LIFE12 ENV/GR/000427 LIFE reclaim "Landfill mining pilot application for recovery of invaluable metals, materials, land and energy

TECHNICAL REPORT - ACTION C1

FOR THE POLYGYROS LANDFILL, IN THE MUNICIPALITY OF POLYGYROS, CHALKIDIKI

SUBJECT:

ENVIRONMENTAL PERFORMANCE INDICATORS

STUDY : **ENVECO S.A.**

ENVECO S.A. ENVIRONMENTAL PROTECTION MANAGEMENT & ECONOMICS

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1. The concept of sustainability

The concept of sustainable development is based on the observation that economy, environment and wellbeing can no longer be separated. The definition of sustainable development is often quoted from the World Commission on Environment and Development (WCED, 1987): "*development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs*". The fundamental principle behind this definition is to accept that all human individuals have equal rights, whether living today or in future (Balkema et al., 2002). This sketches a concept rather than giving rigid rule that can be applied right away. Therefore, sustainability can and will be interpreted differently by different people, evoking the critique that the term sustainability could mean almost anything (Mitcham, 1995).

A number of countries define sustainable development in terms of its different components (pillars, axes or dimensions). Other countries rely on flow or capital based models, or on a combination of both (Hass et al., 2002). The most common framework used by countries in developing indicators of sustainable development starts from the idea of three pillars of sustainability - economic, environmental and social [or cultural].

1.1. Economic sustainability

Economic sustainability implies paying for itself, with costs not exceeding benefits. Mainly focusing on increasing human well-being, through optimal allocation and distribution of scarce resources, to meet and satisfy human needs. This approach should, in principle, include all resources: also those associated with social and environmental values (e.g. in environmental economics). However, in practice most analyses include only the financial costs and benefits.

1.2. Environmental sustainability

The long-term viability of the natural environment should be maintained to support long-term development by supplying resources and taking up emissions. This should result in protection and efficient utilisation of environmental resources. Environmental sustainability refers to the ability of the functions of the environment to sustain the human ways of life. The latter mainly depends upon the ethical basis: to what extent should policies be anthropocentric and to what extent does nature have endogenous qualities. Although public opinion goes further, public policies mainly remain limited to so-called use-values, which can be incorporated in economic analysis relatively easily.

1.3. Social or cultural sustainability

Here the objective is to secure people's social–cultural and spiritual needs in an equitable way, with stability in human morality, relationships, and institutions. This dimension builds upon human relations, the need for people to interact, to develop themselves, and to organize their society. Similar classification can be found in the literature; for instance, Barbier (1987 in Bergh & Straaten, 1994) suggests that sustainable development is an interaction between three systems biological, economical, and social, with the goal to optimise across these systems by taking into account the trade-offs. The difficulty to express and weigh these trade-offs suggests that the optimization is a political process rather than a scientific one. This is in line with the vision of the Scientific Council for Governmental Policies (WRR, 1994). The basic philosophy of this council is that when implementing the concept of sustainability, one cannot ignore the uncertainties and the mutual dependencies between the environment and the society. The forthcoming risks for the environment and for the economy will have to be balanced.

2. The concept of indicators

2.1. Definition of indicators

In order to measure progress towards sustainable development, several countries have developed indicators. An indicator is an observed value representative of a phenomenon of study. In general, indicators quantify information by aggregating different and multiple data (Gabrielsen and Bosch, 2003). The resulting information is therefore synthesised. In short, indicators simplify information that can help to reveal complex phenomena.

Indicators of sustainability are different from traditional indicators of economic, social, and environmental progress. Traditional indicators -- such as stockholder profits, asthma rates, and water quality -- measure changes in one part of a community as if they were entirely independent of the other parts. Sustainability indicators reflect the reality that the three different segments are very tightly interconnected, as shown in the Figure 1.

