Chapter 8
Analytical Frameworks, Impact Categories, Indicators and Performance Evaluation

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Abstract This chapter introduces the background for indicators to be used to monitor and communicate the environmental performance of different systems and activities. They are anchored in the DPSIR-analytical framework which stands for driving force, pressure, state, impact, and response. This framework is fundamental to our understanding the background for many of the tools and standards for analyzing, measuring, communicating, and reporting on environmental performance. DPSIR has been developed as a global model for understanding and analyzing the status of the Earth due to changes in environmental conditions and how to respond to these changes. The model can also be adapted for smaller systems, for example, for city or regional systems (Level 4 in the CapSEM Model), for organizations (Level 3), for products systems (Level 2) and for productions processes (Level 1).

8.1 Sustainability Indicators

At the United Nations conference on Environment and Development in Rio de Janeiro in 1992, the society decided to debate the topic 'Indicators of Sustainable Development' as stated in Agenda 21 (UNCED 1992), which was later signed by most nations. This was further described in the action programme for activities into the twenty-first century addressing the combined issues of environmental protection and equitable development for all and laid the foundation for current UN Sustainable Development Goals (Bell and Morse 2018).

The term *indicator* comes from the Latin verb *indicare*, meaning to *disclose or point out, to announce or make publicly known, to estimate or put a price on.* Indicators are normally used to communicate information and to draw attention to the performance of current policies. Indicators provide information in more quantitative form than words or pictures alone, and they also provide information in a simpler form than complex statistics or other kinds of social, economic, or scientific

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data. In the OECD-definition from 1993, two major purposes are described (Hammond et al. 1995):

- they reduce the number of measurements and parameters that otherwise would have given an exact presentation of a situation, but are difficult to obtain, by providing approximately aggregated measurements
- they simplify the communication process in which measurement results are provided to the user

Indicators therefore tend to be a *proxy* for the best accumulated knowledge available.

An indicator should reflect changes over a period keyed to a problem, be reliable and reproducible, and be calibrated in the same terms as the policy goals or targets to which they are linked. Indicators must be understandable. They must reflect the goals one seeks to achieve and give information that is meaningful for interested parties. Indicators are not an end in themselves, but tools to build support for needed change and guide the actions of management. Indicators communicate information about progress toward stated goals.

The United Nations' Commission for Sustainable Development (UNCSD) encouraged the development of a core set of Sustainability Indicators, mainly on economic and social issues (UNCSD 1995). However, there was a lack of established comparable international indicators to help decision makers to evaluate environmental trends (Hammond et al. 1995; Moldan and Dahl 2007). Environmental indicators (EI) should be subject to frequent reconsideration as conditions of the environmental change. The plan was that indicators should facilitate international compilation. They should guide data collection, even though each nation would have its own priorities for data collection and analysis, reflecting local needs for resource management and environmental regulation. However, if each country is using different indicators or different methodologies, international agencies cannot work effectively, and opportunity for countries to cooperate to solve global or continent-wide environmental issues could be lost.

By using sustainability indicators industry and other organizations have been guided in how to approach their sustainability performance improvements since the 1990s. There is still a need for placing environmental performance in context so that firms can understand how to contribute to sustainable development in the long-term with a reasonable chance for economic benefits, as well as in the short-term.

8.2 Selecting Indicators: Approaches

Indicators can be selected by employing a bottom-up or a top-down approach. The top-down approach typically starts from international or national rules and regulations, while bottom-up indicators are most commonly based on available data. Primary data can be processed, summarized and expressed by indicators. The information expressed through indicators can be further weighted and aggregated into an index. Weighting and aggregation should be done with care to ensure verifiability,

