Indicators of sustainable production: Framework and methodology. Journal of Cleaner Production, 9, 519-549

Article *in* Journal of Cleaner Production · December 2001

DOI: 10.1016/S0959-6526(01)00010-5

2 authors:


Vesela Veleva
University of Massachusetts Boston


Michael J. Ellenbecker
University of Massachusetts Lowell

ELSEVIER

Journal of Cleaner Production 9 (2001) 519–549

Journal of Cleaner Production

www.cleanerproduction.net

Indicators of sustainable production: framework and methodology

Vesela Veleva [a,*], Michael Ellenbecker [b]

[a] Lowell Center for Sustainable Production, Kitson 200, University of Massachusetts Lowell, One University Avenue, Lowell, MA 01854, USA
[b] Toxics Use Reduction Institute, University of Massachusetts Lowell, One University Avenue, Lowell, MA 01854, USA

Received 10 June 2000; accepted 31 January 2001

Abstract

This paper presents a new tool for promoting business sustainability — indicators of sustainable production. It first introduces the concept of sustainable production as defined by the Lowell Center for Sustainable Production, University of Massachusetts Lowell. Indicators of sustainable production are discussed next, including their dimensions and desirable qualities. Based on the Lowell Center Indicator Framework, the authors suggest a new methodology of core and supplemental indicators for raising companies' awareness and measuring their progress toward sustainable production systems. Twenty-two core indicators are proposed and a detailed guidance for their application is included. An eight-step model provides a context for indicator implementation. The paper concludes with a summary of the strengths and weaknesses of the methodology as well as recommendations for testing the indicators.

Keywords: Indicator; Indicator framework; Indicator methodology; Sustainable production; Core and supplemental indicators

1. Introduction

The concept of sustainable production emerged at the United Nations Conference on Environment and Development in 1992 and is closely related to the concept of sustainable development. The conference concluded that the major cause for the continued deterioration of the global environment is the unsustainable pattern of consumption and production, especially in industrialized countries [1]. While sustainable consumption targets consumers, sustainable production is related to companies and organizations that make products or offer services. Although sustainability is still a vague concept, there is a growing consensus that it is necessary to move from trying to define it toward developing concrete tools for promoting and measuring achievements. This paper focuses on business sustainability and offers a new methodology for promoting and measuring companies' performance based on a set of *core and supplemental indicators of sustainable production*[1] *(ISPs)*. Suggested methodology is based on the indicator framework developed at the Lowell Center for Sustainable Production (LCSP), University of Massachusetts Lowell, and presented in an earlier paper [2].

Companies have long used standard financial indicators to determine their business success. Only recently have a growing number of firms begun to use environmental, health and safety (EHS), and social indicators (e.g., 3M, Shell, Amoco, Interface). While the number of sustainability indicators in the literature is growing, none of them advances our understanding of corporate sustainability. A recent survey of fifty corporate sustainability reports reveals that companies fail to address major environmental and social impacts [3]. For Ranganathan, "without any agreement on the fundamentals of what to measure, by whom, and how, we will all be awash in a sea of confusing, contradictory, incomplete, and incomparable information" [4], p. 4. Moreover, the absence of standardized measures "represents a major

* Corresponding author. Tel.: +1-978-934-3275; fax: +1-978-934-3050.

E-mail addresses: vesela_veleva@student.uml.edu (V. Veleva), ellenbec@turi.org (M. Ellenbecker).

[1] Suggested indicator framework is applicable to any company, organization, facility or product line. The terms company, firm, organization are used interchangeably. "Production" is meant to incorporate both products and services.

0959-6526/01/$ - see front matter
PII: S0959-6526(01)00010-5

barrier to future efforts by business to implement sustainable business strategies" [4], p. 7.

It could be argued that it is not possible to have a set of sustainability indicators, applicable to any company or organization, since companies vary enormously in their business activities, and we still do not have the scientific knowledge and technology to implement such sustainability indicators. This paper, however, supports the idea that

(i) it is possible to have a standard set of indicators (i.e., indicators applicable to any company); and
(ii) as Volmann points out, it is better to measure the right things approximately than the wrong ones with great accuracy and precision [5].

While some issues are common for all companies, such as energy use, water use, charitable contributions, work-related injuries and illnesses, the differences between production facilities are enormous and a standardized set of sustainability indicators may miss key impacts. The use of supplemental indicators, as suggested in this paper, responds to this challenge and provides methodological foundation for evaluating production-specific impacts.

Without underestimating other important factors, such as government policies, customer pressures and top management commitment, this paper focuses on a framework and methodology for using sustainable production indicators as a tool for promoting greater sustainability awareness, measurement and reporting.

The paper begins with a brief introduction of the LCSP definition and principles of sustainable production. Then follows a discussion of the ISPs, their objectives, desirable qualities and dimensions. The LCSP indicator framework is briefly presented as a basis for the current work. Main focus of the paper is the methodology for developing and implementing ISPs, which is based on using core and supplemental indicators. Each core indicator is provided with a detailed guidance (Appendix A) and quantitative data for indicator calculation (Appendix B). An eight-step model is suggested to provide a context for using the methodology. The paper concludes with a summary of the strengths and weaknesses of the method as well as recommendations for its further development and practical application. Results from pilot testing the methodology are presented in a separate paper [6].

2. Sustainable production

LCSP defines sustainable production as

> the creation of goods and services using processes and systems that are non-polluting; conserving of energy and natural resources; economically viable; safe and healthful for employees, communities and consumers; and socially and creatively rewarding for all working people. [7]

This definition is consistent with current understanding of sustainable development, since it emphasizes environmental, social and economic aspects of firms' activities. At the same time it is more operational, since it highlights *six main aspects of sustainable production*:

- energy and material use (resources)
- natural environment (sinks)
- social justice and community development
- economic performance
- workers, and
- products.

Companies that wish to become more sustainable in their everyday practices should aim to address each of these six aspects. Risk should not be transferred between different aspects of sustainable production (e.g., between environmental protection and worker health and safety). To promote better understanding of sustainable production among companies, the LCSP has formulated *nine guiding principles* that lay the basis for the present indicator framework (see Table 1). These principles address issues, such as design of products and packaging, elimination of waste and incompatible byproducts, minimizing of work-related hazards and continuously enhancing worker and community well-being and development [8]. Companies often have mission and goals that are consistent with these principles. For example, inspired by its CEO Ray Anderson, Interface aims to become the first sustainable company in the world [9]. As part of its ISO 14001 commitment, Lucent Technologies has set goals for delivering safe products, and is working with suppliers and customers to promote responsible product use throughout the entire life cycle [10]. Stonyfield Farm's mission includes providing healthful, productive and enjoyable workplaces with opportunities for gaining new skills for all employees [11]. Green Mountain Coffee Roasters are determined to make their local and global communities better and to act with honesty and integrity in all their actions [12]. Companies that choose to become more sustainable in their everyday practices may adopt goals and targets consistent with the LCSP principles and measure their achievements or failures using indicators of sustainable production.

3. Framework for indicators of sustainable production

3.1. Defining indicators, their role and objectives

Defining indicators is not an easy undertaking — the literature is quite confusing on this subject. Gallopin pro-

Table 1
Principles of sustainable production (adapted from the Lowell Center for Sustainable Production)

1	Products and packaging are designed to be safe and ecologically sound throughout their life cycles; services are designed to be safe and ecologically sound.
2	Wastes and ecologically incompatible byproducts are continuously reduced, eliminated, or recycled.
3	Energy and materials are conserved, and the forms of energy and materials used are most appropriate for the desired ends.
4	Chemical substances, physical agents, technologies, and work practices that present hazards to human health or the environment are continuously reduced or eliminated.
5	Workplaces are designed to minimize or eliminate physical, chemical, biological, and ergonomic hazards.
6	Management is committed to an open, participatory process of continuous evaluation and improvement, focused on the long-term economic performance of the firm.
7	Work is organized to conserve and enhance the efficiency and creativity of employees.
8	The security and well-being of all employees is a priority, as is the continuous development of their talents and capacities.
9	The communities around workplaces are respected and enhanced economically, socially, culturally and physically; equity and fairness are promoted.

vides a comprehensive analysis of various definitions, and demonstrates that an indicator has been defined as "variable", "parameter", "measure", "statistical measure", "a proxy for a measure", and "a subindex", among others [13]. He concludes that at the more concrete level indicators are considered variables. A variable is "an operational representation of attribute (quality, characteristic, property) of a system" [13], p. 14. Each variable may take different values depending on the specific measurements or observations. Thus, indicators are variables, and data are the actual measurements or observations [13].

Indicators typically provide key information about a physical, social or economic system. They allow analysis of trends and cause-and-effect relationships, and thus are a step beyond primary data. What information is needed and how it will be used in practice guide the selection of a particular indicator [14]. In the case of business performance, management is interested in knowing whether a company/facility is achieving established goals and objectives and/or how it compares to others in the sector.

Indicators of sustainable production are similar to sustainability indicators,[2] since they address all three dimensions of sustainable development — environmental, social and economic. The difference is that ISPs are developed mainly for production facilities, and they aim to address all key aspects of production — energy and material use (resources), natural environment (sinks), community development and social justice, economic performance, workers, and products.

It is clear that not every organization that decides to use the method will have goals and/or targets for each aspect of sustainable production. However, it is important to begin with some indicators, reflecting current goals/targets, and as companies gain experience, to establish new goals and introduce additional indicators of sustainable production. Using such indicators is a continuous, evolutionary process of business transformation through awareness raising and improved dialog with stakeholders. Indeed, by developing indicators to reflect its mission and goals, Stonyfield Farm identified employee turnover as a key concern. The company initiated a project to measure employee job satisfaction and granted two additional days vacation to all employees [6].

The value of ISPs is not only in suggested methodology but also in promoting organizational learning. As part of the feedback system, measures help managers decide whether they are on course or if corrections are needed. Thus, measurement is part of any *adaptive learning system*, argue DiBella and Nevis [15]. Organizational learning is critical for the survival of companies, especially in the globalized economy. Business needs carefully to follow its performance and customer needs, in order to make quick changes when needed. Lucent Technologies, for example, measures customer satisfaction and uses the results to pursue continuous improvement in providing the highest quality products and services [6].

For Vollmann "measures and key performance indicators are basically how an organization describes itself (its performance) to itself. It 'teaches' itself through these tools about success and failure, and it behaves accordingly" [5]. He believes that in many cases the journey is more important than the destination. The process of measurement, involving all employees, helps raise the overall awareness and skills and thus builds the intellectual capital of an organization.

In summary, ISPs have the following *main objectives*:

- *Educate* business about sustainable production;
- *Inform decision-making* by providing a concise information about the current state and trends in a company/facility performance;
- Promote *organizational learning*;
- Provide organizations with a tool to *measure* their

[2] Sustainability indicators can be defined as "information used to measure and motivate progress toward sustainable goals" [4], p. 2.

achievements toward sustainable production goals and targets (internal benchmarking);
- Allow for *comparisons* between organizations' performance in the environmental, social, occupational and economic aspects of their production (external benchmarking);
- Provide a tool for *"cross-checking" organization's mission* and reporting results to interested stakeholders;
- Provide a *tool for encouraging stakeholder involvement* in decision-making.

3.2. Dimensions and qualities of ISPs

Indicator dimensions are key elements that help distinguish indicators from primary data, parameters, goals or issues. For example, "safety" is not an indicator. It is an issue. Possible indicators of safety are "number of accidents", "lost work day case rate", "percent of workers receiving safety training". Another example is "using renewable energy". This, again, is not an indicator. It is a goal. To construct an indicator it is necessary to add a unit of measurement, period of measurement, and boundaries. One possible indicator reflecting renewable energy use is "percent of energy from renewables, measured at a facility over a period of one year".