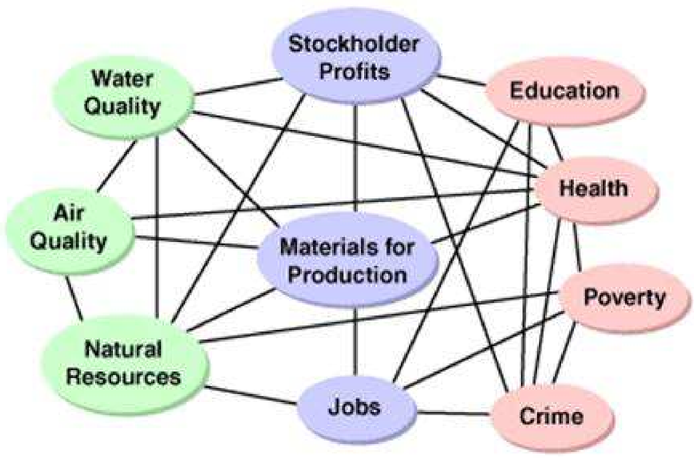

Figure 1: The interactions among a community's environment, economy and society (source: http://www.sustainablemeasures.com/node/89)

As illustrated Figure 1, the natural resource base provides the materials for production, on which jobs and stockholder profits depend. Jobs affect the poverty rate and the poverty rate is related to crime. Air quality, water quality and materials used for production have an effect on health. They may also have an effect on stockholder profits: if a process requires clean water as an input, cleaning up poor quality water prior to processing is an extra expense, which reduces profits. Likewise, health problems, whether due to general air quality problems or exposure to toxic materials, have an effect on worker productivity and contribute to the rising costs of health insurance.

Sustainability requires this type of integrated view of the world -- it requires multidimensional indicators that show the links among a community's economy, environment, and society.

Various institutions and authors have proposed definitions for the concept of indicators.

Hammond et al. (1995) describe an indicator as ‘‘something that provides a clue to a matter of larger significance or makes perceptible a trend or phenomenon that is not immediately detectable. [. . .] Thus an indicator's significance extends beyond what is actually measured to larger phenomena of interest''. To give an example, measuring body temperature not only gives the current temperature of the human body, but if that temperature is higher than normal also provides a strong indication that the person is ill and currently experiencing a virus or infection. So body temperature is not just a temperature indicator, but also a human health indicator.

According to the Quality of Life Counts 1999 report of the British Government (Reyntjens and Brown, 2005) indicators are "broad brush, highly aggregated statistics which summarise the overall picture".

Food and Agriculture Organization (FAO, 1999) defines an indicator as a variable, pointer, or index related to a criterion. Its fluctuations reveal the variations in those key elements of sustainability in the ecosystem, the fishery resource or the sector and social and economic well-being. The position and trend of an indicator in relation to reference points or values indicate the present state and dynamics of the system.

For Slocombe (1999) an indicator is an *a-priori* defined system characteristic that can provide feedback on progress towards management goals and objectives.

For Sainsbury and Sumaila (2001) an indicator is something that is measured, not necessarily numerically, and used to track an operational objective. An indicator that does not relate to an operational objective is not useful in this context.

According to the OECD (2003), an indicator is a parameter, or a value derived from parameters, which points to, provides information about, or describes the state of a phenomenon/environment/area, with a significance extending beyond that directly associated with its value.

Another way to define indicators is to look at the functions they are supposed to fulfil. According to the European Environment Agency (EEA) (Smeets and Weterings, 1999), indicators are used for three major purposes:

a. to supply information on environmental problems in order to enable policy-makers to value their seriousness;

b. to support policy development and priority setting by identifying key factors that generate pressure on the environment; and

c. to monitor the effects of policy.

For FAO (1999) indicators provide a bridge between objectives and actions. They should reflect the state of the system with respect to how well goals and objectives are being pursued or achieved, providing a transparent link between policy objectives and management action (Garcia et al, 2000).

Indicators can help to harmonise reporting at various levels from local to regional, national and international level, particularly where countries are required under conventions and agreements to report on progress towards sustainable development (Garcia et al, 2000).

The United Nations Commission on Sustainable Development (UNCSD, 2001 in Reyntjens and Brown, 2005) has developed indicators for sustainable development in order to:

translate physical and social science knowledge into manageable units of information that can facilitate the decision-making process;

a. help to calibrate and measure progress towards sustainable development goals;

b. provide early warning to prevent damage; and

c. communicate ideas, thoughts and values.

In the report of the Royal Commission on Environmental Pollution (RCEP, 2004 in Reyntjens and Brown, 2005) it is argued that indicators are a formal measure of performance that can be used to judge the success of management strategies.