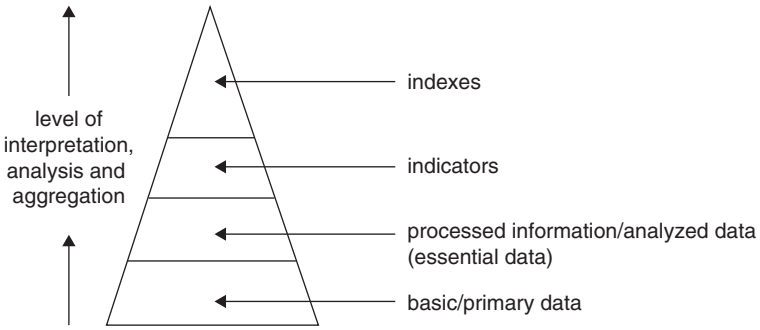

Fig. 8.1 An indicator information pyramid

consistency and comparability. Indicators may have many components based upon measured parameters, but the number of final indexes should be as few as possible. Hammond et al. (1995) produced an *Indicator Information Pyramid* interpreted in Fig. 8.1.

8.2.1 Top-Down Approach

A top-down approach starts with indicators at national and international levels. National indicators can show citizens and decision makers which trends are on course and whether current policies work. They can also provide a framework for collecting and reporting information within nations and for reporting national data to international bodies. Indicators are used to build support for much needed change and guide governments, international organizations, the private sector, and other major groups to act more sustainably. In order to structure *sustainability information* and to make it more accessible to decision makers and the public, various conceptual frameworks have been proposed. A widely used framework for environmental indicators is based on the following simple questions:

- What is happening to the state of the environment or natural resources?
- Why is it happening?
- How can we improve it?

This approach is often called the *Pressure-State-Response* (PSR) approach, see Fig. 8.2. Indicators are used to communicate the interactions between man-made and natural systems (the environment). The pressure corresponds to the extraction of resources *from* the environment or emissions *into* the environment. Pressure indicators are direct measures of policy effectiveness e.g., related to increase of emissions and waste, and support the decision-making process. The state indicators correspond to the condition of the environment. Response indicators express the societal response, which often leads new regulations being developed. For example, for climate change, pressure indicators express emissions of climate gasses, such as

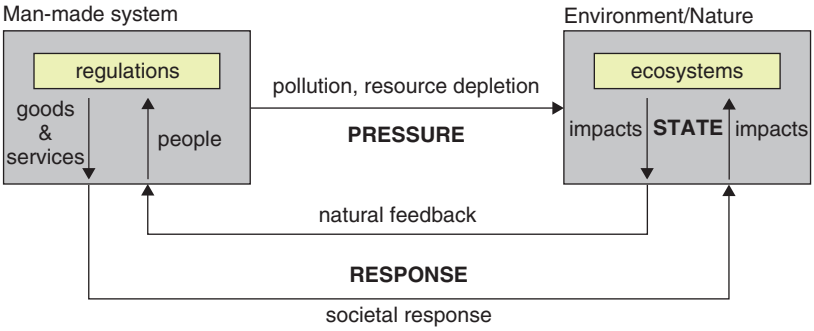

Fig. 8.2 Pressure-state-response (PSR) framework for indicators

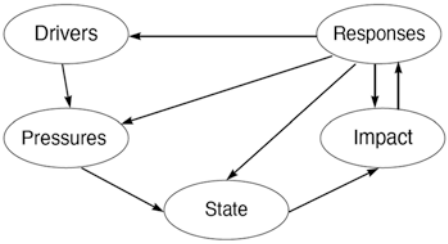

Fig. 8.3 Framework for Reporting on Environmental Issues. (Modified from EEA 1999)

CO_2, the state indicators express atmospheric concentration of greenhouse gases and the global mean temperature and response indicator may be expressed by requirements for increased energy intensity or the reduced use of fossil fuels. For toxic contamination, the generation of hazardous wastes is expressed by pressure indicators. The state indicators express the impact and the response indicators are expressed through new regulations.

