (m)
Hours of preventive maintenance (hours/year)	Number of audit findings addressed (#)	Number of coliform bacteria per liter of potable water
Average fuel consumption of vehicle fleet (L/100 km)	Time spent to correct audit findings (person-hours)	Contaminant concentration in surface soil (mg/kg)
Percentage of product content that can be recycled (%)	Number of environmental incidents (#/year)	Area of contaminated land rehabilitated (hectares/year)
Hazardous waste generated per unit of product (kg/unit)	Time spent responding to environmental incidents (person-hours per year)	Concentration of a contaminant in the tissue of a specific local species (µg/kg)
Emissions of specific pollutants to air (tonnes CO_2/year)	Number of complaints from public or employees (#/year)	Population of an specific animal species within a defined area (#/m^2)
Noise measured at specific receptor (dB)	Number of fines or violation notices (#/year)	Increase in algae blooms (%)
Wastewater discharged per unit of product (1000 L/unit)	Number of suppliers contacted about environmental management (#/year)	Number of hospital admissions for asthma during smog season (#/year)
Hazardous waste eliminated by pollution prevention (kg/year)	Cost of pollution prevention projects ($/year)	Number of fish deaths in a specific watercourse (#/year)
Number of days air emissions limits were exceeded (days/year)	Management levels with specific environmental responsibilities (#)	Employee blood lead levels (µg/100 mL)

Source: Putnam, 2002.

Box 2. A core set of individual indicators

A set of individual indicators can be useful in practical application for sustainable manufacturing. For example, the Lowell Centre for Sustainable Development (LCSD) at the University of Massachusetts, Lowell suggests 22 core single indicators as commonly applicable for any manufacturing companies (see table). These core indicators include not only environmental aspects but also some social aspects such as community and labour issues.

Aspect	Indicator	Metric	Level
1. Energy and material use	(1) Fresh wastes consumption	liters	Level 2
	(2) Materials used (total and per unit of product)	kg	Level 2
	(3) Energy use (total and per unit of poduct)	kWh	Level 2
	(4) Percent energy from renewables	%	Level 2
2. Natural environment (including human health)	(5) Kirograms of waste generated before recycling (emission, solid and liquid waste)	kg	Level 2
	(6) Global warming potential (GWP)	Tons of CO2 equivalent	Level 3
	(7) Acidification potential	Tons of SO2 equivalent	Level 3
	(8) kg of PBT chemicals used	kg	Level 3
3. Economic performance	(9) Costs associated with EHS compliance (e.g., fines, liabilities, worker compensation, waste treatment and disposal, remediation)	USD	Level 1
	(10) Rate of customer complaints and returns	Number of compliants/return per product sale	Level 2
	(11) Organization's openness to stakeholder review and participation in decision-making process (scale 1-5)	Number (1-5)	Level 2
4. Community development and social justice	(12) Community spending and charitable contributions as percent of revenues	USD	Level 2
	(13) Number of employees per unit of product or dollar sales	Number/USD	Level 2
	(14) Number of community-company partnerships	Number	Level 2
5. Workers	(15) lost workday injury and illness case rate	Rate	Level 2
	(16) Rate of employees' suggested improvements in quality, social and EHS performance	Number of suggestions per employee	Level 2
	(17) Turnover rate or average length of service of employees	Rate (years)	Level 2
	(18) Average number of hours of employee training per year	Hours	Level 2
	(19) Percent of workers, who report complete job saticsfaction (based on questionnaire)	%	Level 3
6. Products	(20) Percent of products designed for disassembly, reuse or recycling	%	Level 4
	(21) Percent of biodegradable	%	Level 4
	(22) Percent of products with take-back policies in place	%	Level 4

The LCSD also provides a hierarchy of five levels of indicators relative to the basic principles of sustainability with the purpose of providing a tool for organisations to measure the effectiveness of their sustainability efforts. The lower levels of the hierarchy cover basic elements of sustainability. Level 1 covers necessary compliance with regulations and industry standards, while Level 2 measures individual company efficiency and productivity. At Level 3 and 4, companies are required to look beyond its own organisational boundaries and to consider the impacts of suppliers and distributors. This hierarchy emphasises that the development of indicators for sustainable production is not static but rather a continuous and evolutionary process of setting goals and performance measurement.

Source: Veleva and Ellenbecker, 2001.

Key performance indicators (KPIs)

20. Key performance indicators (KPIs) are a set of key quantitative and qualitative measurements defined by an organisation itself for measuring progress towards its own goals. KPIs are expressed by numbers or values which can be compared to an internal or external target for benchmarking to give an

indication of the organisation's performance. These values can relate to data collected or calculated from any process or activity (Ahmad and Dhafr, 2002). What distinguishes KPIs from other categories of indicator sets is their focus on organisational goals in the development of indicators. If the indicators are defined properly, KPIs can serve as a useful diagnostic tool to understand which measures are working most effectively. Any metrics can be selected to illustrate which factors are critical in assessing the success of the organisation. KPIs are in principle applicable to any organisation with the intension to improve its sustainability performance. They may differ depending on the organisation's structure and strategy.

21. KPIs usually involve long-term considerations which require an analysis of the organisation's mission, the identification of its stakeholders and of its organisational goals. KPIs can be helpful for managers who have to handle complicated sustainability issues. A clear understanding of both the drivers of performance and the effects of that performance on various stakeholders may allow for better integration of the information into day-to-day decision-making and the institutionalisation of social concerns throughout the organisation (Epstein and Roy, 2001).

22. Typically, the development of KPIs by companies involves the following four steps (Keeble, *et al.*, 2003):

1. **Making the indicators relevant to management needs:** It is essential to achieve involvement of key people who manage and operate the organisation based on its mission and goals. The process may generate heated debate, but that is a key part of the organisational learning process and an important step on the way to gaining widespread understanding of sustainable development. Indicators should reflect the business realities, values and culture of the organisation, and should not be constrained to prescribed methodologies or standards.

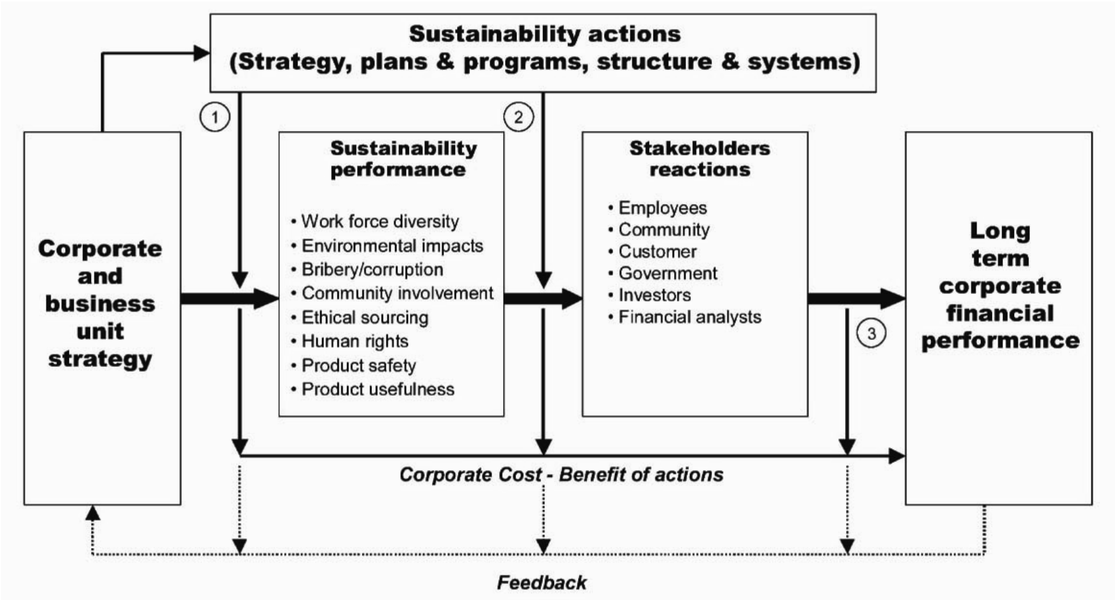
2. **Finding the "ideal set" of indicators:** Organisations can devote significant resources to finding the "ideal set" of indicators. Once a well-balanced set of simple indicators is established, real effort should be put into the review process, ensuring that indicators form the basis for frequent, focused, constructive dialogue on how to improve sustainability performance between different levels and functions of the organisational structure.

3. **Meeting diverse expectations:** Dialogue with key stakeholder groups should inform the process. Identifying what stakeholders expect of the organisation and which policy commitments require substantiation is central to indicator development. The final set of indicators should reflect the concerns of all stakeholders consulted.

4. **Putting the indicators to work:** For the implementation of the indicators, it is critical to assign accountability for delivery to senior operations executives and line managers. These managers must understand how their decision-making can influence sustainability performance.

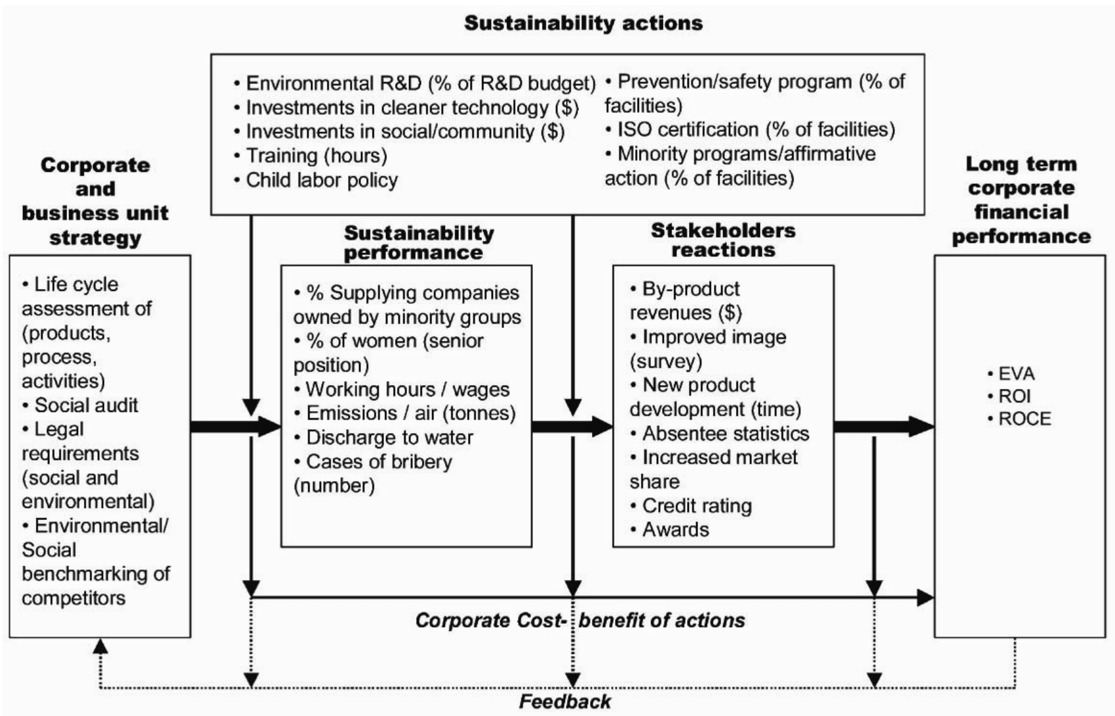
23. Epstein and Roy (2001) developed a model scheme for developing KPIs (see Figure 1), with a focus on the relationships between a company's strategy and actions aiming for sustainable development, its sustainability performance, stakeholder reactions, and long-term financial performance (boxes). The authors suggest establishing KPIs in each of these five areas so that the company can monitor and get feedback on whether and how its sustainability actions can lead to improvement of actual sustainability as well as financial performance. Figure 2 shows an example of KPIs developed based on this model. A company can modify this scheme according to its particular business context.