These different definitions and lists of functions largely overlap. The difference between them is mostly one of emphasis, not substance. They do point to one specific characteristic of indicators and three fundamental functions in which they are used. Indicators are essentially standardised units of information related to societal goals and objectives. The three functions are monitoring, evaluation and communication. It is important to note that each function has specific requirements and is important at different stages in a policy cycle.

Monitoring is the most operational of these three functions. It entails a continuous assessment of management actions in the framework of policies and plans that have been decided on. Evaluation is a more periodic assessment of relevance, efficiency, impact (both intended and unintentional) and performance against stated societal objectives or goals. It is normally linked to a control mechanism that should lead to corrective actions being taken if necessary. It will also feed into the process of specifying the objectives, developing policies and plans to achieve them and the allocation of resources. Monitoring and evaluation functions point to the role of indicators as an integral part of a management information system. Indicators that are relevant in a specific context will therefore depend both on the management objective and on the management institution that is to be informed by the indicator (Degnbol and Jarre, 2004). In considering the communication function it will be necessary to identify the audience and the message that will need to be conveyed. More specifically, communication indicators should enable or promote information exchange regarding the issue they address. An indicator that communicates in a sound way a simplified reality should:

- match the interest of the target audience;
- be attractive to the eye and accessible;

- be easy to interpret;
- invite action (read further, investigate, ask questions, do something);
- be representative of the issue or area being considered;
- show developments over a relevant time interval (a period in which changes can be shown;
- go with a reference value for comparing changes over time;
- go with an explanation of causes behind the trends;
- be comparable with other indicators that describe similar areas, sectors or activities;
- be scientifically well-founded; and
- be based on sound statistics.

It is important to note, however, that indicators are only a tool first for monitoring and then for evaluation and communication. Their selection has normally involved the implicit or, preferably, the explicit formulation of assumptions on the links between actions taken, the indicators and the goals pursued. Indicators need to be supplemented by other qualitative and scientific information, particularly research to explain the causes of change as measured by indicators (OECD, 1998).

2.2. Development and evaluation of national sets of sustainable indicators

Before selecting the Sustainable Development Indicators (SDI), "it is necessary to specify the sustainability principles that are going to be adopted" (Mitchell, 1996). A number of countries have referred to the Bellagio Principles (Hardi and Zdan, 1997) as guidelines for the choice of indicators, their design, interpretation and communication. The Bellagio principles emerged as the synthesis of deliberations of the International Institute for Sustainable Development (IISD).

The Bellagio principles identify a number of criteria for assessing progress towards sustainable development (Table 1). "These principles serve as guidelines for the whole of the assessment process including the choice and design of indicators, their interpretation and communication of the result. They are interrelated and should be applied as a complete set. They are intended for use in starting and improving assessment activities of community groups, non-government organizations, corporations, national governments, and international institutions" (IISD, 1997).

More specifically, Principle 1 stresses the importance of establishing a "vision" of sustainable development, and of translating this vision into concrete goals that are meaningful for decision-makers. Principles 2 through 5 deal with the "content" of any assessment: these stress the need to combine information on the state of the overall system with a practical focus on narrower range of priority issues. Principles 6 through to 8 deal with the "process" of assessment. Principles 9 and 10 highlight the importance of establishing a continuing "capacity" for assessment.