The PSR-framework was further developed into a framework which distinguished driving forces, pressure, states, impact and responses. This became known as the Driver-Pressure-State-Impact-Response (DPSIR) framework which has been widely used by international policymakers. DPSIR gives a structure within which to present the indicators needed to enable feedback to policy makers on environmental quality and the resulting impact of the political choices made, or to be made in the future (Kristensen 2003; Reid and Rout 2020; Carr et al. 2007). For each of the DPSIR-stages, information can be expressed and communicated by indicators (see Fig. 8.3).

Driving Force Indicators

A 'driving force' is a need, and for an industrial sector a driving force could be the need to be profitable and to produce at low costs, while for a nation a driving force could be the need to keep unemployment levels low. Other forces could be the need for specific materials or energy, or the need for land areas to build a facility. A driving force indicator should be designed appropriately to match the need.

Pressure Indicators

As early as 1994, OECD classified human interactions with the environment in four broad categories: 1. Use of natural resources, 2. Flows of pollutants and emissions, 3. Impact on the ecosystem and reshape of the environment and 4. Effect on human welfare caused by environmental conditions.

1. *Resource index and source indicators.*

Indicators in this area directly measure the sustainability of natural resource use, so they signal the effectiveness of natural resource policies. Roughly, the index indicates the degree of departure from sustainable resource use, assuming that the depletion of natural resources is sustainable if their use leads to the creation of other assets of equal value.

2. *Pollution/emission index and sink indicators.*

The pollution index is described by six impact categories (OECD 1994): climate change, depletion of the ozone layer, acidification of soils and lakes, eutrophication of water bodies, toxification of soils, water bodies and ecosystems, and accumulation of solid waste. For each of these there are supporting indicators. Each impact category can be weighted based on the gap between the current value of the indicator and the long-term policy perspective of sustainability, the greater the gap, the larger the weighting factor.

3. *Biodiversity index, ecosystem risk and life support indicators.*

Biodiversity can in some sense be measured on a species level by counting species or listing endangered species. A biodiversity indicator consists, for example, of a summary of national statistics.

4. *Human impact index and exposure indicators.*

This concerns human welfare, the environmental conditions that undermine it, and the social equity. The indicators compare how environmental conditions influence a nation's human welfare. This index could provide important environmental information; it could be combined with other health information to create an overall health index to be used as an indicator of sustainable development.

State Indicators

As a result of pressures, the state of the environment is affected. State indicators should be designed to reflect the quality of air, water, soil and ecosystems, tracking the state of the environment over time. Both physical, chemical, and biological conditions should be measured by state indicators.

Impact Indicators

The changes in the physical, chemical, or biological state of the environment determine the quality of ecosystems and the welfare of human beings. In other words, changes in the state may have environmental or economic impacts on the

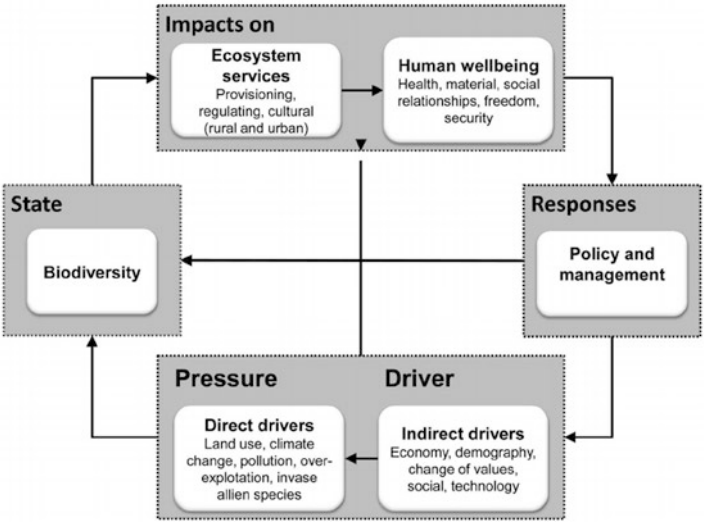

Fig. 8.4 Example of DPSIR with reference to impact on ecosystem services. (Santos-Martín et al. 2013)

functioning of ecosystems, their life-supporting abilities, and ultimately on human health and on the economic and social performance of society (EEA 2003). Impact indicators should be designed to reflect and monitor changes over time.