To promote better understanding of indicators, LCSP has identified *four key indicator dimensions*:

(a) **Unit of measurement** — this is the *metric* used in calculating an indicator, such as numbers, kilograms, tons, dollars, percent, hours, etc.
(b) **Type of measurement — absolute or adjusted** — an indicator can measure a total amount (e.g., total energy used per year in kWh) or adjusted amount (energy used per unit of product/service per year);
(c) **Period of measurement** — the period for tracking and calculating an indicator (e.g., fiscal year, calendar year, six months, quarter, month).
(d) **Boundaries** — determines how far a company wishes to go in measuring the indicators (e.g., product line, facility, suppliers, distributors, entire life cycle of a material or product).

Veleva and Ellenbecker discuss in a greater detail the *desirable qualities of ISPs* [16]. These include:

- Appropriateness to the task of assessing sustainable production;
- Based on available and accurate data;
- Verifiable;
- Based on a set of indicators rather than a single indicator;
- Comprised of core and supplemental indicators;
- Addressing all six aspects of sustainable production;
- Including a manageable number of indicators;
- Easy to apply and evaluate indicators;
- Simple, yet meaningful indicators;
- Using both quantitative and qualitative indicators;
- Allowing comparisons among companies;
- Addressing key global issues;
- Consistent with national and community sustainability indicators;
- Developed and evaluated through an open process encouraging stakeholder involvement.

Both dimensions and desirable qualities are important in raising awareness about sustainable production indicators.

3.3. Shortcomings of existing indicator frameworks

A growing number of initiatives and organizations are presently trying to develop environmental, social or sustainability indicators for companies. Ranganathan provides a summary of about two dozen such efforts [17]. In a previous paper the authors analyzed four of the best-known indicator frameworks [18]: International Organization for Standardization ISO 14031, Global Reporting Initiative (GRI), World Business Council for Sustainable Development (WBCSD), and Center for Waste Reduction Technologies (CWRT). Results demonstrate that:

- Most indicator frameworks are still under development. Indicators are still being discussed, tested and refined. For example, twenty-one companies signed to test the GRI framework and results have been used to revise the guidelines [19].
- No framework is applicable as a whole to evaluate sustainable production. The main reason is that no existing indicator framework equally addresses all six aspects of sustainable production. Only the second draft of the GRI guidelines, issued in June 2000, attempts to accomplish this. However, the emphasis is mainly on environmental, economic and worker issues, with community development, social justice and products receiving least attention.[3]
- Material use and environmental protection are best covered in all reviewed frameworks. This is particularly the case of ISO 14031, which lists about 100 environmental indicators.
- Social issues, workers and products receive least attention in existing indicator frameworks. In the few cases when worker issues are included, these cover mainly health and safety but not worker well-being

[3] In a set of ninety-six sustainability indicators only six are related to community development, social justice, and products [19].

or job security. Exception is the GRI, which provides a comprehensive list of indicators for measuring workplace practices and human rights (e.g., quality of management, child labor, wages and benefits, non-discrimination, and freedom of association).

- Most frameworks attempt to address economic performance but they are still using traditional economic indicators that are not true measures of sustainability (e.g., market share, sales, stock price, profitability).
- All reviewed frameworks, with the exception of the GRI, use only quantitative indicators to measure organizations' performance.
- There is a trend toward using a manageable number of indicators (between ten and twenty) that are simple and easy to apply. Exceptions are ISO 14031 and GRI, each of which includes about a hundred indicators.
- There is a clear trend toward developing standardized indicators, i.e. indicators applicable to any organization. GRI, WBCSD, and CWRT have all suggested common measures for evaluation of business sustainability performance (e.g., water use, energy use, market share, stock price).
- Most indicator frameworks attempt to address key global issues, yet these are typically environmental (e.g., global warming, ozone depletion, acidification).
- Common shortcoming of existing indicator frameworks is the lack of clear and detailed guidance on how to implement developed indicators in practice. For example, the GRI lists ninety-six sustainability indicators (both generally applicable and organisation-specific) but does not provide any guidance on how to select and implement these [19].
- Most indicator frameworks are developed for internal management purposes. They do not emphasize the need for transparency and stakeholder involvement in the process of indicator formulation and evaluation. Again, the GRI makes an exception, since it was developed primarily for external reporting.

On the basis of above key findings, Veleva and Ellenbecker make the following *recommendations* for developing ISPs [18]:

- Building on existing work in the area of company level indicators, develop a methodology based on a manageable set of sustainable production indicators (core indicators) that equally address all six aspects of sustainable production.
- Develop a clear and detailed guidance on how to use the methodology in practice and calculate the core indicators of sustainable production.
- Provide a list of supplemental indicators based on existing indicator sets and the LCSP experience. Encourage companies to use these indicators to evaluate additional, production specific aspects of their activities.
- Aim for simple and easy to implement indicators, but emphasize the importance of developing more sophisticated indicators over time. Based on the LCSP vision, provide a guidance on how to move a company from using compliance (Level One) and facility level indicators (Level Two) toward environmental effect (Level Three), supply chain (Level Four) and sustainable systems indicators (Level Five).[4]
- Include both quantitative and qualitative indicators of sustainable production.
- Aim to include indicators, addressing key global issues, such as climate change, acidification, water shortage, unemployment and the growing gap between rich and poor.
- Emphasize the open and transparent process of indicator use and evaluation, where all stakeholders have access to information and are encouraged to participate in decision-making.
- Test developed methodology at several production facilities and draw conclusions about its applicability in practice.

4. LCSP indicator framework

To promote the idea that using ISPs is not static, but rather a continuous, evolutionary process of setting goals and measuring performance, the LCSP has developed a five-level indicator framework (Fig. 1). This framework is explained in greater detail in an earlier paper [2], therefore, it will only briefly be introduced here. The LCSP framework allows organizing existing indicators

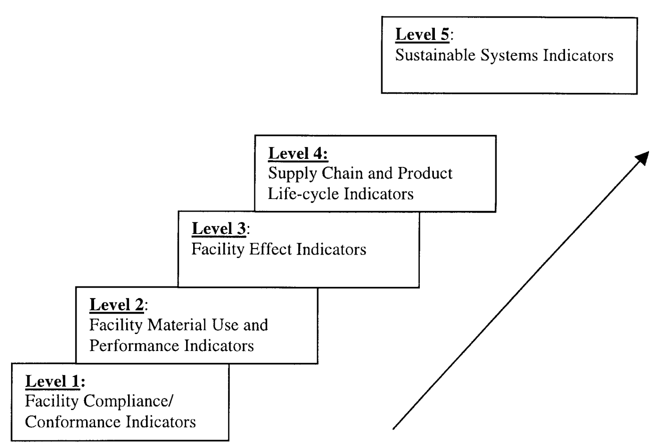


Fig. 1. Lowell Center for Sustainable Production indicator framework.

[4] The LCSP five-level indicator framework is presented in Section 4.

and developing new ones. It reflects the notion that organizations need to begin with simple, easy to implement measures of compliance and resource efficiency and move toward more complex indicators, addressing environmental and social effects, supply-chain and life-cycle impacts. Companies, such as 3M, British Petroleum, and Interface, are already using some environmental, health and safety indicators to measure their compliance or facility efficiency (e.g., dollar amount of fines paid, energy consumption per pound of product, pounds of solid waste generated). The LCSP framework does not suggest dropping indicators at the lower levels. It is necessary for companies to comply with regulations and industry standards (Level One). It will always be important that companies monitor their efficiency and productivity (Level Two). In order to move toward sustainable production, however, an organization needs to begin developing and using indicators that consider impacts of products, suppliers and distributors (Levels Three and Four) [2].

The five levels of the framework represent the five main steps in moving toward more sophisticated indicators of sustainable production. *Level One* indicators measure the extent to which a facility or company is in compliance with regulations or in conformance to some industry/association standards (e.g., number of notices of violations; environmental liabilities, worker compensation). *Level Two* indicators include measures of facility inputs, outputs and performance, such as emissions, by-products, waste, training, and donations. *Level Three* indicators measure potential effects of a company/facility on environmental, worker and public health, community development and economic performance (e.g., global warming potential, percent of workers with work-related disease, population growth in the local area as result of facility operations). *Level Four* indicators measure company/facility production impacts looking at the supply chain as well as product distribution, use and ultimate disposal (e.g., percent of products designed for disassembly, reuse or recycling; embodied energy in key raw materials; percent of suppliers receiving safety training). *Level Five* indicators show how an individual company's production process fits into the larger picture of a sustainable society. They measure effects of production on long-term quality of life and human development within the ecological carrying capacity. Examples of Level Five indicators include percent of water from local sources used at average local recharge rate; percent of energy from renewable sources harvested sustainably; and incidence of a specific disease in the local community compared to the national average.

5. Methodology for implementing ISPs

Developed methodology is based on using *core* and *supplemental indicators* of sustainable production. Core indicators are a standard set of indicators that can be applied at any company or facility. They are simple and easy to use, based on available data and commonly measured aspects of production (e.g., water use, energy use, employee job satisfaction, company donations). Supplemental indicators are an open set and they vary between companies/facilities. These indicators introduce some flexibility by addressing additional, production-specific aspects. An eight-step model is suggested to provide a context for implementing the core and supplemental indicators. This model reveals that using indicators of sustainable production is a *process of continuous improvement*, where the goal is to move organizations from adopting primarily low level (compliance/conformance and facility indicators) to using all levels of indicators of sustainable production (see LCSP framework, Fig. 1).

5.1. Core and supplemental indicators

In a comparative analysis of several indicator frameworks, Veleva and Ellenbecker demonstrate that there is a clear trend toward standardization of indicators [18]. A recent Tellus Institute study demonstrates that comparability is the single most important characteristic of environmental performance indicators [20]. There is a growing need among investors, communities and consumers of standardized sustainability indicators that allow comparisons between companies [21,22].

To respond to this challenge, the authors suggest twenty-two core indicators (see Table 2). These are chosen to measure common issues for all production facilities, such as chemical releases, energy use, water use, hazardous and non-hazardous waste, work-related accidents and injuries, charitable contributions. The goal is not to "reinvent the wheel" but rather include commonly used indicators and build on the work of other groups and organizations, such as the GRI, WBCSD, CWRT, and ISO 14031, providing a detailed guidance on indicator calculation and use (Appendix A and Appendix B). Core indicators are not considered better or more important than supplemental indicators. They are simply the first step in searching for common measures of business sustainability. Results from their pilot testing will demonstrate which ones need to be modified and which ones are working well for most companies.

Proposed *core indicators* of sustainable production aim to:

- provide a standard set of indicators, applicable across companies and sectors, and covering all six aspects of sustainable production;
- suggest simple and easy to implement indicators. Most of these indicators are Level Two and have already been included in other indicator sets or used by some companies (e.g., water use, dollar donations, lost time injury and illness rate).