Figure 1. A model scheme for building KPIs



Source: Epstein and Roy, 2001

Figure 2. An example of KPIs developed based on the above model



Source: Epstein and Roy, 2001.

Box 3. Ford of Europe’s Product Sustainability Index (PSI)

Ford Motor Company Europe introduced new product design management as one of the solutions to tackle the multitude sustainable challenges such as climate change, oil dependency and air quality. This process resulted in establishing the Ford of Europe’s Product Sustainability Index (PSI), by which various dimensions of sustainability have been combined into a comprehensive set of metrics for steering vehicle development. Since automotive product development needs very long lead times and the changes in methods take several years to trickle through buy-in, cycle planning, kick-off, development and launch, the product development in automotive industries has a greater importance in management decision-making compared to other industries. Thus, PSI has been carefully selected to reflect the overall key impact of the different vehicle attributes and makes the trade-offs visible (*e.g.* between lifecycle global warming potential and the lifecycle cost of ownership).

The resulting PSI indicators are:

1) Lifecycle global warming potential (greenhouse emissions along the lifecycle)
2) Lifecycle air quality potential (summer smog creation potential (POCP) along the lifecycle (VOCs, NOx))
3) Sustainable materials (use of recycled & natural materials)
4) Restricted substances
5) Drive-by-exterior noise
6) Safety (pedestrian and occupant)
7) Mobility capability (luggage compartment volume plus weighted number of seats related to vehicle size)
8) Lifecycle ownership costs (vehicle price plus 3-year fuel costs, maintenance costs, taxation and insurance minus residual value)

The implementation of the PSI has been done in a process-driven approach. Clarification of the organisational context is of utmost importance in such complex, big corporations to make the individual departments directly responsible for that specific aspect of sustainability that can be impacted by their area of responsibility. The main affected departments include product development and manufacturing but also human resources and external affairs. Managing sustainable product development is a challenge which goes beyond managing design in a sustainable fashion.

Source: Schmidt, 2008

Composite indices

24. Composite indices are synthesis of groups of individual indicators, expressing the whole phenomenon as one through a limited number of indices. They are effective especially when an organisation wants to present a large amount of information into an easily understandable format for management or external clients.

25. Integrated information on a company’s efforts for sustainable development is very useful for decision-making, since it is often difficult to evaluate the overall performance of the company on the basis of a large number of figures such as a set of individual indicators. Integrating them makes it possible to convey complex sustainability issues in a simple message.

26. Compared to KPIs which offer a core set of indicators chosen by considering organisational goals, composite indexes are valued for their ability to represent a large amount of information into a simple format. They limit the number of statistics and serve as summary indicators, and thus allow for quick interpretation and comparisons of relative performance.[4]

27. The following steps are usually taken when structuring composite indices (OECD, 2003):

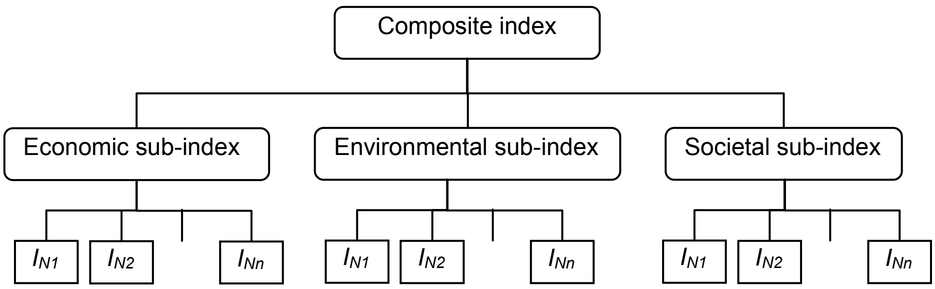
- Developing a theoretical framework for the composite

[4] Recently, a guide for constructing and using composite indicators for policy makers, academics, the media and other interested parties was prepared jointly by the OECD and the Joint Research Centre of the European Commission (OECD, 2005).

- Identifying and developing relevant variables
- Standardising variables to allow comparisons
- Weighting variables and groups of variables
- Conducting sensitivity tests on robustness of aggregated variables

28. A mathematical model has been developed for the determination of composite indices that allows for comparison between companies regarding sustainability performance (Krajnc and Glavič, 2005a; 2005b). The procedure of calculating composite indexes is divided into several parts (see Figure 3). The calculation of the indices is a step-by-step procedure of grouping various basic indicators into the sub-indices for each group of sustainability indicators. Sub-indices are combined into composite indices.

Figure 3. Structure of developing composite indices

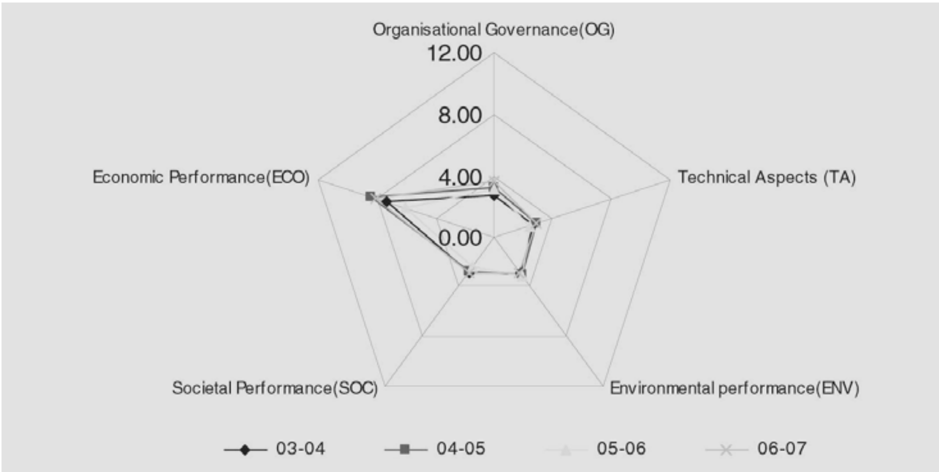


Source: Krajnc and Glavič, 2005a

29. The main issues in aggregating indicators are normalisation and weighting. Normalisation of each indicator is an indispensable procedure because indicators may be expressed in different units. Z-score, which is the most common method of moralisation, converts indicators to a common scale with a mean of zero and standard deviation of one. An appropriate weighting of indicators is also critical because it balances the significance of different sustainability attributes, taking into account a diversity of strategic emphases according to company and sector.

Box 4. Composite Sustainability Performance Index (CSPI) of the steel industry

The steel industry sets a goal to formulate a uniform methodology for assessment of sustainability performance using a composite index to facilitate comparison and decision-making. Singh *et al.* (2007) evaluates the effectiveness of a composite index for steel industry by using a case study from the in the Bhilai Steel Plant of Steel Authority of India Limited (SAIL). Apart from the three pillars of sustainability, organisational governance and technical aspects were considered as additional pillars for evaluating sustainable performance of steel plants. A survey conducted by experts from different functional areas of the steel company identified a framework of Composite Sustainability Performance Index (CSPI), which combines 60 indicators from five categories.



The overall score and sub-indices of various sections of sustainability are evaluated by multiplying the global weights and adding the values of respective sections. These scores are normalised to 10 points, similarly, based on the data collected for the company; the mean value of data has been evaluated for each indicator. The actual values of different sub-indices of the company for the evaluation year are plotted on the corresponding axes with joining of point forms a new 5- sided polygon.

The CSPI aims to formulate a uniform methodology for assessment of steel sector companies through comparison and thus effective decision-making. With the CSPI, corporate sustainability leaders could harness the market's potential for sustainable products and services while at the same time successfully reducing and avoiding costs and risks. Investors can also evaluate the company's role towards sustainable development or alternatively assess its long-term liabilities.

Source: Singh, 2008.

Material flow analysis (MFA)

30. The worldwide use of virtually every significant material has been rising for many years, causing recurrent concerns about shortages in the stocks of natural resources, energy security, supply of other materials, and the environmental effectiveness of their use (OECD, 2008a). According to the law of conservation of mass, total inputs must by definition equal total outputs plus net accumulation of materials in the system (Hinterbergar, *et al*., 2003). Material flow analysis (MFA), a form of material balance analysis, aims to track the movement of materials from extraction to manufacturing, use in a product, reuse, recycling and eventual disposal, and to show emissions to the environment at each step. MFA studies can focus on the whole economy, economic sectors, or individual materials, products, or substances.

31. MFA recognises that material throughput is required for all economic activities and asks whether the flow of materials is sustainable in terms of the environmental burden it creates. It accounts for all materials and energy used in production and consumption, including the hidden flows of materials that are extracted in the production cycle without entering the final product. The physical size of these hidden flows is often many times larger than the flows that end up in actual products.

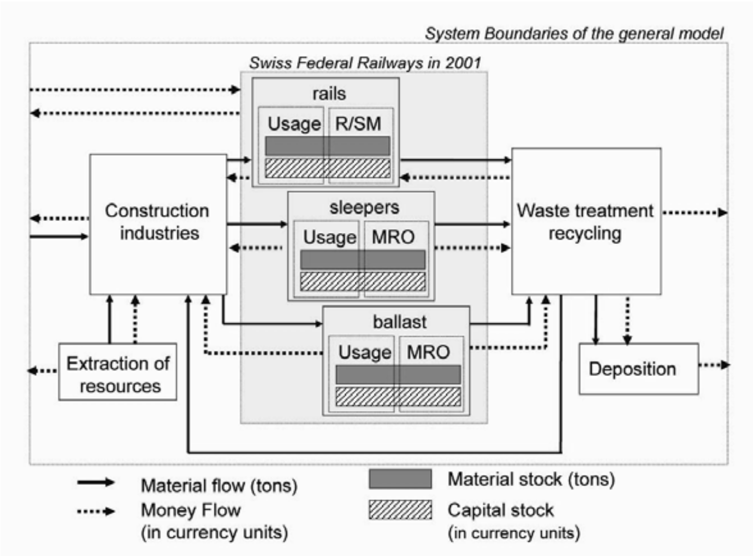
32. In essence, MFA is comprised of two main elements. Firstly, material flow accounting, which refers to an accounting system for materials expressed in physical units (tonnes, kilograms, etc.), describes the material flow as extraction, production, transformation, consumption and recycling, as well as disposal as waste or emissions to air or water (Peele, 2005). Material flow accounting includes inputs, outputs, and accumulations in material stocks. Secondly, material flow indicators derived from these accounts – such as Direct Material Input (DMI), Total Material Requirement (TMR), Total Material Consumption (TMC) – convey policy-relevant messages to a non-expert audience about the significance of material flows with respect to economic and environmental issues.

33. Within companies, the physical balance of inputs and outputs is increasingly being used as part of environmental performance report and provides substantial information for environmental management (see Figure 4). MFA is useful for monitoring development in resource productivity and environmental performance at the company or plant level. It also helps set corporate strategies on investments and emissions, and monitor the availability of critical resources and the vulnerability of a company or a plant to disruptions in the supply chain. MFA of particular industrial materials, such as metals, can shed further light on concepts such as resource productivity and their relation to labour productivity, raw material prices and competitiveness (see Box 5 and Box 6) (Bringezu, 2003).