Table 1: Bellagio Principles

Principle 1. Guiding Vision and Goals
Assessment of progress toward sustainable development should be guided by a clear vision of sustainable development and goals that define that vision
Principle 2. Holistic Perspective
Assessment of progress toward sustainable development should: – include review of the whole system as well as its parts – consider the well-being of social, ecological, and economic sub-systems, their state as well as the direction and rate of change of that state, of their component parts, and the interaction between parts – consider both positive and negative consequences of human activity, in a way that reflects the costs and benefits for human and ecological systems, in monetary and non-monetary terms
Principle 3. Essential Elements
Assessment of progress toward sustainable development should: – consider equity and disparity within the current population and between present and future generations, dealing with such concerns as resource use, over-consumption and poverty, human rights, and access to services, as appropriate – consider the ecological conditions on which life depends – consider economic development and other, non-market activities that contribute to human/social well-being
Principle 4. Adequate Scope
Assessment of progress toward sustainable development should: – adopt a time horizon long enough to capture both human and ecosystem timescales thus responding to needs of future generations as well as those current to short term decision-making – define the space of study large enough to include not only local but also long distance impacts on people and ecosystems build on historic and current conditions to anticipate future conditions - where we want to go, where we could go
Principle 5. Practical Focus
Assessment of progress toward sustainable development should be based on: – an explicit set of categories or an organising framework that links vision and goals to indicators and assessment criteria – a limited number of key issues for analysis – a limited number of indicators or indicator combinations to provide a clearer signal of progress – standardising measurement wherever possible to permit comparison – comparing indicator values to targets, reference values, ranges, thresholds, or direction of trends, as appropriate
Principle 6. Openness
Assessment of progress toward sustainable development should: – make the methods and data used accessible to all – make explicit all judgments, assumptions, and uncertainties in data and interpretations
Principle 7. Effective Communication
Assessment of progress toward sustainable development should: – be designed to address the needs of the audience and set of users – draw from indicators and other tools that are stimulating and serve to engage decision-makers – aim, from the outset, for simplicity in structure and use of clear and plain language
Principle 8. Broad Participation
Assessment of progress toward sustainable development should: – obtain broad representation of key grass-roots, professional, technical and social groups , including youth, women, and indigenous people - to ensure recognition of diverse and changing values – ensure the participation of decision-makers to secure a firm link with adopted policies and resulting action
Principle 9. Ongoing Assessment
Assessment of progress toward sustainable development should: – develop a capacity for repeated measurement to determine trends – be iterative, adaptive, and responsive to change and uncertainty because systems are complex and change frequently – adjust goals, frameworks and indicators as new insights are gained – promote development of collective learning and feedback to decision-making
Principle 10. Institutional Capacity
Continuity of assessing progress toward sustainable development should be assured by: – clearly assigning responsibility and providing ongoing support in the decision-making process – providing institutional capacity for data collection, maintenance and documentation supporting development of local assessment capacity

2.2.1. Criteria for indicator selection, use and presentation

Criteria for determining what is a "good" indicator, depends on who the users of that indicator are. For this reason, it is impossible to identify indicators that are "good" for all purposes. This reason often accounts for the development of different sets of indicators within each country. While detailed indicators are best suited for experts, "headline" indicators are often used for communicating with a wider audience.

In presenting sustainable development indicators, many countries indicate the underlying reasons for their development. Many countries try to illustrate the actual movements in these indicators, although this can be difficult when multiple factors influence their development. To draw attention to key aspects in the evolution of these indicators, some countries have used symbols to highlight the key message.

The Bellagio principles (Hardi and Zdan, 1997) suggest that the following criteria are important for selecting indicators: i) policy relevance; ii) simplicity; iii) validity; iv) availability of time-series data; v)good quality, affordable data; vi) ability to aggregate information; vii) sensitivity to small changes; viii) reliability. Several OECD countries also refer to the criteria for indicator selection put forward by the OECD in its work on environmental indicators (Table 2; OECD, 1998 and 2001).

Table 2: Criteria for selection of environmental indicators

POLICY RELEVANCE AND UTILITY FOR USERS
An environmental indicator should – Provide a representative picture of environmental conditions, pressures on the environment and society's responses; – Be simple, easy to interpret and be able to show trends over time; – Be responsive to changes in the environment and related human activities; – Provide a basis for international comparisons; – Be either national in scope or applicable to regional environmental issues of national significance; – Have a threshold or reference value against which to compare it so that users are able to assess the significance of the values associated with it.
ANALYTICAL SOUNDNESS
An environmental indicator should – Be theoretically well founded in technical and scientific terms; – Be based on international standards and international consensus about its validity; – Lend itself to being linked to economic models, forecasting and information systems.
MEASURABILITY
The data required to support the indicators should be – Readily available or made available at a reasonable cost/benefit ratio; – Adequately documented and of known quality; – Updated at regular intervals in accordance with reliable procedures.

To influence policy formulation, indicators need to be relatively few in number, clear, concise and analytically robust. In addition, their movements should be interpreted as unambiguous "good" or "bad". In general, different types of indicators will be used during the different "stages" of the policy process — policy preparation, policy formulation, policy execution and policy evaluation. State indicators are generally used to identify problems in the policy preparation stage. Performance indicators, which focus on changes in driving forces and pressures, are used in the policy formulation stage. Indicators of policy effectiveness and policy response are used to get a wide acceptance of the measures taken by policymakers during the policy execution phase. State and decoupling indicators become important in the policy evaluation phase, for monitoring results and changes in the state of the environment (EEA 2001).