Table 2
Core indicators of sustainable production

Aspect of SP	LCSP principle	Generic goal	Indicator	Metric	Level
1. Energy and material use	*Principle #3*: Energy and materials are conserved, and the form of energy and materials used are most appropriate for the desired ends.	*Goal*: Reduce the use of fresh water.	(1) Fresh water consumption	liters	Level 2
		Goal: Reduce material use.	(2) Materials used (total and per unit of product).	kg	Level 2
		Goal: Reduce energy use.	(3) Energy use (total and per unit of product)	kWh	Level 2
		Goal: Increase the use of energy from renewable sources.	(4) Percent energy from renewables.	%	Level 2
2. Natural environment (including human health)	*Principle #2*: Wastes and ecologically incompatible byproducts are continuously reduced, eliminated or recycled.	*Goal*: Reduce the amount of waste generated before recycling (air, water, and land).	(5) Kilograms of waste generated before recycling (emissions, solid and liquid waste).	kg	Level 2
	Principle #4: Chemical substances, physical agents, technologies, and work practices that present hazards to human health or the environment are continuously reduced or eliminated.	*Goal*: Reduce greenhouse gas emissions.	(6) Global warming potential (GWP).	Tons of CO_2 equivalent	Level 3
		Goal: Reduce emissions of acid gasses	(7) Acidification potential.	Tons of SO_2 equivalent	Level 3
		Goal: Phase out all PBT chemicals.	(8) kg of PBT chemicals used.	kg	Level 3
3. Economic performance	*Principle #6*: Management is committed to an open, participatory process of continuous evaluation and improvement, focused on the long-term economic performance of the firm.	*Goal*: Reduce EHS compliance costs.	(9) Costs associated with EHS compliance (e.g., fines, liabilities, worker compensation, waste treatment and disposal, remediation).	$	Level 1
		Goal: Zero customer complaints or returns.	(10) Rate of customer complaints and returns.	Number of complaints/returns per product sale	Level 2
		Goal: Increase stakeholder involvement in decision-making.	(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.	*Principle #9*: The communities around workplaces are respected and enhanced economically, socially, culturally and physically; equity and fairness are promoted.	*Goal*: Increase community spending and charitable contributions.	(12) Community spending and charitable contributions as percent of revenues.	%	Level 2
		Goal: Increase employment opportunities for the local community.	(13) Number of employees per unit of product or dollar sales.	Number/$	Level 2
		Goal: Increase community–company partnerships.	(14) Number of community–company partnerships.	#	Level 2

(continued overleaf)

Table 2 (*continued*)

Aspect of SP	LCSP principle	Generic goal	Indicator	Metric	Level
5. Workers	*Principle #5*: Workplaces are designed to continuously minimize or eliminate physical, chemical, biological, and ergonomic hazards.	*Goal*: Achieve zero lost workdays as result of work-related injuries and illnesses.	(15) Lost workday injury and illness case rate (LWDII).	Rate	Level 2
	Principle #7: Work is organized to conserve and enhance the efficiency and creativity of employees.	*Goal*: Increase the rate of employee suggested improvements in quality, social and EHS performance.	(16) Rate of employees' suggested improvements in quality, social and EHS performance.	Number of suggestions per employee	Level 2
	Principle #8: The security and well-being of all employees is a priority, as is the continuous development of their talents and capacities.	*Goal*: Reduce turnover rate	(17) Turnover rate or average length of service of employees.	Rate (years)	Level 2
		Goal: Increase employee training.	(18) Average number of hours of employee training per year.	Hours	Level 2
		Goal: Increase employee well-being and job satisfaction.	(19) Percent of workers, who report complete job satisfaction (based on questionnaire).	%	Level 3
6. Products	*Principle #1*: Products and packaging are designed to be safe and ecologically sound throughout their life cycle; services are designed to be safe and ecologically sound.	*Goal*: Design all products so that they can be disassembled, reused or recycled.	(20) Percent of products designed for disassembly, reuse or recycling.	%	Level 4
		Goal: Use 100% biodegradable packaging.	(21) Percent of biodegradable packaging.	%	Level 4
		Goal: Increase percent of products with take-back policies.	(22) Percent of products with take-back policies in place.	%	Level 4

- whenever possible, use data that have already been collected for other business purposes [23];
- avoid the use of too many indicators;
- suggest indicators that cover key global issues (e.g., global warming, acidification, water shortages, job quality, community impoverishment);
- suggest indicators that drive the right behavior. For example, measuring hazardous waste generated rather than reduction in hazardous material use could drive managers to simply recycle certain materials, rather than eliminate them from the production process; measuring the number of first aid cases on the shop floor may result in underreporting and more serious injuries later [23];
- provide companies with a new tool and guidance on how to measure their achievements toward sustainable production.

The twenty-two core indicators are organized in six sections to address the six aspects of sustainable production. Each section includes the respective LCSP principles of sustainable production that serve as a basis for selecting goals and indicators. Units of measurement and sustainability level are provided for each indicator but these may vary, depending on the organization's choice of indicator dimensions (e.g., unit of measurement, boundaries). It is recommended that both total and production-adjusted amounts be calculated (e.g., "total energy use" and "energy use per unit of product").

Examples of *supplemental indicators* are presented in Table 3. They are organized in accordance to the LCSP five-level framework and the six aspects of sustainable production, and can be used as a *guide* for developing and using higher level, more complex ISPs. A series of workshops, undertaken by the LCSP, revealed that placing an indicator within the five-level framework is not always easy [2]. However, discussing different viewpoints about where an indicator fits within the framework has proven very successful in increasing participants' overall understanding of sustainable production. It is key part of the learning process, where the main goal is to develop indicators at all levels and move beyond facility boundaries to evaluate impacts throughout the life cycle of a product or service.

Constructing an empirical measure for ISPs is only half of the battle — the other half is interpreting and evaluating the findings. For example, Indicator Number One — "Fresh water consumption" — can be calculated as total and adjusted amount. Results may show that water consumption per product has decreased over the last few years (moving in sustainability direction), while total water consumption has increased as result of increased production level. Without additional data on local water withdrawal and replenishment rates, it is difficult to determine whether an organization is moving toward sustainable production systems. Previous research in the area has demonstrated that evaluation of sustainability indicators is much more difficult at lower level (facility, company) opposed to higher level (regional, national or global) [24]. Yet, this is an important exercise that raises awareness and organizational learning.

To further improve suggested methodology, developed indicators need to be tested at some production facilities. Important questions to ask when evaluating indicators' usefulness, include:

- Is there enough data to calculate the indicators? What data are missing?
- Is the number of indicators too large or too small to address all issues deemed important?
- Do companies have the expertise to implement the indicators themselves?
- Is provided guidance sufficient and if not, what needs to be added?
- Which indicators work well and which need to be modified or removed from the set?
- What is the typical choice of boundaries and period of measurement?
- How open is the process of indicator selection, use and evaluation?
- What are the main barriers to implement the methodology?
- What is the overall value of the ISPs?

These and some additional questions may need to be raised when testing the indicators. Results will clearly demonstrate how useful is suggested methodology in practice.

5.2. Process of indicator implementation

An eight-step continuous-loop model for defining and measuring sustainability performance of companies is developed and presented on Fig. 2. It is based on a model, developed by James and Bennett to define and evaluate environment-related performance [25].

The *first step* involves defining sustainable production goals and objectives that are consistent with LCSP principles. These goals and objectives may reflect a company's mission. They should aim to address all key aspects of an organization's activities and encourage stakeholder involvement in decision-making.

The *second step* involves identification of potential indicators to reflect a company's goals and targets toward sustainable production. It is recommended that a company use all core indicators. This, however, may be difficult, especially for small firms with limited resources and expertise. In such cases, firms may begin using just a few core indicators, and then increase their number

Table 3
Supplemental indicators of sustainable production

Aspect of sustainable production	*Level 1*: Compliance/Conformance Indicators	*Level 2*: Facility Material and Performance Indicators	*Level 3*: Facility Effect Indicators	*Level 4*: Supply Chain and Product Life Cycle Indicators	*Level 5*: Sustainable System Indicators
Energy and material use	TUR[a] chemicals used at the facility (MA, NJ)	Quantity of each type of energy used (ISO[b]);	Percent change in specific local resources (forests, water, fisheries, coal, oil, metals).	Total energy use (in kWh) over the life cycle of a product;	Percent renewable materials used at a rate lower or equal to the rate of renewal;
		Percent/amount of water reused (ISO);		Energy use (in kWh) including transportation (raw materials, products, commuting) and embedded energy in used materials.	
		Total mass In (raw materials, products, and packaging)/$ value of product sold (CWRT[c]).		Total vehicle miles traveled.	
Natural environment (including human health)	Number of notices of violation (GEMI[d]);	Amount of hazardous waste generated (GEMI);	Photochemical ozone depleting potential (CFC equiv)	Amount of hazardous materials used by contracted service providers;	Kilograms of endocrine disrupting substances used;
	Kilogram permitted air emissions (GEMI);	Quantity of toxic chemicals released (GEMI);	Nutrification potential;	Amount or waste generated by contracted service providers;	Kilograms of POPs[g] used;
	Number/type of reportable releases (GEMI);	Type/volume of non-regulated materials recycled (GEMI);	Summer smog potential;	Percent of contracted suppliers chosen for environmental reasons;	Ecotoxicity metric (CWRT);
	Number of sites certified under ISO 14001; Tons of TRI[e] releases.	Liters of BOD[f] discharge.	Heavy metal equivalents.		Human health metric (CWRT).
Economic performance	Costs attributable to fines and penalties (ISO);	Total EHS operating costs (GEMI);	Number of positive (negative) press reports on the organization's environmental and social performance;	Percent suppliers without EHS violations;	Company's image;
	Environmental liabilities ($ amount);	Total annual EHS capital costs (GEMI);	Amount ($) invested in EHS and community projects.	Percent suppliers participating in raw material or packaging LCA;	Investment in sustainability R&D as percent of a company spending.
	Number of claims for worker compensation.	Company market share;		Percent distributors supporting/implementing take-back policies.	
		Growth in shareholder value (SVN[h]); After tax income (SVN) Revenue growth (SVN)			

(continued on opposite page)

Table 3 (*continued*)

Aspect of sustainable production	*Level 1*: Compliance/Conformance Indicators	*Level 2*: Facility Material and Performance Indicators	*Level 3*: Facility Effect Indicators	*Level 4*: Supply Chain and Product Life Cycle Indicators	*Level 5*: Sustainable System Indicators
Community development and social justice	Acres of land in the local community used by the company for landfill, incineration or any other type of waste disposal.	Number of community outreach activities (GEMI);	Concentration of specific contaminants in ground waters or surface waters (ISO);	Percent of suppliers from the local area;	Income disparity within company and compared to local community and industry;
		Implementation of a program to improve community outreach efforts.	Concentration of specific contaminants in ambient air at selected monitoring locations (ISO);	Percent of products consumed locally.	Incidence of specific diseases compared to the national average;
		Social and recreational benefits provided to community.	Population growth in the local area (ISO). Percent of days with poor air quality as result of a facility production;		Community quality of life.
Workers	Number of OSHA citations;	Number of employees receiving EHS training;	Percent workers with work-related disease;	Percent of suppliers receiving safety training;	Worker health status compared to other companies in the industry;
	Number of OSHA 200 Log entries;	Percent work stations with noise level exceeding 85 dB;	Percent of workers with some level of hearing loss;	Number of contracts canceled because of non-compliance with EHS standards (PwC);	Stress level compared to the "healthy" level.
	Number of recordable injuries/illnesses (GEMI).	Percent of accident-free workstations;	Employee retention rates (GRI)	Number of suppliers from developing world communities (PwC);	
		Number of near- misses	Percent of employees who believe that company offers equal opportunities to its staff (PwC[i]).	Number of suppliers that have been screened against ethical policy.	
		Percent of employee suggested EHS improvements implemented in practice; Percent of workstations with elimination of the hazards through primary (engineering) controls.			

(continued overleaf)

Table 3 (*continued*)

Aspect of sustainable production	*Level 1*: Compliance/Conformance Indicators	*Level 2*: Facility Material and Performance Indicators	*Level 3*: Facility Effect Indicators	*Level 4*: Supply Chain and Product Life Cycle Indicators	*Level 5*: Sustainable System Indicators
Products	Percent of products with updated and complete MSDS[j].	Percent of products designed to be recycled; Percent of product from recycled material (by weight); Rate of defective products.	Percent of products involving use of GMOs (genetically modified organisms); Percent of products involving the use of endocrine disrupting substances; Customer satisfaction level (GRI)	Number of units of energy consumed during use of product (ISO); Percent of products reused or recycled at the end of the life cycle; Average life cycle cost of products Percent of products with explicit "product stewardship" plans (ISO).	Percent of products leased opposed to sold; Increase in product durability.