Response Indicators

A response by society or policy makers is the result of an undesired impact and can affect any part of the chain between driving forces and impacts as indicated by the arrows in Fig. 8.3. An example of a response to driving forces might be new legislation in transportation systems. A response to pressure could be adjusted to permit a change in the content of nitrogen in wastewater discharges to lakes.

Figure 8.4 gives an example of how the DPSIR framework can be used for a study on drivers that put pressure on biodiversity with an impact on ecosystem services and resulting consequences to human wellbeing. The responses are, in this example, new policies and regulations to avoid damage to ecosystem services.

8.2.2 Bottom-Up Approach and Environmental Performance Indicators

Whereas a top-down approach works best for issues impacting the global environment, a bottom-up approach is more commonly adopted for issues with local environmental impacts. The four pressure indicators presented in the previous section could also be a reference for approaches on a company level. At a macro-level,

the national governmental institutions like statistical offices, normally gather and aggregate company based environmental data from the micro level. Environmental information and statistical data are normally supplied to national and international institutions by companies. Therefore, it is important, practical, time and cost- effective to structure company based environmental information systems in such a way that they are compatible with, and useable for, the macro level. Although this was addressed in the early 1990s, the need for harmonization remains an issue. According to ISO 14031 (ISO 2021), environmental performance (EP) is defined as the result of an organization's management of its environmental aspects. According to ISO 14001 (ISO 2015), environmental aspects are defined as activities, products or services that can make an impact on the environment. The pathway from aspects to impacts is described in Chap. 7 (Fig. 7.3).

8.3 Environmental Performance Indicators and Evaluation

An environmental performance indicator (EPI) is defined as a specific expression that provides information about an organization's environmental performance (ISO 2021). Firms should select EPIs for the purpose of measuring, evaluating, and communicating their performance. Measuring one single firm's contribution to the degradation of global environmental issues is impossible. Likewise, it is challenging for a company to predict how their reduction of, for example, CO_2-emissions contributes to reduced global warming. From a bottom-up-approach, the corporate's EPIs should reflect the most important environmental aspects resulting from internal processes connected to the activities, products, and services of the company. A sample approach to identify appropriate EPIs might be as follows:

1. Identify environmental aspects connected to activities, products and services (e.g., use of fossil fuels) and then the impacts this may cause (e.g., emissions of CO_2 which may cause global warming, or particles that may cause smog).
2. Analyze the organization's existing data on material and energy inputs, discharges, wastes, emissions, and other outputs. Assess these data in terms of quantity and hazards, often termed as the environmental account for the company.
3. Identify the views of stakeholders and other interested parties and use this information to help design the EPIs.

An organization that is committed to improving its environmental performance, should be able to measure its performance level. According to ISO 14031 (ISO 2021), EPIs will help them determine whether they are moving forward with the intention to improve. Environmental Performance Evaluation (EPE) is the process that organizations can use to measure, analyze, and assess their environmental performance against a set of criteria. From the perspective of the CapSEM Model, this takes place within the organization at Level 3 but uses I/O and LCA from Level 1 and 2. EPE helps the organization to understand its significant environmental

aspects and form a baseline from which objectives and targets for improvements can be derived. Therefore, EPE is central for monitoring environmental performance improvements over time, and to compare the performance against another similar organization for benchmarking.

EPE can be developed for a relatively small application, even in a large organization. The process should include (1) establishing measurable goals and targets, (2) setting time schedules for the improvement tasks, (3) implementing action plans to achieve the goals, and (4) communicating the environmental performance to interested parties. As the environmental performance improvements spread within an organization, the EPE process can expand. Since environmental performance improvement should apply to all life cycle phases of a product or a service, data collection should also address relevant information outside the manufacturing site and based upon data from, for example, a life cycle assessment (LCA) of a product (ISO 2012).