34. The identification of waste is a major issue in MFA. Its methodology allows for the monitoring of waste typically unaccounted for in traditional economic analyses. It is thus a method for evaluating the efficiency with which material resources are used. Tracking the values of materials as well as their flow rates can show where value as well as material is lost (see Box 7). MFA achieves this analysis by using already available production, consumption and trade data in combination with environment statistics, though it does not necessarily provide company-specific analysis.

Box 5. Material and waste management at the Swiss Federal Railway (SBB)

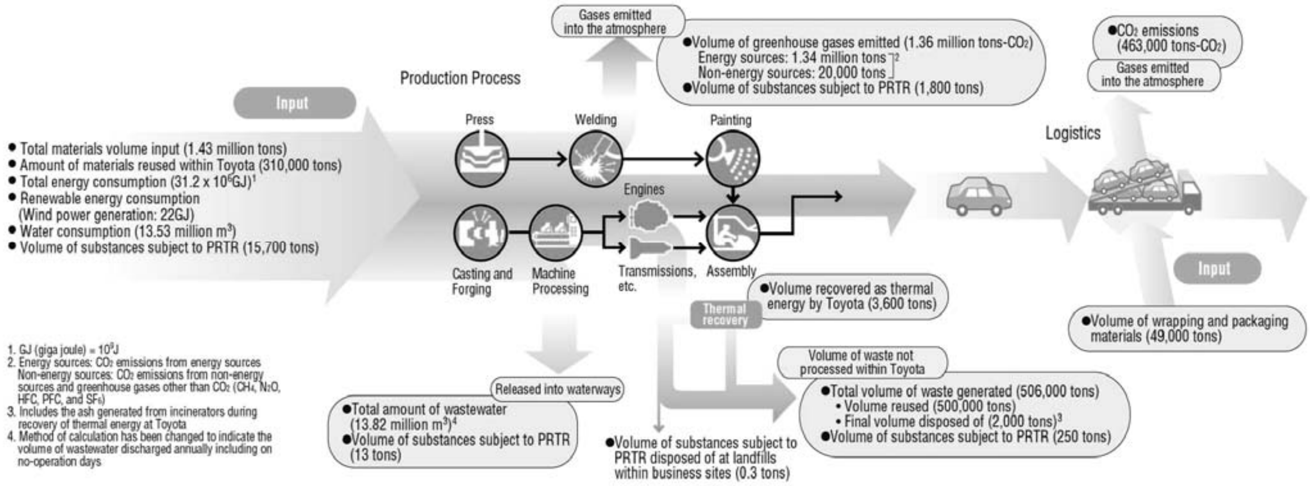
The infrastructures division of the Swiss Federal Railways (SBB) provides information on: *i)* amounts, quality and cost of waste; *ii)* amount and cost of raw materials; and *iii)* driving forces of raw material requirements and waste generation. Data is collected from the corporate information system (material flows and costs), analysis of internal documents (material stocks, capital stocks and maintenance, repair and operations (MRO) activities) and interviews with personnel of SBB (planning of future MRO activities). The overall material balance reveals that the system is near steady state – total input almost equals total output. Rails and sleepers amount to 7% of the mass of input and output flows each. The theoretical average lifespan is defined as ratio between material mass in the stock and material mass in the input flow. Switches, rails and timber sleepers dominate in material costs (input flows) and reconstruction value whereas ballast and sleepers made of other materials are of minor importance.



As the evaluation of future resource management strategies, two scenarios were calculated for the development of the rail track network between 2001 and 2021: Mass of material stock in the rail track network will grow by approximately 2% in the next 20 years due to the relatively higher weight of concrete sleepers. A reduction in the lifespan of components leads to significant cost and flow increase. A variation in the lifespan of different components results in a significant increase of material inputs and in the cost of raw materials. If the lifespan of all components were to be reduced by 5%, material input would increase by 6% and raw material costs by 4%. A reduction of 30% would lead to an increase of both mass input and raw material costs by 35%.

Source: Kytzia, 2003.

Figure 4. An example of material flow analysis: Toyota



Source: Toyota Motor Corporation, 2007

Box 6. Material Input per Service Unit (MIPS)

Material Input per Service Unit (MIPS) measures the total mass of material inputs to create a unit of service output. MIPS can be applied to whole economies, individual sectors of an economy or companies, as well as to single products and services by taking either a problem or systems-oriented approach. The MIPS methodology was designed intentionally to provide "a simple indictor of the material intensity of a product or service". As such, it can be used to measures material inputs used to create a product, a single service offering, one type of material or material groups.

MIPS covers all material inputs at all phases of the lifecycle of the product or service under investigation, including extraction of materials, manufacturing, transport, use, maintenance, and end-of-life. The total mass of material inputs across the lifecycle is aggregated to produce a single score for a particular product, and the score is represented per unit of service the product delivers. The results of a MIPS study can be used as a single indicator that represents material intensity across the five categories: abiotic raw materials, biotic raw materials, soil movements in agriculture and silviculture, water, and air.

The strengths of the MIPS methodology include the comprehensive scope of material inputs across the product lifecycle as well as the fact that it produces an easy-to-understand indicator. A shortcoming is that MIPS treats all materials equally and hence does not account for the qualities of material flows or environmental impacts of different types of materials, their toxicity, fate, transport, or exposure pathways. Another weakness is that the relative scarcity or abundance of materials is not considered.

Source: OECD, 2007a.

Box 7. Material Flow Cost Accounting (MFCA)

Material flow cost accounting (MFCA)[5] is a management tool developed for reducing the relative consumption of resources and material costs, which is applicable for service industries as well as manufacturing industries. MFCA is one of the major tools of environmental management accounting (EMA) and is oriented to internal use within an organisation.

MFCA enables the calculation and management of quantity and cost data for losses incurred in the manufacturing process. This model asserts the final shipped product of the manufacturing process as "positive products," and emissions and waste along the way as "negative products." The material costs associated with negative products, processing and waste treatment costs are determined as "negative product costs." Analysing the quantity of negative products and reducing the number of negative products enables to reduce our environmental burden and costs.

For example, Canon, one of the largest manufacturers of cameras and optical apparatus, started using MFCA at a manufacturing line in a main factory for lenses. Before introducing MFCA, it was considered that there was no waste at the manufacturing line. However, from the standpoint of MFCA, lens polishing sludge was reconsidered to be material loss. Afterwards, environmental performance and environmental costs were improved drastically. In co-operation with the vendor, Canon developed a new thinner glass material that reduces polishing sludge. Now, based on the success at first step, Canon deploys MFCA to the whole company. As of December 2006, MFCA was being used by a total of 20 sites. A joint MFCA project between Canon and its raw material suppliers was initiated in 2004, with both sides working together to reduce environmental burden and costs. During 2006, Canon's environmental accounts show investment of 19.1 billion yen in environmental protection, including 5.8 billion yen for improvements designed to obtain economic benefits from environmental protection. This investment generated benefits of 6.2 billion yen (Canon, 2007)

In November 2007, the Japan's Ministry of Economy, Trade and Industry (METI) formally submitted to the International Organization for Standardization's technical committee on environmental management (ISO/TC 207) a New Work Item Proposal (NWIP). In March 2008, the proposal was approved and ISO/TC207 Working Group 8 (WG8) was set up to establish an ISO standard in three years time.

Source: METI, 2008.

Environmental accounting

35. Environmental accounting is a systematic way to measure important environmental factors based on common financial accounting system (Jónsdóttir, *et al.*, 2005). At its simplest, environmental accounting is about making environment-related costs more transparent within corporate accounting systems and reports. Environmental accounting is a tool to evaluate the (economic and physical) effect generated by the cost (investment and expense) required or invested for environmental protection. Environmental accounting can be applied to the management of companies to link environmental issues with financial cost accounting and to evaluate the potential for 'win-win' solutions to environmental protection and financial profitability. This method is also applicable to accounting at the local and national levels.

36. The concept of environmental accounting was introduced around 1990 as a proactive approach to sustainable development. Its popularity has rapidly increased among companies in recent years (Palme and Tillman, 2008). The benefit of environmental accounting for companies is that the identification and greater awareness of environment-related costs often provides an opportunity to find ways of reducing or avoiding these costs, as well as improving environmental performance.

37. Although it is important for management to uncover and recognise environmental costs associated with production, it may not always be clear whether a cost is "environmental" or not. Some costs fall into a gray zone or may be classified as partly environmental and partly not. The following costs are clearly environmental costs: costs incurred to comply with environmental regulations; costs of

5 MFCA can be considered as a hybrid of material flow analysis and environmental accounting.

environmental remediation, pollution control equipment and non-compliance penalties; and other costs incurred for environmental protection. However, there are other costs that may fall into a gray zone. For example, the costs of production equipment may be considered "environmental" if this equipment is considered part of a clean technology. The development of environmentally sound products/services might be also considered as part of environmental costs. Some companies even include the costs of environmental education, campaigns, donations and voluntary activities. It may also be difficult to distinguish environmental costs from health and safety costs or from risk management costs. Some governments provide national guidelines for corporate environmental accounting that help the standardisation of what can be counted as environmental costs (*e.g.* MoE, 2005).

38. However, whether or not a cost is "environmental" may not be all that important unless it is employed in comparing one company to another. The primary goal of environmental accounting is to ensure that relevant costs receive appropriate attention. To handle costs in the gray zone, some firms can use the following approaches (EPA, 1995):

- Allowing a cost item to be treated as "environmental" for one purpose but not for another;
- Treating part of the cost of an item or activity as "environmental,"; or
- Treating costs as "environmental" for accounting purposes when a firm decides that a cost is more than 50% environmental.

Eco-efficiency indicators

39. Eco-efficiency indicators are the indicators that specify the relationship between economic value created and environmental impacts caused by the same institutional or geographical unit of accounting or economic activity. They focus on the interplay between economic and environmental aspects so that they are in principle two-dimensional. The units to which eco-efficiency indicators can apply vary widely from micro to macro-levels of analysis. They may be applied to one specific economic activity such as a production process, to a set of activities like a product system, to a firm, to a sector to a region or country or to the global economy.

40. The common use of the term eco-efficiency has been promoted through the activities of the World Business Council on Sustainable Development (WBCSD) since the early 1990s (Schmidheiny, 1992). The WBCSD defines eco-efficiency from a broader perspective as "a management philosophy that encourages business to search for environmental improvements which yield parallel economic benefits" (WBCSD, 2000: 8).

41. Since eco-efficiency can be seen from numerous perspectives and used on different levels, no single standard methodology for eco-efficiency indicator systems has yet been developed. Quantification of eco-efficiency in any institutional unit nevertheless involves several options. There are two basic categories of methodology used in eco-efficiency analysis: *i)* value-based eco-efficiency accounting and *ii)* cost-based eco-efficiency accounting.

42. In value-based eco-efficiency accounting, the relationship between economic value and environmental impacts is often summarised in an algebraic ratio, which either measures economic value created per unit of environmental impacts ("environmental productivity") or accounts for environmental impacts per unit of economic value ("environmental intensity"). The ratios of environmental productivity and environmental intensity are inverses of each other. This methodology has the advantage that it can be applied at various levels, *i.e.* to a company, a region, a country or the world.