[a] Toxics Use Reduction.
[b] ISO stands for ISO 14031 — Environmental Performance Evaluation, part of ISO 14000 environmental management stardard.
[c] CWRT stands for Center for Waste Reduction Technologies, based at the American Association of Chemical Engineers.
[d] GEMI stands for Global Environmental Management Initiative.
[e] Toxics Release Inventory in United States.
[f] Biochemical Oxygen Demand.
[g] POPs means persistent organic pollutants. Examples include the pesticides DDT, aldrin, endrin, toxaphene, etc.
[h] Social Venture Network.
[i] PriceWaterCooperhouse.
[j] MSDS is material safety data sheet, required by the Occupational Safety and Health Administration (OSHA) Hazard Communication Standard 1910.1200.

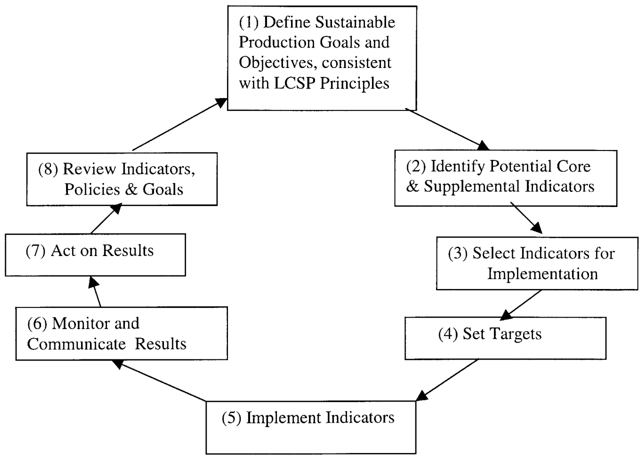


Fig. 2. Continuous-loop model for defining and measuring sustainability performance of organizations.

over time. Both core and supplemental indicators need to be used.

The third step in the model includes selection of indicators for implementation. In addition to the core indicators, companies/facilities are encouraged to consider additional, production-specific indicators. This process needs to include all employees. Top management commitment is important but can not alone ensure successful implementation of ISPs. It is necessary to get the support of different business units [23]. Having middle management and employees participate in the selection of ISPs (i) ensures data availability, (ii) "wins" everyone for the program, and (iii) holds them accountable at the implementation stage.

Setting targets (*step 4*) is a key step, where management (after consultation with stakeholders) sets specific goals, such as "reduce toxic chemicals used per unit of product by 20% in five years" or "achieve zero work-related injuries next year". This step is important, since it ensures management commitment and promotes accountability. Achieving a target, however, does not mean that a firm has become sustainable. It rather emphasizes the need for setting new goals, objectives, or targets as part of a process for continuous improvement in all six aspects of sustainable production.

Indicator implementation (*step 5*) is a key step that involves data collection, calculation, evaluation and interpretation of results. This is the most time-consuming step and requires wide participation of an organization's personnel, in particular the middle management. In order to build a successful and sustainable system of ISPs, the following issues should be clarified: (a) what type of information system will be used to manage the data; (b) what type of computer software will be used to report data; (c) who will collect what kind of data; (d) how facility personnel will be trained to collect data; (e) how the accuracy of the data will be verified [23]. It is important that ISPs are not viewed only as a short-term project of the EHS staff but rather become an integral part of the business decision-making system.

Step 6 involves monitoring and communicating results. For continuous improvement to occur, an organization needs periodically to communicate and evaluate results from indicator use. Therefore, it is recommended to establish a system for regular evaluation, interpretation and presentation of results to employees and other interested parties (e.g., shareholders, consumers, and community). A company/facility can significantly improve its public image and gain customers' trust through an open process of evaluation and communication of progress toward its mission and goals.

Acting on results (*step 7*) is a critical step in the process of indicator use. Here management takes corrective measures and demonstrates that ISPs are not simply a "public relations exercise" but rather a process of continuous improvement of an organization's environmental, occupational and social performance. Pollution prevention and cleaner production are among the most effective approaches for development of concrete solutions.

The last step (*step 8*) includes review of indicators, policies and goals. This is a key step, since it lays the grounds for setting new goals, objectives and indicators. The process of indicator elimination is as important as the process of selecting new ISPs. Only through a regular review and revision of goals, objectives and indicators can a continuous improvement be achieved.

6. Strengths and limitations of the methodology

Suggested methodology for using indicators of sustainable production can be implemented at different levels within an organization — a product line, facility level or company/corporate level. The type of organization, information needed and data availability will determine this choice.

The developed methodology has the following *strengths*:

- Proposes indicators that *equally* address all six aspects of sustainable production (three to five core indicators are suggested for each aspect).
- Includes both *quantitative* and *qualitative indicators*. For example, "employee job satisfaction" is a qualitative indicator that reflects key aspects of employee well-being but can not be measured directly. The authors suggest measuring percent of employees reporting complete job satisfaction, based on completing a simple questionnaire.
- Provides *detailed guidance* on how to use the method-

ology and calculate each core indicator (see Appendix A). For instance, calculation of the global warming potential of a company or facility is based on using a series of conversion factors (see Appendix B) to account for electricity, fuel oil, transportation, etc.
- Suggests indicators that *cover key global issues* — global warming, acidification, water shortage, decreasing worker job satisfaction and job security, community isolation, and impoverishment.
- *Promotes standardization* in measurement and reporting. Developed core indicators are applicable across companies and industrial sectors.
- *Provides flexibility* — companies have an opportunity to develop their own production-specific indicators.
- *Builds on the experience* in the field of environmental/sustainability indicators and incorporates some commonly used indicators, such as water use, energy use, global warming potential, donations, lost time injuries and illness rate.
- *Promotes continuous improvement* through the process of indicator development, use, and modification (the eight-step model). For instance, as a result of using the indicator methodology, Acushnet Rubber set a goal for 5% reduction in water use over three year period, beginning in 1999 [6].
- *Encourages involvement of managers and front line workers* in indicator development, evaluation and revision. With the active participation of its leadership team Stonyfield Farm, for example, developed about fifty indicators to measure progress toward company mission and goals.

At the same time, the developed methodology has several *weaknesses and limitations*:

- Suggested ISPs involve some subjectivity related to the authors' choice of what to measure. Any set of indicators, however, is going to be affected by the individuals who produce it.
- Level Five (sustainable production systems) indicators are difficult for companies to develop and use, since they require community and government support, expanded databases and information on limits and thresholds [2].
- Although the goal is to suggest simple and easy to implement indicators, some organizations may still find these difficult to use. This is particularly the case for small and medium size companies, and for companies in developing countries, where lack of resources and data availability are major barriers.
- No detailed guidance is provided how to construct and calculate supplemental indicators. Companies may choose to use the ISO 14000 methodology for selecting significant aspects, setting goals/targets and constructing indicators to measure progress.
- No criteria are provided for distinguishing between effective and ineffective indicators of sustainable production. One difficulty relates to the fact that the same indicator may be effective at one company and ineffective at another. For example, after developing a comprehensive set of indicators, Stonyfield Farm selected turnover rate as the most important issue to address currently and initiated a series of projects to reduce it (e.g., survey of employee job satisfaction, increased vacation days for all employees) [6]. This may not be the case for many other companies, where turnover rate may simply be registered with no consecutive action taken. Undoubtedly, top management commitment and involvement of key stakeholders are among the key factors behind indicator effectiveness.

7. Conclusions

This paper focused on business sustainability and offered a new methodology for promoting and measuring companies' achievements, based on a set of core and supplemental indicators of sustainable production. Building on existing efforts to develop sustainability indicators and the LCSP indicator framework, the authors propose a set of twenty-two core indicators (applicable to any organization) and a guidance for selecting additional, production-specific indicators. An eight-step model for indicator implementation has been suggested to ensure integration of the methodology within the business decision-making system. The paper concludes with a summary of the strengths and weaknesses of the methodology as well as recommendations for its further development and practical application. Results from pilot testing the indicators are presented in a separate paper [6].

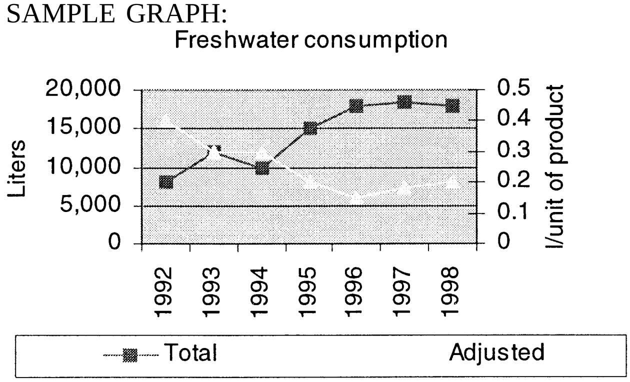
Even if one concludes that the creation of a set of meaningful and simple ISPs, applicable to any organization, is not possible, the exercise of trying to do so is not in vain. The very fact of focusing on the issue heightens companies' awareness about sustainable production, promotes organizational learning and improved measurement practices. It is clear that ISPs alone can not change the current production paradigm. Strong government policies, top management support and consumer pressures are among the key factors that can foster the transition toward sustainable production systems.

Acknowledgements

This research was supported by the Toxics Use Reduction Institute, University of Massachusetts Lowell. The authors wish to acknowledge the assistance of Dr Ken Geiser and Dr Robert Forrant in the preparation of this paper.

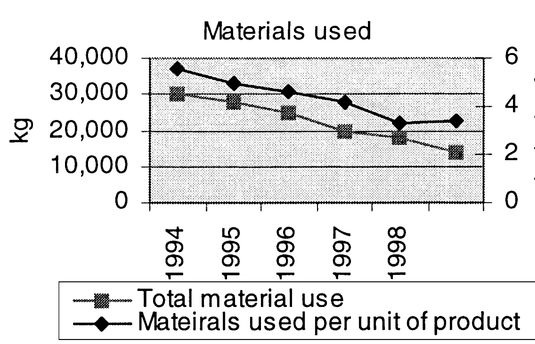
Appendix A

INDICATOR 1: **Freshwater consumption (total and per unit of product)**
METRIC: Liters
GOAL: Reduce freshwater consumption.
BOUNDARIES: Facility.
LEVEL: Second.
SIGNIFICANCE: Scarcity of freshwater is believed to be one of the key problems of the 21st century. No international mechanism exists to address it, since it is typically a local problem.
CALCULATION: 1) Calculate total facility freshwater consumption, using water utility bills. Add the rainfall water on the property.
2) Subtract any amount that is reused, re-circulated (closed-loop cycle).
3) Divide the total amount by the kilograms of product sold during the current year. In case of various different products, use the dollar value of product sold to get adjusted measure.
4) Present both indicators (total and adjusted) on a graph. Include results from previous periods and evaluate the trend over time.
5) Develop cleaner production programs/projects for reduction of freshwater consumption.
SAMPLE GRAPH:



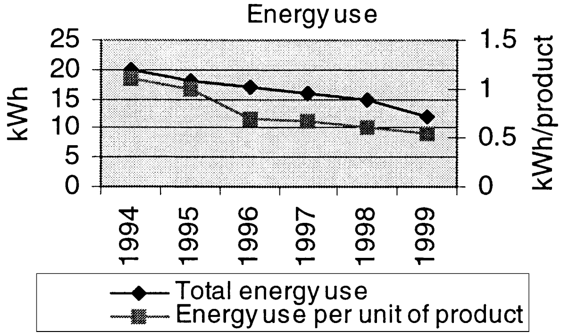
INTERPRETATION: Freshwater consumption per unit of product has declined over the last 6 years (the company is moving toward greater sustainability). However, the total water consumption is still increasing. There is a need to look at the rate of local freshwater withdrawals compared to average rate of replenishment (Level 5 indicator).