Other criteria used by countries to guide them in their selection process include the need of a close connection between indicators, on one side, and quantitative targets, stated objectives, policy intentions or public expectations, on the other. In addition, indicators should distinguish human interference from natural variability, and should give societies sufficient time to act before crossing a critical threshold. While several countries recognise the importance of including information on critical thresholds for each indicator, they also recognise that this is very difficult in most cases.

2.3. Types of indicators

There are different types of indicators, often corresponding to the level of a management system to which the indicator refers, or just due to the fact that different groups working on indicators have approached the subject in slightly different ways (Table 3). For instance, indicators can be based on either processes or outputs. Process-based indicators aim to assess the organisational efficiency of processes that achieve results, whereas outcome-based indicators measure results or the degree to which an (environmental) goal has been met.

Table 3: Some examples of different types of indicators (Grieve et al, 2003)

Type of indicator	Definition
Process-based indicator	Aim to assess the organisational efficiency of processes that achieve results.
Outcome-based indicator	Measure results or the degree to which an environment goal has been met.
Headline indicator	Strategic; providing feedback on progress against overarching policy objectives, e.g. a measure of stock health or ecosystem diversity.
Operational indicators	Measure the more detailed components of headline indicators, e.g. stock mortality or recruitment, or number of species within a particular ecosystem.
Driving force indicator*	Measure human activities and natural processes and patterns that have an impact on sustainable development of a sector or issue.
Pressure indicator*	Represents the pressure on the environment exerted by different driving forces.
State indicator*	Refer to the 'state' of a particular environmental or socio-economic resource or feature, e.g. water quality, stock numbers.
Impact indicator*	Describe the immediate impact on the environment
Response-type indicator*	Measure policy response to achieve objectives, e.g. number of boats decommissioned if capacity reduction is an objective supported by aid for decommissioning.
*One of the DPSIR indicator categories	

OECD work on environmental indicators (OECD, 2003), initiated in 1989, includes several categories of indicators, each corresponding to a specific purpose and framework (Figure 2).