43. Cost-based methodology processes data in a similar way. Environmental improvement per unit of cost can be called "environmental cost-effectiveness". The inverse of this ratio conveys similar information and is called "environmental improvement cost" (*e.g.* marginal cost of emission reduction). Cost-based eco-efficiency accounting, however, can only be applied at the micro level, for example to individual companies (Huppes, 2007).

44. The concept of eco-efficiency is beginning to be applied in the daily operations of companies. Various manufacturing companies have developed in-house metrics for eco-efficiency (Figge and Hahn, 2004). These metrics allow managers the early recognition and systematic detection of economic and environmental opportunities and risks in existing and future business activities. The concept of "Factor" is a practical application of the eco-efficiency for environmental improvement of products/services and has been widely applied by Japanese electronics companies (see Box 8).[6] The formula of Factor is principally expressed as follows:

(Factor) = (Eco-efficiency of a product to be assessed) / (Eco-efficiency of the benchmark product)

Lifecycle assessment (LCA) indicators

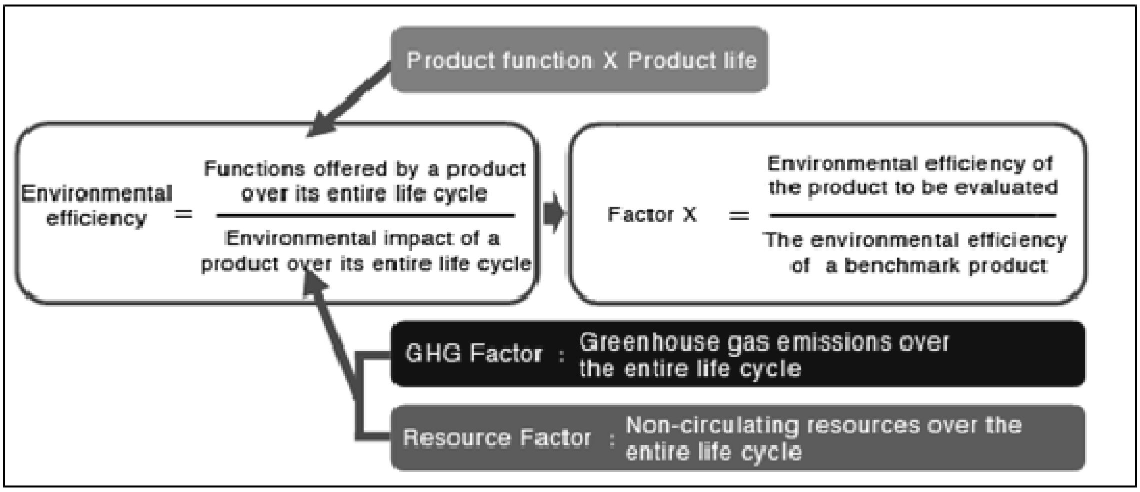
45. Lifecycle assessment (LCA) is defined as a study of "the environmental aspects and potential impacts of a product or process or service throughout its life, from raw material acquisition through production, use and disposal" (ISO, 1997). The term LCA refers to the evaluation of the entire lifecycle of a product, "from the cradle to the grave", *i.e.* from extracting basic resources, through production, transportation, to use and disposal of the product itself. The LCA methodology can address a single product, a material or material groups as well as services from the lifecycle perspective.

46. LCA is often used to compare products with equivalent functions, or to determine "hot spots" during the lifecycle which are critical to the overall environmental impact. When we consider a specific product, we only see a small part of the total material flows that were mobilised in the course of its production. The "hidden" flows, *e.g.* fossil fuels used in manufacturing and transport, should be considered as a part of the product's total impacts on the environment. LCA can help us to identify the important aspects of a production process from the sustainability perspective.

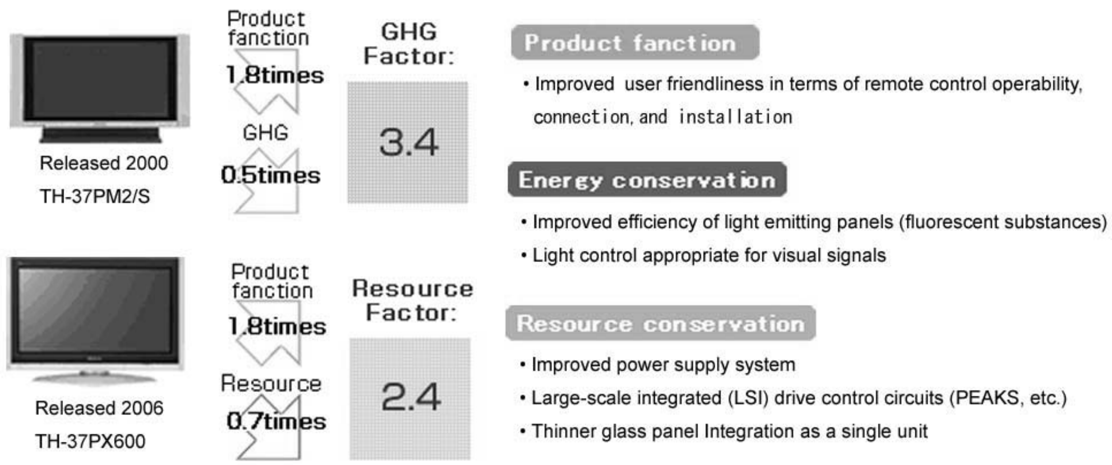
6 A number of Japanese electronics companies applying the Factor concept define eco-efficiency as a ratio of "product value" (*e.g.* functions in case of Panasonic) created per unit of environmental impacts, instead of using economic value or cost as explained above (Aoe, 2006).

Box 8. Application of an eco-efficiency indicator system for product development at Panasonic

Matsushita Electric Industrial (Panasonic), a Japanese electronics manufacturer, has been applying the concept of "Factor X" as an eco-efficiency indicator system "to quantify the way in which the product value can be increased while reducing the impact on the environment". By comparing the eco-efficiency of both new and old models of a product, the improvement level is then expressed in how many times more the eco-efficiency of the new model is than that of the old model. Accordingly, higher values show that the eco-efficiency of the new model has been increased in comparison with older models.



Panasonic applies Factor X to two major environmental aspects – greenhouse gas (GHG) emission reduction and efficient resource use. The GHG Factor and the Resource Factor are defined as the above chart. Factor X is expressed using simple mathematical values to indicate the level of improvement in these eco-efficiency criteria and utilise these values in subsequent evaluations or as numeric targets in product development.



By this way, Panasonic does not adopt the "minimisation of environmental pollution risks" as just one of the indicators used but conducts evaluations on whether or not adequate efforts are being made to minimise environmental pollution risks throughout the whole production and distribution system.

Source: Panasonic's website http://panasonic.net/eco/factor_x.

47. One of the most recent approaches applying LCA in an attempt to make production more sustainable is the idea of "carbon footprint", reflecting increasing concerns over climate change (see Box 9). While the LCA methodology usually addresses different environmental aspects, carbon footprint focuses on a single type of environmental impact – carbon dioxide (CO_2) emissions. Carbon footprint may

be defined as a measure of the exclusive total amount of CO_2 emissions (directly or indirectly) caused by the activity or accumulated over the life stages of the product.

Box 9. Carbon footprint

The concept of carbon footprint has been widely used in the public domain in the last few years. Carbon footprints indicating CO_2 emissions generated throughout product lifecycles have been applied as eco-labels to a range of products, such as potato chips and canned beer. It is associated with individual responsibility and abatement action in the face of global climate change. A number of approaches have been proposed to provide estimates, ranging from basic online calculators to sophisticated LCA or input-output-based methods and tools. This concept not only enables companies to demonstrate their efforts in reducing CO_2 emissions, it also improves consumer awareness of the issue.

The British Standards Institution (BSI) is currently leading the development of a Publicly Available Specification (PAS) for a method for measuring the embodied greenhouse gas emissions from goods and services across their lifecycle. The method was developed by the Carbon Trust, an independent company set up by the UK government. The PAS 2050 was published in March 2007 and is currently being tested on a pilot basis.

The Japan's Ministry of Economy, Trade and Industry (METI) started to convene a study group to research possible programmes and methodology regarding carbon footprint. Environmental managers from over ten companies, including manufacturers, are participating. The METI intends to establish guidelines for calculating and displaying carbon footprints, and is proposing the standardisation of carbon footprint to the ISO (METI, 2008).

48. "Ecological footprint" is another popular resource management tool based on LCA, measuring how much land and water a human population requires to produce the resources it consumes and to absorb its waste under prevailing technology. At the company level, for example, SITA, one of largest waste management companies in France, has created a tool for calculating the ecological footprint of the waste collection portion of SITA's operations, and has been using this both to determine how to lower their ecological impact and increase the efficiency of their operations, as well as for communication with customers (Wackernagel, 2008).

49. Whereas material flow analysis (MFA) applies mass balance approaches, LCA starts by compiling mass balances over the entire supply chain of a product/service. This extends from the "cradle" of primary resources – metal ores or fossil fuel deposits, for example – to the "grave" of recycling or disposal (Clift, 2006).

50. The International Organization for Standardization (ISO) developed an internationally standardised method of LCA, ISO 14040 series. These standards advise companies to carry out LCA in four distinct phases: *i)* defining goal and scope; *ii)* making a lifecycle inventory (ISO 14041); *iii)* conducing lifecycle impact assessment (ISO 14042); and *iv)*interpreting the assessment results (ISO 14043).

51. LCA also provides a wide range of environmental tools which incorporate lifecycle thinking. It allows for an analysis of the problems related to a particular product/service, comparing improvement variants of a given product/service, designing new products/services, and choosing between several comparable products/services. Eco-design is one of the approaches assessing the environmental aspects of a product system commonly based on LCA. Eco-design aims to ensure that new products/services are designed to cause minimal environmental damage over their lifecycle.

52. LCA is also useful to assist decision-making of individual and institutional consumers. Eco-labels have been widely applied to products as a means to communicate their lifecycle environmental impact as calculated by LCA to consumers, and hence make it easier for them to choose more environmentally sound products/services.

Box 10. EIME: A software for LCA

The EIME, which is widely used by the major industries of the electrical and electronic sector, enables users to assess environmental risks and to manage new opportunities. The software was developed in 1998 by leaders of the electrical and electronic business associated with the French Federation of Electrics, Electronics and Communication Industries (FIEEC) to support companies of the sector.

Based on LCA information respecting the ISO 14040-44 standards, the EIME is designed to adapt the following user needs:

1) Assessment and control of product environmental risks during the whole design process
2) Comparison between competing design alternatives in order to improve products
3) Internal dissemination to customer requirements, company rules and legal constraints
4) Active contribution to environmental management system
5) Communication of an environmental declaration or an eco-profile to customers and shareholders

Lifecycle inventory (LCI) is a collection of data related to the system boundaries, including air emissions, water emissions, soil emissions, energy consumption, and material consumption. Through the EIME software, the database of LCI is regularly updated by the Conception Développement Durable Environnement (CODDE), a company created by the FIEEC.

Other LCA software and tools to assist manufacturers currently on the market include umberto, GABI, COMPASS and Eco-indicator 99.