INDICATOR 2: **Materials used (total and per unit of product)**
METRIC: Kilograms
GOAL: Reduce materials used.
BOUNDARIES: Facility.
LEVEL: Second.
SIGNIFICANCE: Depletion of non-renewable materials (fossil fuels and metals) and over-consumption of renewables (wood, fisheries, plants, soil) is becoming the limiting factor for traditional economic growth. Conserving and more efficient resource use is critical for the survival of humankind, considering present population growth and rate of consumption.
CALCULATION: 1) Calculate total facility material consumption in kilograms, using the materials tracking system. Do not include water and fuel.
2) Determine an appropriate measure for production—units of product or service, value added or dollar sales.
3) Calculate both total and production-adjusted material use. Divide total materials used by the measure of production to calculate material use per unit of product (material intensity).
4) Make a chart and compare calculated values to results from previous years.
5) Draw conclusions on changes in material intensity over time.
6) Develop cleaner production projects for reduction of material use (e.g., process changes, reuse, recycling).
SAMPLE GRAPH:



INTERPRETATION: Material use per unit of product has declined by almost 50% over the last 6 years. This is consistent with the goal of decreasing material intensity, therefore the company is moving in the right direction (toward more efficient resource use).

INDICATOR 3: **Energy use (total and per unit of product)**
METRIC: kWh
GOAL: Reduce energy use.
BOUNDARIES: Facility/or supply chain-distribution, LCA/.
LEVEL: Second/or fourth/.
SIGNIFICANCE: Increased use of energy has brought to depletion of fossil fuels (coal, gas and oil) as well as global warming, acidification and increasing pollution. Conserving energy and switching to renewable energy sources (solar, wind, tides, biomass) is critical for achieving sustainable development.
CALCULATION: 1) Calculate the total energy consumption (for a facility or entire supply chain-distribution) in kWh, using utility bills and materials tracking system.
2) Determine an appropriate measure for production—units of product/service sold or simply value added or dollar sales.
3) Divide total energy used by the measure of production to calculate energy intensity.
4) Draw a graph, including results from previous years. Evaluate the trend and develop cleaner production projects to reduce energy use (e.g., improve lighting, use more efficient machinery).
SAMPLE GRAPH:

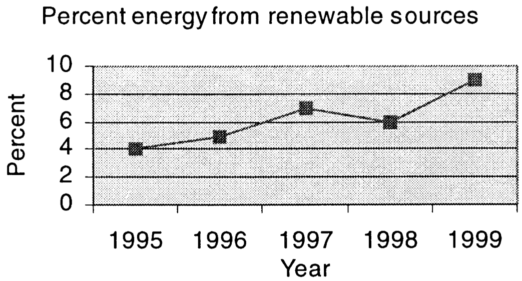


INTERPRETATION: Over the last six years both total energy use and energy intensity of production has declined significantly. This is consistent with the established goal. Therefore, the organization is moving toward greater sustainability in respect to this indicator.

INDICATOR 4: **Percent energy from renewable sources (e.g. solar, wind, hydro-, biomass)**
METRIC: Percent
GOAL: Increase the use of energy from renewable sources.
BOUNDARIES: Facility/or supply chain—distribution, life cycle of products/
LEVEL: Two/Four/
SIGNIFICANCE: Burning of fossil fuels (petroleum, coal, natural gas) to meet increasing energy needs has two dangerous consequences: a) depletes these resources and compromises economic well-being of future generations; b) causes global warming, acid rain and overall pollution beyond the carrying capacity of nature. Therefore, a key goal of sustainable production is to reduce consumption of fossil fuels and switch to renewable energy sources, such as sun, wind, hydro-power, and biomass.
CALCULATION: 1) Calculate total facility/LCA/ energy consumption in kWh, using utility bills, materials tracking system or published data.
2) Calculate energy from renewables (in kWh). For % renewable energy for electricity generation in your area consult ClimateWise.
3) Divide the energy from renewables to the total energy used and multiply by 100 to convert to percent.
4) Make a graph and include data for previous years.
5) Compare current value to previous years' results and draw conclusions about changes in renewable energy use. Discuss

possible ways to increase percent renewable energy used.

SAMPLE GRAPH:



INTERPRETATION: Over the five-year period the percent of energy from renewables has almost doubled. This is consistent with the established goal, so it might be argued that the organization is moving toward a greater sustainability in terms of energy use.

INDICATOR 5: **Kilograms of waste generated before recycling (total and adjusted for production)**

METRIC: Kilograms

GOAL: Reduce the amount of waste generated (air, water, and land) before recycling.

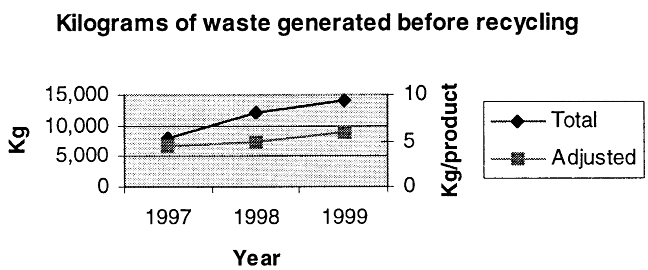
BOUNDARIES: Facility/or supply chain—distribution, LCA/.

LEVEL: Second/fourth/.

SIGNIFICANCE: The total amount of trash generated in the United States each day is about 400,000 tons. Each of us is responsible for four to six pounds per day (http://www.clearwater.org/news/fs6.html) There are two major problems with the present rate of waste generation: a) Nature can not assimilate the huge amounts of wastes generated; and b) Most of this waste contains toxic, nondegradable and bioaccumulative substances that endanger human and ecosystem health, in particular over the long term (e.g., cancer, endocrine disruption, infant birth defects, reduced IQ in children).

CALCULATION: 1) Calculate total waste from the facility (or supply chain—distribution) in kilograms. Include waste to all media.
2) Divide this amount by production level to receive both total waste and waste per unit of product/service.
3) Make a graph and include data for previous years. Compare calculated value to results from previous years and draw conclusions about changes in waste generation. Discuss possible ways to reduce waste at the source.

SAMPLE GRAPH:



INTERPRETATION: Both, total and adjusted amount of waste generated is increasing over the last three years. This is a clear trend away from sustainability. Initiate cleaner production programs to reduce waste generation at the source (e.g., reducing raw materials use, increasing production efficiency, designing durable goods).

INDICATOR 6: **Global Warming Potential (GWP)**

METRIC: Tons of CO_2 equivalents.

GOAL: Reduce greenhouse gas emissions.

BOUNDARIES: Facility/supply chain—distribution/

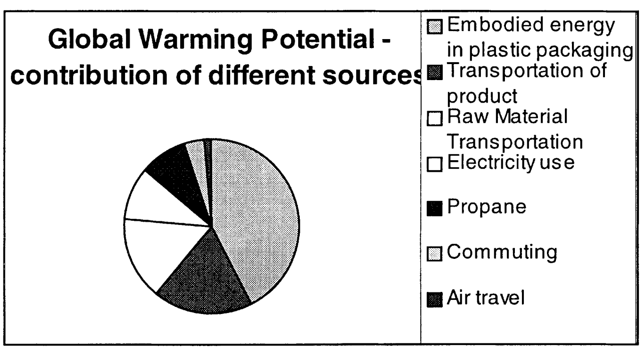
LEVEL: Third/fourth/

SIGNIFICANCE: Global warming emerge as one of the key environmental concerns for the 21st century. International mechanism to address it: Kyoto Protocol and the Convention for Climate Change of 1996. According to this international agreement, US has to reduce its emissions of six greenhouse gases by seven percent below 1990 levels over the period 2008–2012.

CALCULATION: 1) Identify all sources of global warming gases such as

electricity use, propane and other fuel, transportation of raw materials and products, commuting, business travel, embodied energy in key used materials and packaging.
2) Calculate the global warming potential for each of the above sources in tons of CO_2 equivalent per year, using the conversion factors and sources of information provided in Appendix B.
3) Add all the results in step 2) and subtract any offsets (planting trees).
4) Present above results in a chart both as total and production adjusted amounts. Include data for previous years to see trends.
5) Create a pie chart to present the share of each source of global warming, identified in step 1). Discuss ways to reduce GWP.

SAMPLE GRAPH:

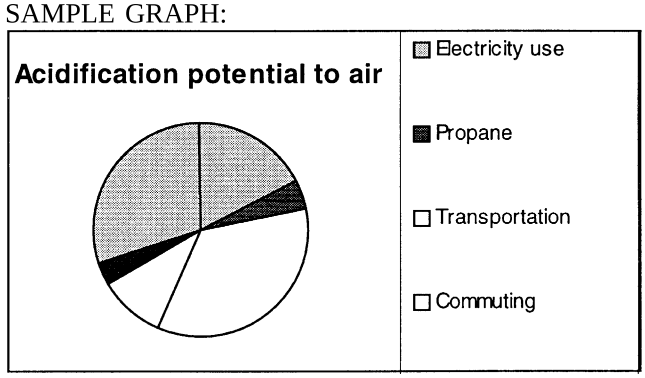


INTERPRETATION: Above sample graph demonstrates that the largest impact on global warming comes from plastic packaging, transportation of products and raw materials. Therefore, improvements in these areas are critical for minimizing the GWP of an organization.

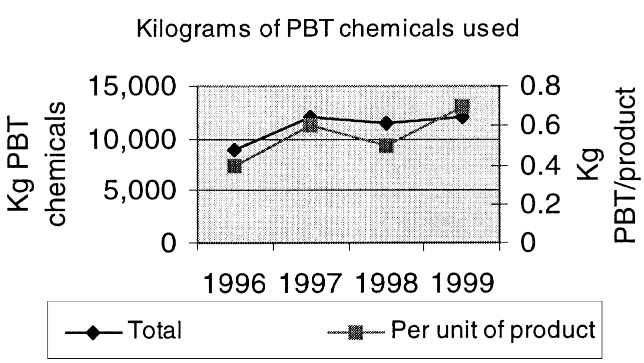
<u>INDICATOR 7</u>: **Acidification potential (to air)**
METRIC: Tons (or kilograms) of SO_2/SOx equivalents.
GOAL: Reduce emissions of acid gasses.
BOUNDARIES: Facility/or supply chain—distribution/
LEVEL: Third/or fourth/
SIGNIFICANCE: Acidification emerged as one of the key environmental concerns of the twentieth century. Acidic soils, rivers and lakes endanger the ecosystem health. International mechanism to deal with acidification: The Convention on Long Range Transboundary Air Pollution of 1979; Clean Air Act in the United States.
CALCULATION: 1) Identify all *sources* of SOx, NOx and other acid gases, such as:
- Electricity use
- Propane and other fuel
- Transportation of raw materials and products
- Commuting
- Business travel
- Embodied energy in key used materials.

2) Calculate the acidification potential for each of the above sources in tons (or kilograms) of SO_2 equivalent per year (or chosen period), using the conversion factors in Appendix B. Add all results to receive a total amount.
3) Present above amount both as total and production-adjusted. Make a chart and include data for previous years.
4) Make a pie chart to present the contribution of each source of acidification, identified in Step 1.
5) Discuss trends, major factors in acidification and possible ways to reduce acidification potential through cleaner production.