The areas for EPE can be split into operational performance measured by OPIs and management performance measured by MPI. The operational area includes physical facilities and equipment, design and operation, and the material and energy flows required to generate and provide the products and services. Most EPIs are related to the operational area; they could also be expressed as operational performance indicators (OPI). According to ISO 14031 (ISO 2021), OPIs should provide information about the impacts resulting from an organization's operations. Similarly, a management performance indicator (MPI) is defined as an indicator that provides information about management (ISO 2021). The management area of an organization includes the policies, practices, people and procedures at all levels, and their decisions and activities, which in turn result in impacts on the environment. Environmentally related inputs to management include legal requirements, views of interested parties, information from the operational system, and information about the condition of the environment.

Examples of OPIs and MPIs are presented in Table 8.1. These can be used as inspiration for companies for internal performance improvements programmes, and EPE can then be carried out in relation to the goals set for each indicator for external reporting. OPIs and MPIs are mainly designed for evaluation internal practices. Another evaluation criterion is the evaluation of the state of the nature in the surrounding area. This can be carried out using Environmental Condition Indicator. The condition of the environment covers air, water, soil, flora, and fauna. Environmental condition indicators (ECI) should be selected regarding these categories. Evaluating the state of the environment caused by one single organization's activities is complex. In most cases, evaluation of the state of the environment will be undertaken by regional authorities or by help from consultants or scientific organizations. Good insight into the condition of environmental surroundings can assist an organization in planning the EPE process and selecting relevant EPIs.

Table 8.1 Examples of EPIs expressed by OPIs and MPIs

Example of operation performance indicators (OPI).	**Example of management performance indicators (MPI).**
Category – materials	**Conformance – degree of compliance with regulations**
Quantity of materials used per unit of product	Costs (operational and capital) that are associated with a product's or process' environmental aspects
Quantity of processed, recycled or reused materials used	Return on investment for environmental improvement projects
Category – energy	**Category - financial performance**
Quantity of energy used per year or per unit of product	Costs (operational and capital) that are associated with a product's or process' environmental aspects
Quantity of energy used per service or customer	Return on investment for environmental improvement projects
Category – emissions	**Category - implementation of policies and programmes**
Quantity of specific emissions per year	Number of achieved objectives and targets
Quantity of specific emissions per unit of product	Number of organizational units achieving environmental objectives and targets
Category – wastes	**Category - community relations**
Quantity of waste per year or per unit of product	Number of inquiries or comments about environmentally related matters
Quantity of hazardous, recyclable or reusable waste produced per year	Number of press reports on the organization's environmental performance

8.4 Other Frameworks for Evaluating Sustainability Performance

There are many frameworks, guidelines, and standards available for supporting business and other organizations in their efforts to use indicators in the process of evaluating their sustainability performance. At the same time, it is important to remember that indicators are designed to encapsulate complexity into condensed information, and it has long been known that sustainability indicators can be selectively used to support polarized sides of a given debate (Bell and Morse 2018). Chapter 9 gives an overview of the most recent and most used framework for driving performance improvements and for reporting and communicating business performance.

8.5 Conclusion

This chapter has presented various frameworks for choosing indicators that can be used for communicating sustainability performance on different systems levels. At the macro level, the DPSIR-model is a systematic approach for embracing the

complexity involved when dealing with sustainability in a global society. On the micro level, the framework for EPE-evaluation is mainly designed for corporate levels and their activities, products, and services. DPSIR models use indicators for communicating aspects connected to the operational and management areas in a company. Even though none of the existing models provide a perfect link between the indicators selected from a top-down view with those from a bottom-up view, the DPSIR- and EPE-models offers guidance for companies and other organizations when selecting an indicator for communication purposes. The use of indicators and reporting practices is further described in Chap. 9.

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