Source: CODDE, 2007

Sustainability reporting indicators

53. Sustainability reporting indicators are a set of indicators through which organisations can publicly disclose information about their performance considering economic, environmental and social aspects of their activities and processes. Sustainability reporting can be applied to a variety of institutional or geographical units at various levels, but has been mostly used at the facility, company and sectoral levels.

54. The early models of sustainable reporting indicators can be found in the environmental reporting initiatives of chemical companies which suffered from serious image problems in the late 1980s[7]. Responding to growing pressure and expectations from customers, business partners, investors and the wider community, sustainability reporting indicators may help companies identify and manage non-financial and intangible risks and opportunities connected to their operations through measurement and data collection. An increasing number of governmental departments and local authorities are also publishing sustainability reports.

55. Some governments, including those in Denmark, The Netherlands and Portugal, have made sustainable reporting mandatory for public agencies and private companies. There are even some efforts to mainstream sustainability reporting by requesting non-financial disclosure as part of mandatory annual financial accounts, for example in the New Economic Regulations in France. Other governments including Austria, Japan and Australia are taking a voluntary approach by providing guidelines that standardise the content and qualities of sustainable reporting indicators. However, the Global Reporting Initiative (GRI)'s Sustainability Reporting Guidelines are rapidly becoming the internationally accepted voluntary framework for sustainability reporting as widely used by companies around the world[8] (see Box 11).

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7 These concerns led the way to a global initiative Responsible Care which was first conceived in Canada in 1985 to address public concerns about the manufacture, distribution and use of chemicals.

8 By August 2008, it is identified that over 1,500 organisations from 70 countries have applied the GRI Guidelines as a framework to report their sustainability performance.

56. Sustainable reporting indicators are a combination of multiple types of indicators – both quantitative and qualitative. They are often categorised according to the three pillars of sustainable development. Most guidelines also ask for information on the reporting organisation's mission, governance and management system. While the guidelines incorporate a multi-dimensional understanding of sustainable development, all indicators are individually standing and their interpretation is left to the reader of sustainability reports.

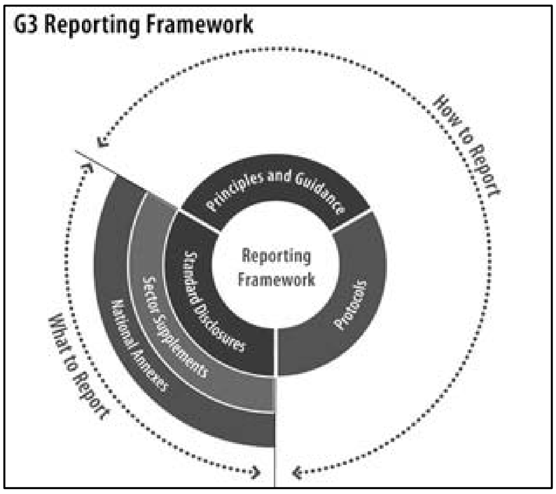
57. Since sustainable reporting indicators were primarily developed for external disclosure, they are not intended to serve for internal management of product/service development and production processes. However, sustainability reporting is a good starting point for many companies in collecting environmental and social data and monitor the progress in order to improve their sustainability performance at the site and company levels. While sustainability reporting is still practiced mainly by relatively large companies, the GRI encourages small and medium-sized enterprises (SMEs) to report their sustainability performance by issuing a handbook. It is also developing a list of sector-specific indicators to supplement the general set of indicators in order to respond to demands from industry, while providing technical protocols that aim to unify the measurement unit and methodology as well as organisational boundaries.

58. The listing requirements for more accountability and disclosure on corporate governance from stock markets and financial regulators are another good example of a context in which sustainability reporting may take place. Business community also may effect and drive the needs and requirements of sustainability reporting in terms of certain membership rules. A good example of this case is the sustainability development framework of the International Council on Mining and Metals (ICMM) for its member companies. The UN Global Compact now requires its signatories to report their sustainability performance annually aligned with its ten universally accepted principles in the areas of human rights, labour, the environment and anti-corruption. Some sector associations such as chemicals, steel and aluminium even provide their own reporting indicator sets and guidelines and compile the data reported from member companies (*e.g.* CEFIC, 2007; IISI, 2005; EAA, 2006).

Box 11. Global Reporting Initiative (GRI)

The Global Reporting Initiative (GRI) was established in 1997 by a Boston-based NGO, CERES, with the vision that "reporting on economic, environmental, social performance by all organizations becomes as routine and comparable as financial reporting". It was soon developed into a multi-stakeholder international organisation with support from the United Nations Environment Programme (UNEP).

The work of the GRI is targeted at private companies of all sectors and sizes, which are interested in reporting sustainability aspects of their business activities, as well as other organisations such as public institutions. In addition to the Guidelines that are generally applicable to all businesses alike, supplements that provide guidance specific to particular sectors have also been developed. The GRI Sustainability Reporting Guidelines are the result of a continuous process of consultation with its stakeholders such as organisations using the Guidelines and other experts.



The Guidelines consist of three parts. The first part contains the principles of sustainability reporting with regards to the content and scope of the report. The reporting organisation is expected to develop its sustainability reports based on certain principles including *relevance, completeness, comparability, accuracy* and *transparency*. The second part provides a list of relevant indicators on the economic, environmental and social performance of the company or organisation. The third part contains advice on more general questions, for example how to use the Guidelines and how to ensure the credibility of a report. The Guidelines list 13 indicators for economic performance including economic value generated, spending on locally based suppliers and indirect economic impacts. 35 indicators describe the environmental performance of the organisation with regards to water, energy, biodiversity and other important environmental media. Finally, 49 social indicators include statements about management practice and child labour as well as corruption and community involvement.

Source: GRI website www.globalreporting.org

Socially responsible investment (SRI) indices

59. Socially responsible investment (SRI) indices are generic, generally composite-type indices which incorporate a number of indicator types, approaches and methodologies to convey the investors' criteria in terms of economic, environmental or social sustainability in the growing SRI markets. SRI indices aim to analyse and evaluate companies or industries for particular groups of financial investors, according to predefined criteria. Some leading banks also publish sustainability criteria which lenders are required to fulfil for financing certain projects.

60. SRI refers to an investment strategy that seeks to maximise both financial return and social or environmental good simultaneously. Since it originated in faith-based activism, two fundamental elements are incorporated into SRI: *i)* an anti-militarist and anti-racist agenda; and *ii)* health and environmental concerns. Since the late 1990s, SRI activism has given increasing attention to environmental and social issues. Many investors now consider climate change as a significant business and investment risk (Richardson, 2008).

61. Thanks to the participation of institutional investors such as corporations, universities, hospitals, foundations, insurance companies, pension funds, non-profit organisations, religious and other mission-driven associations, SRI has become a booming financial market worldwide. Assets in socially screened portfolios climbed to USD 2.71 trillion in 2007 in the US, reaching a share of some 11% of professionally

managed capital services (Social Investment Forum, 2008). The European SRI market grew to EUR 1.6 trillion in 2007 (Celent, 2007).

62. In earlier periods, the technical aspect of SRI indices was simply based on negative selection criteria, avoiding investment in some undesirable sectors such as tobacco, gambling, slave trade and defence industry ("negative screening"). In recent years, a new approach has been developed in looking for best practices among competitors. This is to encourage companies to improve their performance through benchmarking in a more positive way ("positive screening").

63. Sustainability criteria have mainly been set by the leading financial index providers such as Dow Jones and FTSE as well as specialised rating agencies (see Box 12). Financial firms and institutional investors either develop their own criteria or purchase rating information from those providers in order to make their decisions. As of October 2004, there were at least 12 "families" of market indices of sustainable companies, and over 35 individual indices in at least 7 countries (Hamner, 2005). They are generally constructed through a stylised composite indexing methodology and include sector-specific aspects of economic, environmental and social issues. Rating agencies use publicly available information such as sustainability reports, questionnaire surveys and face-to-face interviews as well as stakeholder reputations and media reports to evaluate sustainability performance of companies according to predefined criteria.

64. Since SRI indices are set by external parties, they are not directly used by companies to improve their own manufacturing processes and products/services. However, their criteria are significant because leading companies receive a number of questionnaire surveys and interviews from rating agencies, and because the results of benchmarking are clearly comparable between competitors and directly influence investors' decisions. It is therefore assumed that sustainability criteria for SRI indices have a strong influence on what sustainability aspects and practices companies need to focus upon. According to a recent study, investors in SRI markets have a tendency to define sustainability with a strong focus on internal organisational efficiency and soundness. The study also found that investors particularly value pollution prevention, resource efficiency, innovation and community welfare (Hamner, 2005).

Box 12. Dow Jones Sustainability Indexes (DJSI)

The Dow Jones Sustainability Indexes (DJSI), as an aggregated family of sub-indices, account for the performance of leading companies worldwide since its launch in 1999. The company provides services at different levels of international scale in the form of regionalised sustainability indices and customised indices throughout European and North American benchmarks. Some of sub-indices include: Dow Jones Sustainability World Index (DJSWI), Dow Jones STOXX Sustainability Index, Dow Jones EURO STOXX Sustainability Index, Dow Jones Sustainability North America Index and Dow Jones Sustainability United States Index.

To construct a composite sustainability index, corporate sustainability criteria are initially identified by assessing economic, environmental and social driving forces and trends. Sustainability criteria can be defined in terms of either general criteria or industry specific terms. All criteria are based on widely accepted accounting, statistical and information standards and procedures. Weightings are attached accordingly.

At the second stage, during the process of input gathering, four major sources of information are used: company questionnaire; company documentation; media and stakeholders; and direct contact with companies. At the final step, the company's total corporate sustainability score is calculated through the Sustainability Information Management System (SIMS) based on predefined scoring and weighting structure.

Corporate sustainability assessment criteria and weightings for DJSWI

Dimension	Criteria	Weighting (%)
Economic	Codes of Conduct / Compliance / Corruption&Bribery	5.5
	Corporate Governance	6
	Risk & Crisis Management	6
	Industry Specific Criteria	Depends on Industry
Environment	Environmental Performance (Eco-Efficiency)	7
	Environmental Reporting*	3
	Industry Specific Criteria	Depends on Industry
Social	Corporate Citizenship/ Philanthropy	3.5
	Labor Practice Indicators	5
	Human Capital Development	5.5
	Social Reporting*	3
	Talent Attraction & Retention	5.5
	Industry Specific Criteria	Depends on Industry

* Criteria assessed based on publicly available information only

Source: Dow Jones Sustainability World Indexes - Version 9.1, January 2008.

4. Analysis of the existing sets of indicators

Criteria for analysis

65. In this section, each category of indicator sets and related elements introduced in the previous section is analysed in detail to evaluate its effectiveness in initiating and advancing corporate sustainable manufacturing practices. In order for this analysis to be objective, several benchmarking criteria that are desirable for companies' usage of indicator sets are identified:

- **Comparability for external benchmarking**: This is an important characteristic for sustainable manufacturing indicators. Companies are facing intense competition and need to be performing better than their competitors and the industry average, as well as improving their performance overtime. In the absence of benchmarks, companies have no idea on how they compare with their competitors (Matthews and Lave, 2003). This principle is also applied to environmental and other sustainability performance. It is pointed out that the lack of the common measurement for sustainable production has hampered the adoption and dissemination of sustainable manufacturing technologies and best practices (OECD, 2006). Even though some companies have established their own benchmarks for continuous improvement, these are uniquely tailored to each company and not comparable within and across sectors. A recent study demonstrates that comparability is the single most important characteristic of environmental performance indicators. There is a growing need among investors, communities and consumers of comparable standardised sustainability indicators that allow comparisons between companies and between products/services (Veleva and Ellenbecker, 2001).