SAMPLE GRAPH:

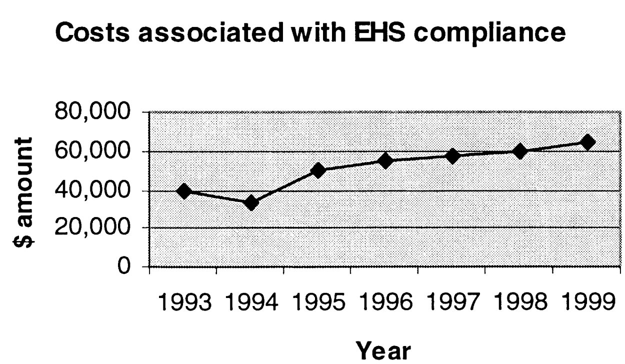


INDICATOR 8: **Kilograms of persistent, bioaccumulative and toxic (PBT) chemicals used.**
METRIC: Kilograms
GOAL: Phase-out all PBT chemicals used by the company.
BOUNDARIES: Facility/company (or supply-chain—distribution, LCA)
LEVEL: Third (or fourth)
SIGNIFICANCE: The use of PBT chemicals creates wastes that can stay indefinitely in the environment (e.g., plastics), accumulate in the living organisms (plants, human tissues) and lead to serious ecosystem and human health effects (death, cancer).
CALCULATION: 1) Using the Illinois EPA list (see Appendix B), identify all sources of PBT chemicals used by the company or facility;
2) Calculate the total amount of PBT in kilograms.
3) Divide total amount by production level (e.g., dollar amount of sales, number of products sold) to receive adjusted amount.
4) Construct a graph to present above results and include data for previous years. Draw conclusions about the trend and develop cleaner production programs for reducing (and gradual phasing out) the use of PBT chemicals.
SAMPLE GRAPH:



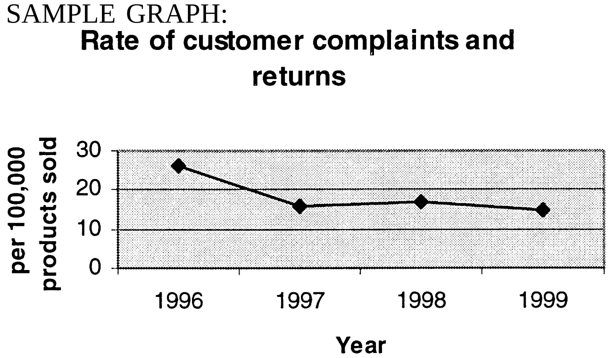
INTERPRETATION: Both total and production adjusted amount of PBT chemicals has increased over the period 1996–99. This is inconsistent with established goal and clearly indicates a trend away from sustainable production.

INDICATOR 9: **Costs associated with EHS compliance**
METRIC: $
GOAL: Reduce EHS compliance costs.
BOUNDARIES: Facility.
LEVEL: One
SIGNIFICANCE: Costs associated with EHS compliance reduce the economic performance of an organization. Their elimination through pollution prevention and cleaner production means real savings and increased profits (e.g., reduce product/service price, increased shareholder value, salaries, worker benefits, investment in R&D).
CALCULATION: 1) Identify all costs associated with EHS compliance for the respective period (e.g., fines, liabilities, worker compensation, fees for waste treatment and disposal, tradable permits, remediation costs, cost/depreciation of control equipment, labor costs).
2) Calculate total amount of dollars paid for EHS compliance for the respective period.
3) Make two graphs:
a) total and adjusted amount, including data for previous measurement periods;
b) pie chart, representing the contribution of the different sources of EHS costs.
4) Compare current and previous amounts and draw conclusions about changes in compliance related expenditures. Use a pie chart to identify the highest costs and possible ways to reduce them.
SAMPLE GRAPH:



INTERPRETATION: This indicator shows that the EHS compliance costs have increased over time. This is inconsistent with the established goal and is a step away from sustainable production.

INDICATOR 10: **Rate of customer complaints and/or returns**
METRIC: Rate (e.g., number of complaints/returns per 100,000 products sold)
GOAL: Achieve zero customer complaints and returns.
BOUNDARIES: Facility/company.
LEVEL: Two.
SIGNIFICANCE: This is an indicator of production/service quality that is directly linked to organization's business and economic performance. In addition, reducing the rate of returns decreases waste generation (or recycling) and thus—the burden on the environment.
CALCUATION: 1) Identify all customer (or distributor) complaints and returns.
2) Calculate the rate of complaints and returns by dividing the total amount of complaints/returns by the level of production/service for the particular period (e.g., fiscal year, quarter, month).
3) Construct a graph to present the rate of complaints and returns. Include data for previous measurement periods.
4) Compare current and previous rates of returns/compliants. Discuss possible ways to reduce this rate.
Note: If considered useful, the dollar amount of complaints and returns may be calculated as well.
SAMPLE GRAPH:



INTERPRETATION: The trend over the four-year period demonstrates a reduction in the rate of customer complaints and returns. This is consistent with the established goal but additional efforts are needed to reduce the rate to zero. Analyze each complaint or return and discuss possible measures to address the problems.

INDICATOR 11: **Organization's openness to stakeholder[5] involvement in decision-making process.**
METRIC: Level of openness (1–5)
GOAL: Increase stakeholder involvement in decision-making.
BOUNDARIES: Facility/company
LEVEL: Two
SIGNIFICANCE: Promoting transparency in decision-making is a crucial condition for moving toward a greater sustainability of any organization. It improves organization's credibility, public image and promotes social and environmental justice.
CALCULATION: Use the table below to determine the level of openness. Compare it to results from previous years. Discuss possibilities for increasing transparency and encouraging stakeholder involvement.
See Table 4

INDICATOR 12: **Community spending and charitable contributions as percent of revenues.**
METRIC: Percent
GOAL: Increase community spending and charitable contributions.
BOUNDARIES: Company/facility
LEVEL: Two
SIGNIFICANCE: Community spending and charitable contributions are not the ultimate solution to social problems (see Indicator 14) but they are the first step in "sharing" wealth. Such spending may help enhance local (or global) community

[5] *Stakeholders*—all interested parties, such as employees, unions, NGOs, comunity, shareholders, insurance companies, etc.

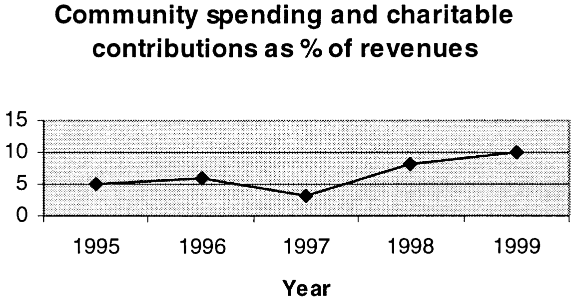
Table 4

Level of openness of an organization	Characteristics
Level 1: Completely closed.	• No reporting of environmental/social goals and/or targets. No indicators developed.
Level 2: Some reporting.	• Mission, goals, targets are made public. • No indicators or environmental/sustainability report are developed.
Level 3: Internal reporting. (Passive invovement of employees)	All characteristics of Level 2 plus: • Environmental report prepared and communicated internally.
Level 4: External reporting. (Passive involvement of stakeholders)	All characteristics of Level 3 plus: • ISPs or other quantitative/qualitative information on company environmental/sustainability performance is organized in formal report and provided to stakeholders.
Level 5: Completely open. (Active involvement of all stakeholders)	All characteristics of Level 4 plus: • Sustainability report is prepared and published annually; • Goals, targets and ISPs are developed and reviewed with the *active* participation of *all* stakeholders.

economically, culturally and physically. No one company can exist in isolation from community, since its customers are members of the community. Their purchasing power is directly linked to the company's sales and profitability.

CALCULATION: 1) Identify all different types of community spending and charitable contributions for the respective period (e.g., donations of money and product, investment in community development or revitalization, NGOs support, volunteering)
2) Add all sources of spending to receive total dollar amount.
3) Divide community spending and charitable contributions by the revenues and multiply by 100 to receive a percent.
4) Draw a graph and include data for previous years. Discuss possible ways to increase community spending and donations.

SAMPLE GRAPH:



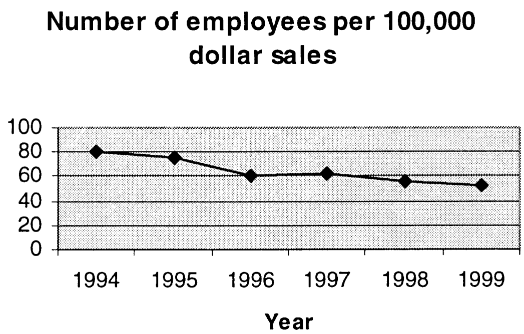
INTERPRETATION: Despite the drop in 1997 (which may be due to financial difficulties), community spending and charitable contributions have increased over the five-year period. This is consistent with established goal and helps promote community development and social justice.

INDICATOR 13: **Number of employees per unit of product/dollar sale**.
METRIC: Number
GOAL: Increase employment opportunities for the local community.
BOUNDARIES: Company/facility
LEVEL: Two
SIGNIFICANCE: Employment from the local community leads to enhancement and revitalization of the area. In a time when natural resources are in short supply and labor is abundant[6], the goal should be to increase labor intensity and reduce material intensity of production.
CALCULATION: 1) Identify the total number of workers employed (including part-time and temporary workers) by using information collected through Human

[6] This relates to the global economy and not simply in the United States, where unemployment in year 2000 reached a record low of 3.9%.

Resources Department.
2) Divide number of workers by revenues, dollar sales, or units of product/service sold.
3) Make a graph and include data for previous periods.
4) Discuss possible ways to increase employment.

SAMPLE GRAPH:

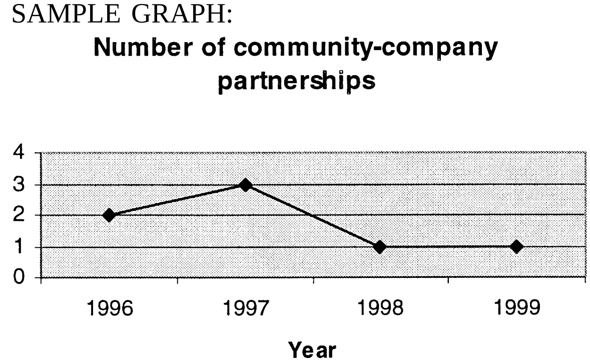


INTERPRETATION: This indicator shows gradual decrease in the number of workers employed at the company/facility. This is clearly a trend away from established goal for promoting social justice and community development. To address the problem, first analyze employment patterns, labor changes and regional development over the period, to identify possible factors outside the company.

INDICATOR 14: **Number of community-company partnerships.**
METRIC: Number
GOAL: Increase community-company partnerships
BOUNDARIES: Company/facility
LEVEL: Two
SIGNIFICANCE: Establishing community-company partnerships is the preferred way of promoting corporate social responsibility and community development. Traditional charity does not reach the root of the problems; it just treats the symptoms [26]. Partnerships benefit both sides. For business this is an opportunity for learning and business development; it gets bottom-line benefits: new products, new solutions to critical problems, and new market opportunities.

CALCULATION: 1) Define what is a partnership and distinguish it from charity. Kanter lists six characteristics of successful private-public partnerships [26]: a) clear business agenda; b) strong partners committed to change; c) investment by both parties; d) rootedness in the user community; e) links to other community organizations; and f) long-term commitment to sustain and replicate results.
2) Identify all projects that meet above six criteria.
3) List these projects and for each include a brief description, amount invested, and benefits (both tangible and non-tangible).
4) Compare results to previous years and discuss possible ways to establish new projects or expand existing ones.

SAMPLE GRAPH:



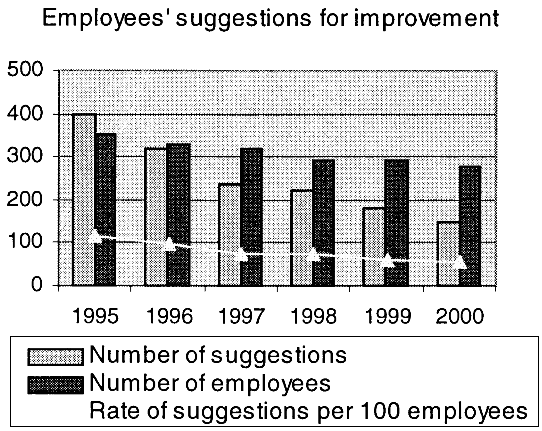
INTERPRETATION: The trend in this indicator shows decline in the number of community-company partnerships (inconsistent with established goal). Analyze the reasons why some partnerships were not sustained over time. Encourage stakeholder involvement in planning new partnerships.

INDICATOR 15: **Lost workday injuries and illness case rate (LWDII).**
METRIC: Rate
GOAL: Achieve zero lost workdays as a result of work-related accidents.