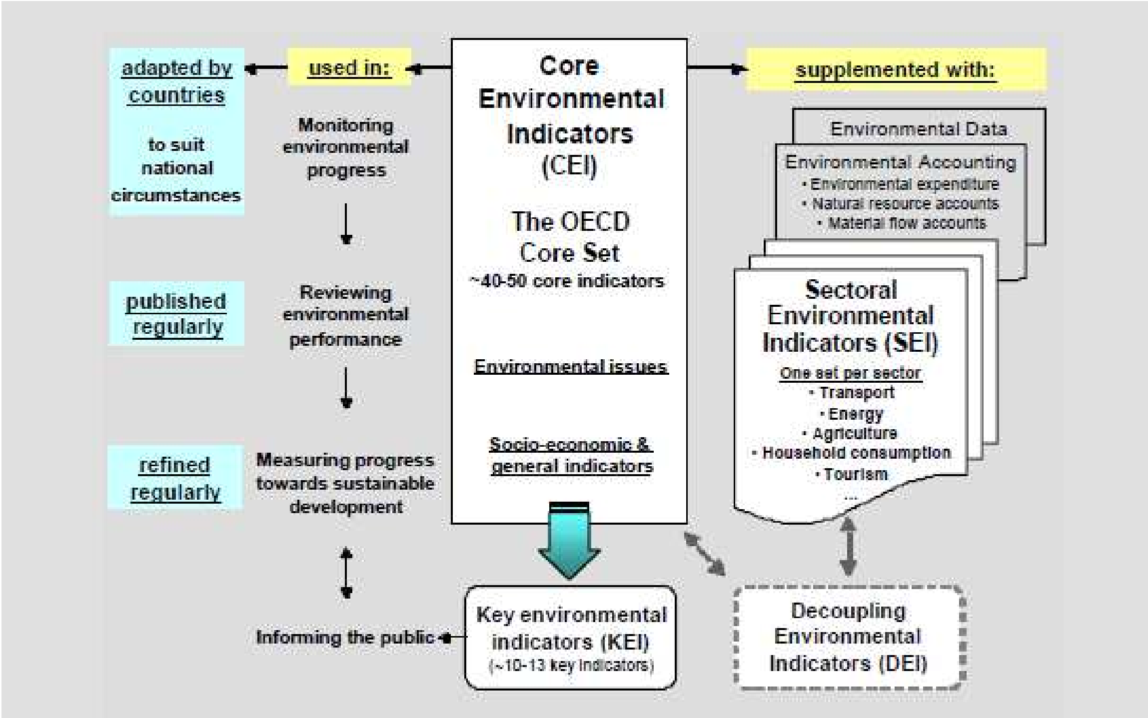

Figure 2: OECD sets of environmental indicators

CORE ENVIRONMENTAL INDICATORS (CEI) are designed to help track environmental progress and the factors involved in it, and analyse environmental policies. The OECD Core Set is a set commonly agreed upon by OECD countries for OECD use. It is published regularly. The Core Set, of about 50 indicators, covers issues that reflect the main environmental concerns in OECD countries. It incorporates core indicators derived from sectoral sets and from environmental accounting. Indicators are classified following the PSR model: indicators of environmental pressures, both direct and indirect; indicators of environmental conditions; indicators of society's responses.

KEY ENVIRONMENTAL INDICATORS (KEI), endorsed by OECD Environment Ministers, are a reduced set of core indicators, selected from the OECD Core Set, that serve wider communication purposes. they inform the general public and provide key signals to policy-makers.

SECTORAL ENVIRONMENTAL INDICATORS (SEI) are designed to help integrate environmental concerns into sectoral policies. Each set focuses on a specific sector (transport, energy, household consumption, tourism, agriculture). Indicators are classified following an adjusted PSR model reflecting: sectoral trends of environmental significance; their interactions with the environment (including positive and negative effects); and related economic and policy considerations.

INDICATORS DERIVED FROM ENVIRONMENTAL ACCOUNTING are designed to help integrate environmental concerns into economic and resource management policies. Focus is on: environmental expenditure accounts; physical natural resource accounts, related to sustainable management of natural resources; and physical material flow accounts, related to the efficiency and productivity of material resource use.

DECOUPLING ENVIRONMENTAL INDICATORS (DEI) measure the decoupling of environmental pressure from economic growth. In conjunction with other indicators used in OECD country reviews, they are valuable tools for determining whether countries are on track towards sustainable development. Most DEIs are derived from other indicator sets and further broken down to reflect underlying drivers and structural changes.

A simple set of questions: what is happening (A); is this relevant (B); can we make progress in improving the way we do things (C); and does this contribute to our overall welfare (D)?; led to a first **typology of indicators from EEA.** The typology was used to demonstrate that (in 1997) the majority of indicators used in state of the environment reports and indicator sets were descriptive, answering only the question "what is happening?". The list of indicators developed consequently for the Transport and Environment Reporting Mechanism showed for the first time that moving from descriptive indicators (A-type) to performance and ecoefficiency indicators (B- and C-type) delivered more policy relevant information (Gabrielsen and Bosch, 2003).

During the discussions on the EEA core set of indicators around 2000-2002, the typology of questions with the loosely connected indicator types given above, developed into the more formal typology of indicator designs and assessments presented below (Gabrielsen and Bosch, 2003). At the same time an extra category of policy effectiveness indicators has been inserted.

DESCRIPTIVE INDICATORS (TYPE A) are usually presented as a line diagram showing the development of a variable over time, for example "number of indigenous species in "biogeographical regions", or "share of organic farming in total agricultural area". They are most commonly used as state, pressure or impact indicators. If descriptive indicators are presented using an absolute scale, such as in "mg/kg dry matter", the relevance of the numbers given is often difficult to assess for a layman. Presentation in comparison with another relevant variable (or as a performance indicator) often improves their communicative value.

PERFORMANCE INDICATORS (TYPE B) may use the same variables as descriptive indicators but are connected with target values. They measure the 'distance(s)' between the current environmental situation and the desired situation (target): "distance to target" assessment. Performance indicators are relevant if specific groups or institutions may be held accountable for changes in environmental pressures or states. They are typically state, pressure or impact indicators that clearly link to policy responses.