- **Applicability for SMEs**: This criterion implies that sustainable manufacturing indicators should be easily applied by SMEs in terms of cost and labour for data collection. Even though SMEs have a strong role to play in promoting sustainable manufacturing as a large majority of manufacturers are SMEs located in the supply chain, they are generally much less likely to embark on environmental improvement programmes than larger companies. SMEs tend to consider environmental issues as a potential cost and most of them do not see environmental concerns as a market opportunity. They also tend to take environmental measures only in response to threats of imposed penalties or closure by authorities and usually respond with "end-of-pipe" pollution control solutions (Rao, *et al*., 2006). Many of them have not established their indicator systems due to lack of resources such as finance, personnel, time and technical knowledge as well as motivation and awareness.

- **Usefulness for management decision-making**: Sustainable manufacturing indicators need to be capable of providing useful information that adequately responds to management decision-making. This criterion implies simplicity in the interpretation and comprehension of indicators. The indicators can be used as a help in decision-making on a basis that reflects the objectives of the organisation and considers systematic mechanisms. In the same way, indicators could serve as a measure for evaluating results delivered by management. This also implies that indicators need to accommodate longer-term perspectives towards sustainable development. From the standpoint of strategic business, this allows management to create more value while causing less environmental impact.

- **Effectiveness for actual improvement at operational level**: Sustainable manufacturing indicators should also be able to provide effective information that responds to actual improvement at the operational level, *i.e.* production processes and manufacturing of products/services. This requires integrity of the information that covers all important operation. The indicators can be helpful to actual improvement when they reflect an understanding of day-to-day operations. This criterion also implies clarity and timeliness in the implementation of possible improvements. It clarifies what can be done immediately and what should be left for later.

- **Possibility of data aggregation and standardisation**: This characteristic implies that the indicators be stackable in a standardised form so that the information collected at the site or corporate level can be used in wider levels, for example, within a sector, a country or around the globe. Data collected in stackable units can be aggregated for comparison and evaluation of diverse aspects of businesses. Considering the fact that supply chains have sprawled over facility fences, company walls and national boundaries, and have been growing in significance for economy and the environment, stackable indicators would also be useful for evaluating effects throughout the value chain.

- **Effectiveness for finding innovative products/solutions**: Since technological developments and systemic solutions are expected to contribute to sustainable development in the manufacturing sectors, it would be ideal if indicator sets were also effective for finding innovative products and solutions. This implies that indicators should be consecutive and sensitive to the data. Comparing experimental results with consecutively accumulated data can reveal which products/solutions are more sustainable. Sensitive indicators could serve this purpose far better.

Analysis according to indicator categories

Individual indicators

66. In terms of comparability, individual indicators are not suitable because they are applied to a large number of corporate daily procedures and can be created for each company according to necessities. However, if a core set of indicators could be agreed upon within a sector, this would facilitate sector-level benchmarking when the company's boundary and balanced normalisation can be established.

67. Regarding the applicability for SMEs, individual indicators are the most familiar type for SMEs and can be easily utilised for internal evaluation since they can be adopted without the kind of organisation analysis and complicated calculation needed in the case of key performance indicators or composite indices. However, since SMEs would have difficulties in collecting data for too many aspects, the number of indicators must be limited.

68. From the viewpoint of management decision-making, individual indicators could not help management understand the full picture since they present a large number of different data independently. In order to be useful for management decisions, the number of individual indicators should be restricted and the priority issues for management need to be identified. Individual indicators cannot identify links between environmental performance and financial outcomes, which management tends to require for making decisions on environmental investment.

69. Concerning actual improvement at the operational level, individual indicators can be applied only to the improvement of a few selected environmental aspects such as water and resource use or waste and emissions. It is difficult to handle when improvement of one aspect might lead to deterioration in other aspects as indicators are monitored independently.

70. If consensus can be reached among concerned parties (*e.g.* members of a sector association) on the units of data and if organisational boundaries and a system to avoid double counting are properly established, individual indicators can be used for data aggregation and standardisation.

71. With regard to finding innovative products/solutions, individual indicators can be applied only when companies focus on a few environmental attributes. However, as the focus on one aspect might lead to overall deterioration of environmental performance, the use of individual indicators for product and process development is not advisable.

Key performance indicators (KPIs)

72. In terms of comparability for external benchmarking, key performance indicators (KPIs) are not suitable because these indicators are principally customised for each company based on system analysis in terms of mission, stakeholder expectations and goals. They are specifically designed to help companies to measure progress towards their own organisational goals, depending on the nature of the organisation and its strategy. KPIs could only have the scope for external benchmarking if a group of companies or an

industrial sector with similar organisational structures, mission, stakeholders and strategies, were to agree upon unified KPIs.

73. Regarding the applicability for SMEs, the preparation for organisational system analysis as the initial cost of the development might be something of an obstacle for SMEs. In practice, the management of companies considering adoption of KPIs as a business tool sometimes realises that KPI are too expensive and that it is too difficult to measure exactly the performance required for a particular business or process objective. Since KPIs are usually defined by long-term considerations and cannot be changed frequently, they are not suitable for SMEs which need to modify structures, business models and target customers as well as strategies much more frequently.

74. From the viewpoint of management decision-making, KPIs provide quantifiable milestones towards its success, reflecting the organisation's goals, missions and stakeholders in addition to the organisational structure and mechanism. Therefore, KPIs can provide management with adequate information for their decision-making with a long-term perspective.

75. Concerning actual improvement at the operational level, KPIs may not be applied effectively as they are usually designed on the organisation's strategy and principally lack actual operational level information due to using a confined number of indicators selected for the key organisational challenges in the course of system analysis. KPI may have the possibility to apply effectively for actual operational improvement when operational level indicators are set as part of KPIs, as illustrated by the Ford of Europe's case (see Box 3).

76. KPIs are unsuitable for data aggregation and standardisation as they are customised for each company.

77. KPIs are not necessarily suitable for finding innovative products or solutions since they are primarily designed for strategic evaluation. However, if KPIs include management indicators that set targets for innovative products/solutions (*e.g.* number of eco-labelled products), they could motivate employees to focus on developing innovative ideas and putting them on the market.

Composite indices

78. Composite indices can be suitable for external benchmarking as they give both simplified and quantified expressions of a more complex composition of several indicators. They can be used to compare and rank companies within a specific sector. Composite indices could also offer consistent and flexible benchmarking of companies for private and institutional investors (Krajnc and Glavič, 2005a). However, establishing composite indices usually requires careful consultation and negotiation about selecting and weighing objective indicators to reach an agreement among companies in the same sector.

79. Regarding the applicability for SMEs, a series of steps necessary for aggregating indicators could become an obstacle for SMEs to adopt composite indices. An important feature of composite indices is the option to compare and rank companies by compiling a large number of indicators. In this respect, they are more suitable for those sectors which have the resources to exert influences on their supply chain companies to take up the same indicator sets. If the appropriate software to facilitate the collection and processing of data were provided, this might encourage SMEs to adopt this approach.

80. From the viewpoint of management decision-making, composite indices can work usefully because they simplify information on a more complicated indicator set covering various fields in corporate activity. Decision-makers can easily interpret composite indices and its corresponding sub-indices, rather than having to identify a trend using many individual indicators. However, reducing the number of indicators by condensing information carries the risk of misinterpretation since users are not always aware

of the scope and limitations of this indexing methodology and the message conveyed may be distorted by gaps in the data and by the way indicators are selected and weighed.

81. Concerning actual improvement at the operational level, composite indices can be applied effectively if they combine sufficient information with regard to actual operations. For example, the sector-specific composite index presented in Box 4 was developed specifically to demonstrate the contribution of the steel industry to sustainable development. Composite indices are suitable to develop a comprehensive framework of sustainability criteria in the manufacturing sectors that focus both on management decision-making and practical operations (Krajnc and Glavič, 2005b).

82. Composite indices can help with data aggregation and standardisation within a sector, because the number of indices is relatively small and it is easy to compile them once consensus has been reached within the sector. It would be ideal to show sector-level performance together with that of each company for objective benchmarking. However, it is unlikely to be able to apply the composite indices for data aggregation and standardisation beyond the sector.

83. If appropriate indicators are selected, composite indices can be used to encourage the identification of innovative products or solutions. However, they cannot help develo individual products/solutions unless users return to the original indicators and sub-indices before aggregation. They can instead highlight opportunities for improvement and respond to emerging issues and pressures (Krajnc and Glavič, 2005b).

Material flow analysis (MFA)

84. In terms of comparability for external benchmarking, material flow analysis (MFA) is applicable as MFA is principally designed to provide aggregated background information on the composition and changes of the physical structure of systems. Material flow-based indicators can be aggregated from the micro-level, such as a site and a factory. One would need to fix the objectives for comparison as well as adjust organisational sizes and boundaries among companies or sectors.

85. MFA can be applied for SMEs, especially when material balance of manufacturing procedures is analysed through basic metrics such as material input and waste generation. However, expert support would be needed to identify “hidden” flows of materials apart from tangible material flows through within a company.

86. Concerning usefulness for management decision-making, MFA can basically work effectively as the issues relating to materials have been increasing in significance for management on the grounds that the price of oil and raw materials has been rapidly increasing over the last few years. MFA would be more effective to management decision-making were it to be combined with cost calculation of materials as this helps to identify where the company can cut costs (see Box 7).

87. From the viewpoint of effectiveness for actual improvement at the operational level, MFA can be very useful in identifying ways of how to minimise material inputs and outputs, which could make production processes most efficient.

88. Regarding the possibility for data aggregation and standardisation, MFA can be applied effectively as it is principally designed to provide aggregated information on the composition of and changes in the physical structure. Company or plant-level material flow accounting can be relatively easily compiled depending on the purpose for which the information is used. Most of the time, the basic data are readily available from internal business sources. The most important challenge is to ensure a minimum coherence with meso and macro-level material flow accounting (OECD, 2008b). If input-output data at national or sectoral level is applied for micro-level MFA, the result may not be fit for aggregation.

89. MFA can extensively be applied for finding innovative products/solutions, as it helps to identify the way to minimise material inputs and outputs for making products/services. If appropriate benchmarks are available, MFA can help highlight opportunities for improvement and respond to emerging issues and pressures.

Environmental accounting

90. Environmental accounting can be applied for external benchmarking if as much attention as possible is given to the highest degree of comparability in the way environmental accounting data is composed. The guidelines developed by some governments may help companies provide consistent data by guiding what can be included as environmental costs and benefits.

91. Regarding the applicability for SMEs, environmental accounting can be applied by SMEs because environmental accounting is based on the existing framework of financial accounting usually adopted by SMEs. However, as the initial cost of environmental accounting is relatively high and external help would be needed, SMEs have been hesitant to adopt this category of indicators. Proactive entrepreneurs could take advantage of environmental accounting for significantly reducing or altogether eliminating environmental costs.

92. From the viewpoint of management decision-making, environmental accounting can work usefully because it focuses on cost calculation and the results are shown in simple monetary terms. Environmental accounting can provide management with useful data that takes the environment into consideration and motivates to continuously increase environmental protection efforts. Many environmental costs can be significantly reduced or even eliminated as a result of business decisions taken through the environmental accounting system. It can also be applied for decision-making about investment in new process technologies and redesigning of products/services.