BOUNDARIES: Company/Facility
LEVEL: Two
SIGNIFICANCE: This indicator allows for comparisons between different companies and facilities, since it is measured by most companies (monitored and reported by the Bureau of Labor Statistics http://stats.bls.gov/osheval.htm) Its disadvantages include measuring only *lost time* injuries, possible underreporting, etc. Minimizing lost time due to injuries and illness leads to real *savings* through avoided worker compensation, reduced medical costs, insurance, improved productivity and corporate image.
CALCULATION: 1) *Calculate the number of nonfatal injuries and illnesses.* Count the number of OSHA recordable cases for the year from the Log and Summary of Occupational Injuries and Illnesses (Log) OSHA No. 200; or the TOTALS line for the yearly total on the Log for nonfatal injuries and illnesses with lost workdays, and injuries and illnesses without lost workdays.
2) *Calculate the total number of hours worked by all employees.* Use payroll or other records. "Hours worked" should not include any non-work time, such as vacation, sick leave, holidays. (If actual hours worked are not available for employees paid on commission, by salary, or by mile, they may be estimated on the basis of scheduled hours or 8 hours/workday).
3) Calculate the incidence rate of injuries and illnesses using the formula below and include a brief qualitative description of the major reasons for the lost workdays:
(Number of injuries and illnesses X 200,000)/Employee hours worked=Incidence rate
(The 200,000 hours in the formula represents the equivalent of 100 employees working 40 hours per week, 50 weeks per year, and provides the standard base for the incidence rates.)
5) Make a graph to present results for current and previous periods. Discuss trends, main reasons for the lost workdays and develop programs for reducing the rate.

INDICATOR 16: **Rate of employees' suggested improvements in quality, social and EHS performance.**
METRIC: Rate
GOAL: Increase the rate of employees' suggested improvements.
BOUNDARIES: Company/Facility
LEVEL: Two
SIGNIFICANCE: Having a system to collect and implement employee suggested improvements leads to significant savings, improved employee job satisfaction and morale. Providing financial compensation or public acknowledgement are two possible ways to reward participants.
CALCULATION: 1) Using records for employees' suggestions, determine the number of suggestions for the specific period of indicator implementation.
2) Calculate the rate of employee suggestions by dividing the number of suggestions by the number of employees.
3) Construct a chart to present number of employees, number of suggestions and suggestion rate for the current and previous periods.
4) Evaluate the trend and discuss possible ways to increase the rate of suggestions.
5) If applicable, calculate other related indicators, such as "adoption rate", "total savings", "total dollars awarded".

SAMPLE GRAPH:



INTERPRETATION: This indicator shows decreasing rate of employee suggestions over the last six years, which is a trend away from sustainable production. With employee participation analyze and modify (as applicable) the system for promoting and collecting suggestions.

INDICATOR 17: **Turnover rate (or average length of service of employees)**

METRIC: Rate (Years)

GOAL: Reduce turnover rate (or increase the average length of service of employees).

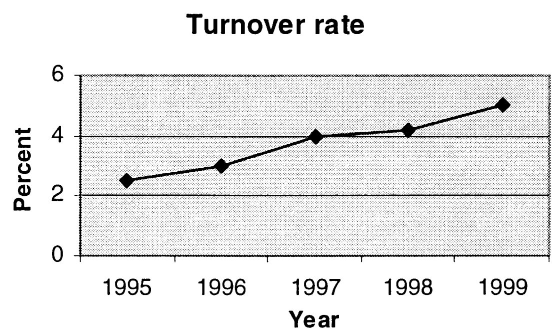
BOUNDARIES: Company/Facility

LEVEL: Two

SIGNIFICANCE: Turnover rate indirectly reflects employee well-being and job satisfaction (e.g., salary and benefits, health and safety, opportunities for learning and personal development). High turnover (or low average length of service) is associated with expenses for recruitment and training of new employees, and reduced production efficiency. The disadvantage of this indicator is that it may be influenced by factors outside a company's control, such as low unemployment, strong competitors. These factors should always be considered when evaluating and interpreting results.

CALCULATION: 1) Using data from department of Human Resources, determine the number of employees, who left/came during the respective period.
2) Divide this number by the total number of employees and multiply by 100 to get a percent (you may calculate per 1,000 or more employees).
3) Construct a chart and include current and previous results.
4) Evaluate the trend and discuss possible ways to decrease turnover (or increase length of service).

SAMPLE GRAPH:



INTERPRETATION: Results show increasing turnover rate of employees. Analyze the reasons (internal and external) for this and discuss possible measures to address the root problems. Undertaking a job satisfaction survey may provide key information for the increasing turnover rate.

INDICATOR 18: **Average number of hours of employee training.**

METRIC: Hours

GOAL: Increase employee training

BOUNDARIES: Company/Facility

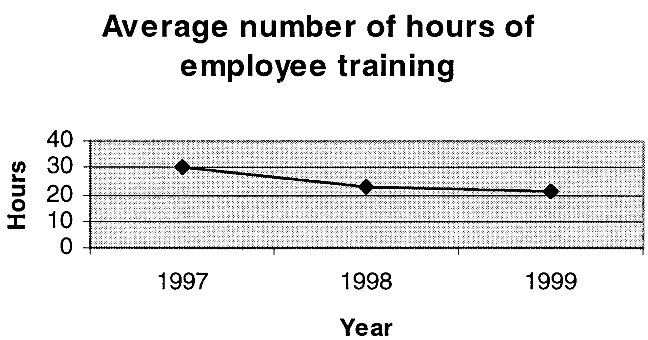
LEVEL: Two

SIGNIFICANCE: Continuous training of employees is critical for the bottom line of an organization. It a) improves business, environmental and safety performance of an organization; b) raises employees' job satisfaction and work morale; c) promotes organizational learning and long-term competitive advantage.

CALCULATION: 1) Using organization's records

determine the total number of hours of employee training (e.g., safety, environmental, quality, or other). Construct a table to summarize results.
2) Divide total hours of training for the period by the number of employees to calculate the average hours of training per employee.
3) Construct a chart to present both current and previous periods' results.
4) If applicable, construct a pie chart to present different types of training for the period as well as dollars spent on training.
5) Evaluate results and discuss possible ways to increase (and improve) employee training.

SAMPLE GRAPH:



INTERPRETATION: Decline in employee training over the three-year period is a trend away from sustainability. Discuss possible rasons for such a change and propose measures for increasing and improving the effectiveness of employees' training.

<u>INDICATOR 19</u>: **Percent of workers who report complete job satisfaction.**

METRIC: Percent

GOAL: Increase employee well-being and job satisfaction.

BOUNDARIES: Company/Facility

LEVEL: Third

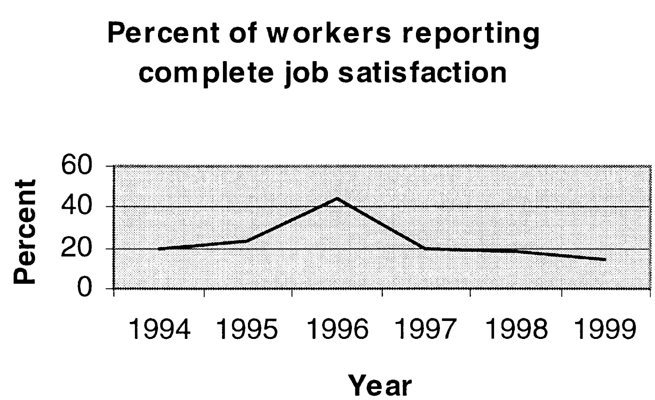
SIGNIFICANCE: Employee well-being and job satisfaction lead to numerous tangible and intangible benefits, such as increased productivity, reduced absenteeism and turnover.

CALCULATION: The following questionnaire can be used to determine worker job satisfaction.

See Table 5

1) Use above questionnaire (or another IF available) to survey employees about their job satisfaction. Distribute it to all employees and aim for higher response rate.
2) For each questionnaire determine the average score.
3) Determine the number of questionnaires with an average score of 4.5 or higher.
4) Calculate the percent of workers reporting complete job satisfaction by dividing the result in step 3 by the total number of completed questionnaires.
5) Make a chart to present above result and results from previous surveys. Discuss possible ways to address workers' concerns by (i) identifying main reasons for dissatisfaction, and (ii) instituting programs to address key concerns.

SAMPLE GRAPHS:



INTERPRETATION: Evaluation of this indicator over time shows a trend toward reduced worker job satisfaction. This is inconsistent with the established goal and a step away from sustainable production. In order to address the issue, analyze the main reasons for the lack of job satisfaction and initiate programs/projects to address them.

Table 5

#	Work-related issue	1 (completely unsatisfied)	2	3	4	5 (completely satisfied)
1	Salary, profit-sharing, bonus, awards					
2	Benefits (e.g. health insurance, paid leave, vacation, retirement benefits)					
3	Health and safety					
4	Stress at work					
5	Work time (e.g., length, flexibility)					
6	Discrimination (racial, sex)					
7	Opportunity for learning and career advancement					
8	Training and educational opportunities (tuition reimbursement, on-site training)					
9	Employee involvement in decision-making (e.g., meetings to discuss key issues, system for suggestions)					
10	Organization's approach to addressing employees' health and safety, economic, social and other needs					
11	Work atmosphere (e.g., management accessibility, coworker relations)					
12	Social/cultural life (e.g., celebration of holidays and other events, picnics, trips)					
	TOTALS (how many times selected):	X	X	X	X	X
	AVERAGE SCORE:	X				
COMMENTS:						

INDICATOR 20: **Percent of products designed for disassembly, reuse or recycling.**

METRIC: Percent

GOAL: Design all products to be disassembled, reused or recycled.

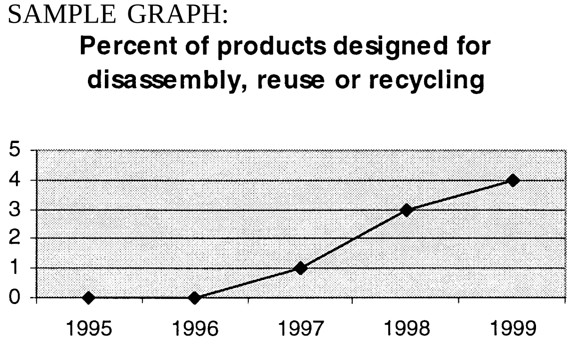
BOUNDARIES: Product life cycle

LEVEL: Four

SIGNIFICANCE: Designing products that can be reused or recylced reduces the material throughput and the burden on ecosystems (e.g., land for waste disposal, water and air pollution, and soil contamination). It also may lead to significant savings and improved bottom line (reduced cost of disposal/emission permits, less raw material used).

CALCULATION: 1) Make a list of all products and include brief information whether a product or its parts are designed for disassembly, reuse or recycling.
2) Using this list count all products that are designed for disassembly, reuse or recycling. If only some parts of a product meet these requirements, include this item as a weight-based ratio. For example, if only 30% of a product is recyclable (by weight), include it as 0.3 instead of 1.
4) Divide the number of products designed for disassembly, reuse or recycling (step 2 above) by the total number of different products made and multiply by 100 to get a percent.
5) Make a chart to present results and include data for previous periods. Develop cleaner production programs to increase product reusability or recyclability.

SAMPLE GRAPH:



INTERPRETATION: The organization is moving in the right direction (toward a greater sustainability), since the percent of products designed for disassembly, reuse or recycling has continuously increased over the five-year period.

INDICATOR 21: **Percent of biodegradable packaging.**
METRIC: Percent
GOAL: Use 100 percent biodegradable packaging.
BOUNDARIES: Product life cycle
LEVEL: Four
SIGNIFICANCE: Most packaging today is made of non-biodegradable materials (e.g., plastics) that stay indefinitely in the environment and when recycled or incinerated produce toxic emissions (e.g., dioxin). To help prevent this, reduce liabilities and gain long-term competitive advantage, companies need to switch to benign, biodegradable materials.
CALCULATION: 1) Make a list of all products and include brief information about weight of packaging, biodegradability and total sales for the period.
2) Calculate the total weight of packaging for each product type.
3) Calculate the weight of biodegradable packaging for each product type.
4) Calculate the total weight of (a) biodegradable packaging; and (b) total packaging for all products.
5) In order to calculate the percent of biodegradable packaging divide 4 (a) by 4 (b) and multiply by 100.
6) Make a chart to present the result and include data for previous periods. Initiate projects to reduce the amount of packaging and increase the use of biodegradable materials.

See Table 6

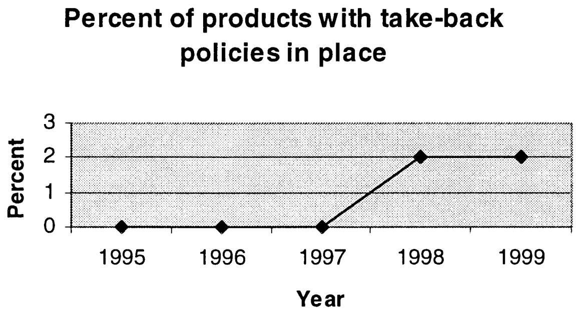
INDICATOR 22: **Percent of products with take-back policies in place.**
METRIC: Percent
GOAL: Increase percent of products with take-back policies.
BOUNDARIES: Product life cycle
LEVEL: Four.
SIGNIFICANCE: Implementing a take-back policy means that at the end of a product life cycle the company has the responsibility to take this product and reuse or recycle it. Although this may seem costly, companies like Interface have gained real savings from reduced use of virgin materials [9]. Implementing take-back policies stimulates designing products for disassembly and reuse, increased product durability and leasing opposed to selling disposable products. Such policies reduce material use without affecting standard of living.
CALCULATION: 1) Make a list of all products and include a brief information about the existence of take-back policies for each of them.
2) Divide the number of products with take-back policies by the total number of products made by a company/facility and multiply by 100 to get a percent.
3) Make a chart to present results and include data for

Table 6

#	Product	Weight of packaging	Weight of biodegradable packaging	Total sales (#)	Total weight of packaging	Total weight of biodegradable packaging
1	Product 1	25g	10g	2000	25g × 2000	10g × 2000
2	…					
	…					
	TOTALS				Σ of above	Σ of above

previous periods. Develop cleaner production program to increase percent of products with take-back policies.

SAMPLE GRAPH:



INTERPRETATION: The introduction of a few products with take-back policies in 1998 is a step in the right direction. Discuss possible ways to promote these policies for larger number of company's products.

Appendix B

Table 7
Examples of quantitative data for indicator calculation

#	Issue	Calculate	Conversion factor	Source
1	Fuel economy for:	Gallon fuel		
	(a) Loaded trucks		6 miles per gallon	http://www.ucsusa.org/transportation/CAFE.campaign.htm
	(b) Cars		27.5 miles per gallon	
	(c) Light trucks		20.7 miles per gallon	
2	Persistent, bio-accumulative and toxic chemicals (PBTs)	Pounds PBTs	List of PBT chemicals	EPA's PBT Final Rule Summarywww.epa.gov/tri/pbtrule_sum.pdf
3	Electricity factors (for New Hampshire and Massachusetts)	CO_2	0.852 lb CO_2/kWh	Climate Wise Emissions Tracking Software, by Business for Social Responsibility
			1.459 lb CO_2/kWh (MA)	
			0.386 metric tons CO_2/MWh (NH)	
			0.662 metric tons CO_2/MWh (MA)	
		SO_2	0.0067 lb/kWh (NH)	Climate Wise
			0.0076 lb/kWh (MA)	
		NO_x	0.0022 lb/kWh (NH)	Climate Wise
			0.0025 lb/kWh (MA)	

(continued on opposite page)

Table 7 (*continued*)

#	Issue	Calculate	Conversion factor	Source
4	Motor gasoline and CO_2 generation	CO_2	1 US gallons motor gasoline=19.594/2204=0.00889 Mtons CO_2	Climate Wise
5	Propane	CO_2	1 US gallons propane=12.669/2204=0.00576 Mtons CO_2	Climate Wise
		NO_x	1 US gallons propane=0.0019 lb NO_x	Climate Wise (special request for information)
6	Global Warming Potential	CO_2 equivalent	CO_2: GWP=1	EPA web site http://www.epa.gov/oppeoee1/globalwarming/inventory/1999-inv.html
			Methane: GWP=21 N_2O: GWP=310	
7	NO_x generated from cars	NO_x	≈1 g/mile	EPA web site http://www.epa.gov/oms/cert/veh-cert/stds-lda.pdf
8	Diesel heavy duty vehicles (moderate)	N_2O	0.03 g/km	EPA web site http://www.epa.gov/oppeoee1/globalwarming/inventory/1999-inv.html
		CH_4	0.05 g/km	
		CO_2	1.011 g/km	
		NO_x	1 gallon diesel fuel=0.1275 lb NO_x (1998 fleet)	Climate Wise (special request for information)
9	Air travel	CO_2	Fuel=[7840+10.1*(distance−250)](*2 if return) CO_2=fuel*(44/12*156/184)−molecular masses *Rule of thumb*: CO_2 emissions per passenger are about *the same* as CO_2 emissions from driving a car at the same distance.	http://www.benjhm.free-online.co.uk/flying
10	Acidification potential	Ratios per equal weights, compared to SO_2, SO_x=1	Ammonia=1.88	NL Environmental Ministry
			HCl=0.88	http://www.ecosite.co.uk/depart/sandm.html#Existing Methods
			HF=1.6 NO=1.07 NO_2=0.7 NO_x=0.7 SO_2, SO_x=1	
11	Ozone depletion potential	Weight ratios, compared to CFC-11=1	1,1,1-trichlorethane=0.12	NL Environmental Ministry
		CFC-11=1		http://www.ecosite.co.uk/depart/sandm.html#Existing Methods
		CFC-113=1.07		

(continued overleaf)

Table 7 (*continued*)

#	Issue	Calculate	Conversion factor	Source
12	Embedded energy in plastic packaging (virgin material)	Million BtU per ton of plastic	HDPE: 79.61	Tellus Packaging Study: "Assessing the impacts of production and disposal of packaging and public policy measures to alter its mix", May 1992
			LDPE: 84.57 Polypropylene: 83.71 Polystyrene: 76.28 PVC=72.31	
13	Agricultural yield	lb per acre	Alfalfa hay: 2.49 tons per acre Corn for silage: 14.4 tons per acre	Economic Research Service, USDA, April 1999 http://usda2.mannlib.cornell.edu//data-sets/crops/88007/
14	Pesticides and herbicides intensity	lb pesticides/acre	Corn for grain: 5.10 lb/acre Hay: 2.14 lb/acre	California pesticide use report http://www.igc.apc.org/panna/risingtide/appen.html#app1
15	Nutriphication potential	Ratios per equal weights, compared to phosphate=1	To water: To air:	NL Environmental Ministry
			COD=0.022 Ammonia=0.33	http://www.ecosite.co.uk/depart/sandm.html#Existing Methods
			NH_3=0.33 Nitrates=0.42 NH_4^+=0.33 NO=0.2 N_{total}=0.42 NO_x=0.13 P_{total}=3.06 Phosphate=1	
16	Heavy metal equivalents	Ratios per equal weights, compared to lead=1	Cadmium oxide=50	NL Environmental Ministry
			Cd=50	http://www.ecosite.co.uk/depart/sandm.html#Existing Methods
			Hg=1 Mn=1 Pb=1 As=1	
17	Particulates	g/mile	Light Duty Diesel Vehicles (91–93)=0.132 g/mi	EPA Office of Mobile Sources
		g/BHp-h	Light Duty Diesel Trucks (91–93)=0.294 g/mi Heavy Duty Diesel Vehicles (91–93)=0.2709 g/BHp-h	http://www.epa.gov/oms/models/part5/part5uga.pdf
18	Rainfall	Inches	40.6 inches per year for Manchester, NH	World Climate, www.worldclilmate.com
19	Endocrine disrupting substances	Pounds	List of known and suspected endocrine disrupters	Illinois Environmental Protection Agency (1997:3)

References

[1] United Nations Conference on Environment and Development, Rio de Janeiro, Brazil. Agenda 21: Programme of Action for Sustainable Development. New York: United Nations, 1992.

[2] Veleva V, Hart M, Greiner T, Crumbley C. Indicators of Sustainable Production. Journal of Cleaner Production 2001;9:447–52.

[3] SustainAbility, Team Spotlights Top 50 Corporate Sustainability Reports. GreenBiz, November 15, 2000, http://www.greenbiz.com/news/news_third.cfm?NewsID=13397

[4] Ranganathan, J. Sustainability Rulers: Measuring Corporate Environmental and Social Performance. Sustainable Enterprise Perspectives, World Resource Institute: Washington, DC, 1998. http://www.wri.org/meb/pdf/janet/pdf

[5] Vollmann T. The transformation imperative: achieving market dominance through radical change. Boston, MA: Harvard Business School Press, 1996.

[6] Veleva, V. Indicators of Sustainable Production: How Do They Work in Practice (in preparation) 2001.

[7] Lowell Center for Sustainable Production. Sustainable Production: A Working Definition. Informal Meeting of the Committee Members, 1998.

[8] Quinn M, Kriebel D, Geiser K, Moure-Eraso R. Sustainable production: A proposed strategy for the work environment. American Journal of Industrial Medicine 1998;34:297–394.

[9] Anderson R. Mid-course correction. Toward a sustainable enterprise: the Interface model. USA: Chelsea Green Publishing Company, 1998.

[10] Lucent Technologies, Environmental Management Systems Manual. Merrimack Valley Works, Issue 3, 2000.

[11] Stonyfield Farm, 2000, http://www.stonyfield.com

[12] Green Mountain Coffee Roasters, 2000, http://www.greenmountaincoffee.com/

[13] Gallopin G. Indicators and their use: information for decision-making. In: Moldan B, Billharz S, editors. Sustainability Indicators: Report of the Project on Indicators of Sustainable Development. John Wiley and Sons Ltd, 1997.

[14] Farrell A, Hart M. What does sustainability really mean? Environment 1998;40(9):5–31.

[15] DiBella A, Nevis E. How Organizations Learn: An Integrated Strategy for Building Learning Capability. San Francisco: Jossey-Bass Press, 1998.

[16] Veleva V., Ellenbecker, M. Indicators of Sustainable Production: A New Tool for Promoting Business Sustainability, New Solutions (in press) 2001.

[17] Ranganathan, J. Corporate Sustainability State-of-Play: List of Initiatives, 1999. http://www.wri.org/meb/sei/state.html

[18] Veleva, V., Ellenbecker M. A proposal for measuring business sustainability: Addressing shortcomings in existing frameworks (forthcoming) 2001.

[19] Global Reporting Initiative, 2000, http://www.globalreporting.org

[20] White, A. and Zinkl, D. Raising standardization. The Environmental Forum, January–February 1998:28-37.

[21] Dow Jones Sustainability Group Index (DJSGI), 1999, Guide to the Dow Jones Sustainabiity Group Indexes, Version 1.0, www.sustainability-index.com

[22] Low J. Plenary presentation. In: 2nd International Symposium of the Global Reporting Initiative, November 13-15, George Washington University, Washington, DC, USA, 2000.

[23] Global Environmental Management Initiative. Environmental reporting in a Total Quality Management Framework, 1994.

[24] Veleva, V. Development of Environmental Sustainability Indicators for Use in Environmental Impact Assessment. M.Sc. thesis. University of Manchester, UK, 1994.

[25] James P, Bennett. Sustainable Measures: Evaluation and Reporting of Environmental and Social Performance. UK: Greenleaf Publishing, 1999.

[26] Kanter, R. From spare change to real change: The social sector as Beta Site for business innovation. Harvard Business Review, May-June, 1999:122-132.