93. Concerning actual improvement at the operational level, environmental accounting can be applied effectively because it focuses on environmental costs to be reduced or eliminated ranging from operational and housekeeping changes to improvement of processes/products. By employing environmental accounting at one of its individual sites or factories, the company can also obtain information to facilitate effective and efficient environmental activities aimed at resolving local environmental issues.

94. Regarding the possibility for data aggregation and standardisation, environmental accounting looks promising because it is designed based on financial accounting system. In terms of international standardisation, environmental accounting at national level has been formalised into the System of Integrated Environmental and Economic Accounting [9], while some guidelines for environmental management accounting have been proposed (IFAC, 2005; UNDSD, 2001). However, the connection between national-level and business-level accounting system is currently weak and still developing.

95. Environmental accounting can be used to identify innovative products or solutions since it enables management to make pragmatic decisions of investment on innovative processes/products as the results are monitored in monetary terms. If appropriate benchmarks are available, it can work as an effective compass for innovation path-finding.

[9] United Nations, European Commission, International Monetary Fund, OECD and World Bank (2003), *Integrated Environmental and Economic Accounting 2003.*

Eco-efficiency indicators

96. Eco-efficiency indicators can be put into operation in a number of different ways. Due to the proliferation of eco-efficiency as a conceptual and operational framework, functional comparability of eco-efficiency in terms of company performance is not yet given. Generally, companies continue to develop eco-efficiency analysis in-house or publish eco-efficiency indicators on a voluntary basis as part of sustainability reporting. On the other hand, if methodology and baseline of the industry were to be unified, eco-efficiency indicators could become a very powerful tool to encourage sound competition with the aim of providing more efficient products/services and processes through external benchmarking.

97. Technically, eco-efficiency indicators can be implemented by SMEs as a unit of accounting and reporting. Nevertheless, it is generally argued that in practice SMEs lack necessary managerial and financial resources and awareness, or that they simply do not have an incentive to adopt such advanced indicator systems.

98. In principle, eco-efficiency indicators can be applied for both products/services and production processes, and the overall corporate performance. However, most applications can be found at the level of operations. Canon, a Japanese electronics manufacturer, provides an interesting example as the company applies its "Factor 2" concept and methodology for evaluating corporate management progress by making it a part of the corporate vision and targets for 2010 (Canon, 2008).

99. Eco-efficiency indicators collect information that can be utilised in daily company operations and decisions. Some companies that have developed in-house metrics have started to integrate eco-efficiency estimates into their operational management. This shows that eco-efficiency indicators can be used as part of incremental cost gains and deliver more long-run economic value. They may provide operational managers with the option of systematic detection and early recognition of economic and environmental opportunities and risks in existing and future business activities.

100. Eco-efficiency indicators can be aggregated and standardised in a number of ways depending on their conceptual, institutional and operational context. However, a majority of applications are found at the level of products/services and production processes.

101. Eco-efficiency indicators may provide managers with the option of early recognition and systematic detection of economic and environmental opportunities and risks in existing and future business activities. This may result in incremental innovation in products, processes or organisational models of business.

Lifecycle assessment (LCA) indicators

102. In terms of comparability for external benchmarking, lifecycle assessment (LCA) indicators are suitable in principle as the methodology of LCA has been developed to establish the international standards of ISO 14040-44, enabling the comparison of environmental impacts including all lifecycle stages of material use and their associated emissions and energy requirements. The results of LCA can be presented in common comparable units. However, in reality, the fact that users of LCA indicators tend to make different assumptions and set system boundaries to fit their individual needs has made it difficult to compare similar products produced by different companies. Therefore, benchmarking and further standardisation by independent third parties is essential.

103. As for their applicability for SMEs, LCA indicators could be used by SMEs because various tools for application such as software are already available (see Box 10). These tools can also assist SMEs in providing the database for lifecycle inventory, which is the most difficult obstacle to LCA use. In addition, managers of SMEs have many resources at their disposal to overcome problems with comprehension of

LCA, such as various written manuals and consultants. But there is still a common perception that the use of LCA indicators is too resource-intensive for SMEs.

104. LCA results are used as the basis for comparison of environmental effects associated with alternatives of products/services and the identification of "hotspots" where environmental efforts can be focused upon. Relatively simple expressions of LCA indicators also serve to inform management about indirect environmental effects of companies' operations beyond their organisational boundaries and hence encourage more systemic thinking. On the other hand, LCA indicators are only applicable to the level of products/services and not the entire company.

105. LCA indicators are a powerful tool for improving operations as the comparison of LCA results make it easier to identify those parts of the production processes that need to be improved. It is possible to identify which stage of the production process has the highest environmental impact so that effective improvement of processes and products/services becomes possible.

106. Concerning data aggregation and standardisation, LCA indicators can be aggregated and standardised if their results are presented in common comparable units such as kg CO_2-equivalent. Once consensus regarding system boundaries and expression of results has been reached among all concerned parties, LCA indicators can be used for data aggregation and standardisation on a product/service basis.

107. LCA indicators have a strong potential for identifying innovative products/solutions within the "cradle-to-grave" scope. Because LCA provides information about impacts of a product over its lifecycle, companies can evaluate new processes/products in a holistic manner. LCA may be used for evaluating the feasibility of potential products in terms of environmental impact by testing prototypes or through simulation.

Sustainability reporting indicators

108. The Global Reporting Initiative (GRI) Guidelines include comparability as part of reporting principles and software providers offer standardised data processing options for sustainability reporting. However, comparability of data between reporting companies still remains underdeveloped, partly because of the voluntary nature of sustainability reporting and the difficulties in setting consistent organisational boundaries.

109. Sustainability reporting frameworks offer wide-ranging possibilities to facilitate the application of sustainability reporting by SMEs. Most guidelines are provided free of charge and SMEs can benefit from information services provided by non-profit platforms, public agencies or global initiatives. The GRI provides a handbook specifically designed for SMEs. Nevertheless, SMEs' uptake of sustainability reporting has been relatively low.

110. Sustainability reporting can be an important tool for the company to manage its decisions and operations from more strategic and long-term perspectives. Sustainability reporting enables companies to present their overall vision and strategies with regard to managing the key challenges associated with economic, environmental, and social performance. A quality report can demonstrate its stakeholders and investors what measures the company is taking to reduce risks and seize opportunities. This will support marketing, reputation and financial management of the company. The publication of sustainability reports can facilitate the integration of sustainability issues into the mainstream management because a strong commitment by management is indispensable for such disclosure.

111. Many sustainability reporting frameworks are adequately developed for companies to be able to support overall operational management. They in general require timeliness, completeness and balance of information criteria to enable companies to measure the complete sequence and timing of their activities.

On the other hand, the presentation of individual indicators in sustainability reports does not necessarily help companies prioritise particular aspects or consider different aspects in an integrated manner to improve their overall environmental performance. The GRI Guidelines recommend identifying “material” issues through stakeholder engagement rather than asking companies to report on all indicators listed in the guidelines.

112. In order to make data aggregation and standardisation possible, consistent organisational boundaries need to be set to avoid double counting. Although the GRI provides a boundary protocol, it does not intend to set boundaries in as a strict manner as that of financial accounting. Sustainability reporting indicators also include many qualitative data which is not suitable for data aggregation.

113. Sustainability reporting itself is not suitable for finding innovative product or solutions, as its ultimate aim is to provide corporate-level performance information rather than information on products/services or production processes. However, since many reporters disclose information on products/services and production processes through sustainability reports, this activity may have an indirect influence on improving production.

Socially responsible investment (SRI) indices

114. Socially responsible investment (SRI) indices are specifically designed for financial firms that wish to benchmark different companies (often within the same sectors) for investment decisions by using the composite methodology. The indices strongly reflect investor perspectives and can only be benchmarked at corporate level.

115. SRI indicators are not applicable to SMEs. SMEs have not been a part of recently growing trend of SRI, since most investors focus on global and national companies. However, as some banks in OECD countries have introduced screening based on sustainability criteria for lending to SMEs, pressure from ethical investors may affect SMEs.

116. SRI indices provide the evaluation by financial firms regarding companies’ strategies and management of sustainability opportunities, risks and costs. By integrating economic, environmental and social factors in their business strategies, this can enhance motivation for companies to increase long-term shareholder value. From a broader perspective, this group of indicators may also allow companies to access to insights into the trends driving sustainable production.

117. When assessing the true value of SRI indices in terms of strategising corporate management, one should always remember that they are developed from the perspective of investors and not designed for internal management purposes. This set of indicators contains hardly any useful information for daily activities at the operational level.

118. The information SRI indices include is designed for specific needs and interest of investors and not intended for data aggregation and standardisation. As each rating institution rather emphasises and promotes its originality of benchmarking criteria, establishing a unified approach is difficult.

119. Since SRI indices are not designed for internal operational management but external benchmarking of companies overall, they cannot help companies identify innovative products or solutions unless the criteria address the targets for innovative products/solutions (*e.g.* number of eco-labelled products).

Synthesis of analysis

120. It is not necessarily easy to compare the above categories of indicator sets since they have different structures and a diverse scope of application. However, a comparison is attempted based on the criteria used for the above analysis in order to establish which categories are most effective for advancing sustainable manufacturing in what context. Table 3 provides a summary of the analysis.

121. **Comparability for external benchmarking**: LCA indicators may be the best among the introduced categories of indicator sets in terms of comparability because the methodology has been established as an international standard. However, LCA indicators are mostly applied only for each product/service and the fact that the application of the LCA methodology is not necessarily consistent has made comparisons between products/services of different companies difficult. Even though they incorporate smaller numbers of indicators, eco-efficiency indicators lag behind in terms of comparability because their methodology is erratic and still under development. Composite indices appear suitable for external benchmarking as the number of figures they use is limited, but companies or sectors still need to agree on the exact methodology. Environmental accounting also looks suitable for external benchmarking, but further development of methodology and agreement regarding what counts as an environmental cost is needed. Although SRI indices were originally developed for external benchmarking, the number of companies involved here is limited. Individual indicators can be used for external benchmarking if companies agree on a core set of indicators for comparison.

122. **Applicability for SMEs**: Individual indicators are the most commonly used by SMEs since they can be applied without special preparation, followed by LCA indicators because various support tools for using these are already available. SMEs might be advised to use environmental accounting for their sustainability assessment. The methodology is attractive because applying it might reduce environmental costs while increasing economic benefits. Since sustainability reporting indicators provide a menu of well-designed indicators, they can be useful for SMEs willing to prepare sustainability indicator sets for the first time. MFA and eco-efficiency indicators can technically be implemented by SMEs, while KPIs and composite indices demand preliminary procedures before instituting them, and hence may not be suitable for SMEs.

123. **Usefulness for management decision-making**: KPIs and composite indices are optimum for management use since they are designed to assist decision-making. Environmental accounting might be useful because it is based on financial accounting system and focuses on cost and benefit calculation. SRI indices can provide management with good external benchmarks on their sustainability strategies and understanding on opportunities, risks and costs from sustainability challenges. LCA indicators could help management identify hotspots for environmental efforts and encourage more systemic and value chain-based thinking beyond organisational boundaries. The significance of MFA and eco-efficiency indicators for management has been increasing due to the high price of oil and other material inputs. Individual indicators could assist decision-making only if a restricted numbers of appropriate indicators conveying sufficiently relevant information were to be selected.

Table 3. A summary of the analysis of indicator sets

Criteria / Type of indicator sets	Comparability	Applicability for SMEs	Management decision-making	Operational performance improvement	Data aggregation and standardisation	Finding innovative products or solution
Individual indicators	*	***	*	**	*	*
Key performance indicators			***	*		*
Composite indices	**		***	**	**	*
Material flow analysis	*	*	*	***	***	***
Environmental accounting	**	**	**	***	**	**
Eco-efficiency indicators	**	*	**	***	*	***
LCA indicators	***	**	*	***	**	***
Sustainability reporting indicators	*	**	*	**	*	*
SRI Indices	**		**			*

Note: ***: Strongly suitable for the purpose
**: Suitable if certain conditions are met
*: Could be applicable but not necessarily suitable

124. **Effectiveness for actual improvement at the operational level**: Environmental accounting is one of the most useful measures for reducing the costs of business operations. LCA indicators offer the best solution for reducing environmental impacts as a result of actual operational improvement throughout the value chain. MFA and eco-efficiency indicators can also be very useful in order to identify ways in which to make resource use more efficient. The advantage of eco-efficiency indicators is that the same indicator sets could be used for both operational (levels of product/services and processes) and management (corporate-level) improvement. Composite indices, individual indicators and sustainability reporting indicators could be applied effectively if they were to contain sufficient information relevant to actual operation. KPIs might be useful if actual operational-level indicators were set to be part of them.

125. **Possibility for data aggregation and standardisation**: MFA is principally designed to provide aggregated information, but availability of company-specific data can be a problem. LCA indicators can be used for aggregation since they can be presented in common comparable units, but require consensus among concerned parties regarding system boundaries and expression of results. Composite indices are also suitable for this purpose due to their relatively small number of indicators. Environmental accounting can be utilised for data aggregation if the definition of environmental costs is unified. Eco-efficiency indicators might be standardised, but the effectiveness of this depends on the conceptual, institutional and operational context.

126. **Effectiveness for finding innovative products/solutions**: MFA, environmental accounting, eco-efficiency indicators and LCA indicators could be useful for identifying innovative products or solutions. It is hard to judge which is best as they focus on different aspects of environmental and economic solutions. Individual indicators, composite indicators and KPIs can be used for this purpose if appropriate indicators are selected as a benchmark for innovative products/solutions, but they can only target either improvement in single environmental aspects or the whole range of products (*e.g.* number of eco-labelled products).

Key findings

127. To sum up, key findings of this analysis are as follows:

- *Increasing demand for information disclosure*: Manufacturing companies are operating under increasing demand for better information on the sustainability of their products/services, activities and business strategies from government, investors and civil society, who have been the main driving force behind models of sustainability measurement and management. There is a growing acceptance among companies that sustainability measurement can lead to better informed strategies and more responsive customer service, let alone improvement in operation-level environmental performance.

- *Measurement challenge:* The concept of sustainable development poses a significant challenge for measurement at the corporate level. The demands for information are multiple, change over time and originate from various sources such as management of companies, investors, communities and customers. It is critical for companies to choose the right aspects and methodology to measure for effectively advancing sustainable manufacturing, but this is challenging under the current proliferation of different indicator sets. Conceptual approaches and operational frameworks used to implement sustainable manufacturing remain fragmented.

- *Capacity challenge:* Increased competitive pressures due to technological shifts and globalisation are forcing companies to reconfigure their value chains. The production process is now diffused in a web of many companies of different size and in different locations. As the scope of sustainable manufacturing is also expanding from a single facility or company to "cradle to grave" or even "cradle to cradle" cycle, engagement of supply chain and downstream companies, often SMEs, is becoming inevitable. However, most of SMEs lack incentives to implement sustainability indicators and face structural bottlenecks and capacity gaps. It is strongly advisable that large companies and government provide a range of supportive measures for increasing the use of indicators among SMEs.

- *No ideal indicator set*: Ideally, sustainability indicators should be able to serve two main purposes – management decision-making and improvement in products/services and production processes at the operational level. With the exception of eco-efficiency indicators, each of the nine categories of indicator sets is designed either to help decision-making by management or to facilitate improvements at the operational level. Each category of indicator sets has strengths and shortcomings and there appear to be no single ideal indicator set. In reality, many companies have been utilising more than one set of indicators at management and operational levels, often without relating them at all.

5. Conclusions and recommendations

128. This paper focused upon reviewing the existing sets of indicators that assist industry and companies to track and benchmark different aspects of their performance in order to improve their production processes and products/services towards sustainable development. There is no precedent literature that comprehensively categorises those existing indicator sets, although there are a multitude of such indicator sets around the world. Therefore, the authors classified them into nine heuristic categories: *1)* individual indicators; *2)* key performance indicators (KPIs); *3)* composite indices; *4)* material flow analysis (MFA); *5)* environmental accounting; *6)* eco-efficiency indicators; *7)* lifecycle assessment (LCA) indicators; *8)* sustainability reporting indicators; and *9)* socially responsible investment (SRI) indices. The effectiveness of these existing sets of indicators was then analysed according to the predefined criteria.

129. As analysed above, there is no ideal single set of indicators among the existing nine categories that can cover all aspects that manufacturing companies need to address to improve their production processes and products/services with a view to sustainable development. Rather, an appropriate combination of the existing indicator sets could help companies gain the most comprehensive picture of economic, environmental and social effects across the value chain and product lifecycle.

130. For example, it could be valuable to consider combining MFA, LCA indicators and environmental accounting. MFA results alone can only show the physical figures of material flow through the economy (*e.g.* the entire company), but this could be complemented by using LCA methodology to incorporate the product lifecycle perspective. The use of environmental accounting would further strengthen the understanding of links between material use, financial implications and environmental impact. When combining different approaches, it is necessary to ensure that basic geographical and temporal scope, metrics, etc. are compatible in order for the process to yield useful results.

131. Eco-efficiency indicators would be more valuable if concept and methodology are unified since they can be applied to managerial and operational purposes at the same time. Another way to ensure that corporate management commit to sustainable manufacturing is the use of composite indices if operational-level indicators are well-presented in indexing processes.

132. Most SMEs lack the incentives to use sustainability indicators and are facing capacity gaps. They need to start by collecting data such as a minimum set of individual indicators, and then develop their indicators step by step. The development of indicators for sustainable manufacturing is not necessarily static but should be a continuous, evolutionary process of setting goals and performance measurement. The Lowell Centre for Sustainable Development (LCSD) suggests that companies can start by monitoring compliance and gradually begin to address resource efficiency and more complex indicators that cover social effects as well as supply chain and lifecycle considerations.

133. Lifecycle thinking has helped companies to consider environmental effects beyond their factory gates, but to date there is no indicator set which companies apply that takes into account system-level impacts beyond a single product lifecycle. In order to encourage “system innovation” as advocated, for example, by the cradle-to-cradle concept, it is needed to develop a new set of system-level indicators which allow for identification of the system-wide impact of new production processes and products/services. The development of an “environmental contribution indicator” by Japan’s Green IT Initiative is an encouraging step in that direction (see Box 13).

Box 13. Development of an "environmental contribution indicator" in Japan

The potential contribution of information and communication technologies (ICT) to tackling global environmental challenges has recently started to attract greater attention from industry and policy makers. In the latest report, The Climate Group, a UK-based non-profit organisation, estimated that the ICT sector currently contributes to around 2% of annual global man-made CO_2 emissions and this figure will almost double by 2020. But the transformation of the way people live and businesses operate through the effective use of ICT could reduce global CO_2 emissions by 15% during the same period. This opportunity for environmental contributions will be realised through smart ICT application for building design and use, smart logistics, smart electricity grids and industrial monitor systems, as well as the replacement of physical products and services with their virtual equivalents such as tele-working, video-conferencing and e-commerce (The Climate Group, 2008).

However, if measurement of environmental impacts focuses only on a single company or a single product, such system-wide contributions may be missed out as the sales of more energy-efficient products are counted as more CO_2 emissions. To balance out these negative and positive impacts, Japan's Green IT Initiative started developing an "environmental contribution indicator" with involvement of ICT industry. The initiative was launched in 2007 with an aim to make positive changes in every aspect of production, society and national life through the application of ICT.

The environmental contribution indicator is defined by the following formula:

(Environmental contribution) = (Efficiency ratio) × (Number of sales) × (Contribution ratio)

"Efficiency ratio" is the amount of CO_2 emissions reduced by the products/activities in comparison with the original amount of emissions without them. "Contribution ratio" is a ratio of the company's contribution to CO_2 reduction from those products/activities throughout their production and consumption. The "net impact" of the company is calculated through discounting part of the CO_2 emissions caused from the company by this environmental contribution indicator:

(Net impact) = (CO_2 emission) – (Environmental contribution)

The initiative expects that the development of this indicator will not only encourage the ICT industry to consider more systemic innovation beyond immediate costs and benefits but also facilitate consumer choices of energy-efficient products and services through visualisation of the net impact. The initiative also proposes an incentive scheme in which the government and companies can purchase the credits of environmental impact reduction from consumers who bought energy-efficient products.

Source: Sumita, 2008.

134. To conclude, it is recommended that the OECD could work with other stakeholders on developing a common understanding of the relative value of existing indicator sets. Further down the line, the OECD could utilise the previous experience in leading the development of the Pollutant Release and Transfer Register (PRTR) system for standardising indicator sets and methodology applicable for both the micro level (facility or company) and the macro level (national or global) (see Box 14). The OECD could also play a role in guiding and providing supportive measures for the increasing use of indicators by SMEs.

135. This paper will be updated with more concrete information on the actual usage of indicator sets, based on the data obtained through the questionnaire survey and focus group meetings of corporate practitioners conducted during the summer and the autumn of 2008.

Box 14. OECD and Pollutant Release and Transfer Register (PRTR)

A Pollutant Release and Transfer Register (PRTR) is a national or regional environmental database or inventory of hazardous chemical substances and pollutants released to air, water and soil, and transferred off-site for treatment or disposal. Industry and business quantify and report the amounts of substances released to each environmental medium (air, water, soil) or transferred off-site for waste management or wastewater treatment.

The OECD began the work on PRTRs in response to Agenda 21, agreed at the UN Conference on Environment and Development (UNCED) in 1992. Agenda 21 called for governments to implement and improve databases about chemicals including inventories of emissions, with the co-operation of industry and the public. In 1996 the OECD Council adopted a Recommendation on Implementing Pollutant Release and Transfer Registers [C(96)41/Final; amended to C(2003)87 in 2003], which calls for the member countries to establish a PRTR. The subsequent publication of a manual in 1996 and other tools have facilitated the development of PRTRs across OECD countries and beyond. In 2007, 17 OECD countries had an operational PRTR and more governments are also in a process of developing a PRTR system. OECD work on PRTRs is currently a part of the Environment, Health and Safety Programme co-ordinated by the Environment Directorate.

Under this system, individual facilities are obliged to determine, collect and report their releases and transfers to a national PRTR. Industry can also benefit from PRTR data, as they can verify their own data by comparing it with others engaged in the same business activity. PRTR reporting may also contribute to industry identifying leaks, reducing waste and thereby saving money. Trade associations and other business groups assess PRTR data to identify more effective chemical management practices and improvements to processes.

Source: OECD, 2007b.

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