EFFICIENCY INDICATORS (TYPE C) relate drivers to pressures. They provide insight into the efficiency of products and processes in terms of resources, emissions and waste per unit output. The environmental efficiency of a nation may be described in terms of the level of emissions and waste generated per unit of GDP. The energy efficiency of cars may be described as the volume of fuel used per person per kilometer travelled. It should be noted that most relevant for policy-making are indicators that show the most direct relation between environmental pressures and human activities. Sometimes an output measure in monetary terms, such as value added, can be a good representation of the development of human activities, but in many cases a physical output measure is more appropriate. For clarity reasons, these indicators are best presented with separate lines rather than as a ratio. This is because eco-efficiency is a relative concept. If the growth of an activity outweighs the eco-efficiency gains, then the burden on the environment still increases. Therefore and absolute decoupling of environmental pressure from economic development is often necessary. Presented in this way, eco-efficiency indicators combine pressure and driving force indicators.

POLICY-EFFECTIVENESS INDICATORS (TYPE D) relate the actual change of environmental variables to policy efforts. As such they are a link between response indicators on one hand and state, driving force, pressure or impact indicators on the other. They are crucial in understanding the reasons for observed developments. Whereas for the previously mentioned indicators an assessment text is necessary to communicate the background information on the reasons behind the development of an indicator, for policy-effectiveness indicators much of this information is included in a graph. The production of this type of indicator requires a considerable amount of quantitative data and expert knowledge.

TOTAL WELFARE INDICATORS (TYPE E). In any discussion on sustainability and human welfare, the balance between economic, social and environmental development will ultimately be crucial. Efforts are underway to design balanced sets of individual indicators to support decision-making. However for an integral assessment, some measure of total sustainability would be desirable to answer the question: "are we on the whole better off?". A variant of 'Green GDP', such as the Index of Sustainable Economic Welfare (ISEW) or "genuine savings", may be used for this purpose.

Different classifications have also been made within Sustainable Indicators according to the following aspects (Zabaleta, 2008):

- Spatial scale: Global Scale, Local Scale
- Temporal scale: Short term indicator, Long term indicator
- Aggregation level (Bockstaller and Girardin (2003): Simple Indicators (resulting from the estimation or measurement of an indicative variable), Composite Indicators (obtained by aggregation of several variables or simple indicators)

3. Conceptual frameworks

The need to develop and use indicators of sustainable development is based on the approach that "you can only manage what you can measure". Developing indicators, however, requires a clear "vision" of sustainable development, and the definition of a framework for structuring these indicators. Once this framework is in place, data from existing monitoring programs, accounting systems and statistical surveys can be used to quantify the indicators. Where the data basis is missing or insufficient, new routines can be established. Through this iterative process, the conceptual work on indicators helps to focus on data collection needs.

3.1. Conceptual models in general

A conceptual model is a verbal, or visual, abstract description of a part of the world from a certain point of view. It is important that the model is described in words or pictures. Such a model facilitates communication within a group by providing a conceptual structure, by indicating boundaries and by providing a framework for further expansion. Consensus building is an important aspect. The building blocks of a conceptual model are: objects (the rectangles) and relationships (the links between them). Objects are in fact classes of objects possessing the same functional properties. An object is any real or abstract entity that is considered to be important. Objects can interact with each other and may have structural relations (for instance an object can be part of another). Relationships are not restricted to causal relationships (Bakkes et al., 1994).

This approach to conceptual modelling is useful since it closely follows the way in which experts think. It prescribes a structure that is flexible enough to express many possibilities. The diagrams explaining conceptual models are kept simple by using only two types of conceptual blocks.

3.2. A simple conceptual model for the environment

As a tool for discussing indicators, a simple conceptual model for the environment is outlined in Figure 3 (UNEP/RIVM, 1994). It consists of: objects, such as the socio-economic system and the environment; two-way interactions between the objects; and processes that relate to one object only.

As shown in Figure 3 the world is represented by two objects: the socio-economic system and the environment, indicated by two rectangles. Their interactions are indicated by the arrows. The main concept in the interaction between the environment and the socio-economic system is that the socio-economic system changes the environment:

- through use and management of resources (right-to-left arrow); and
- by restructuring the environment (left-to-right arrow) through: physical, biological and chemical changes; depositing waste; and counter-measures against earlier disturbances (the social response).

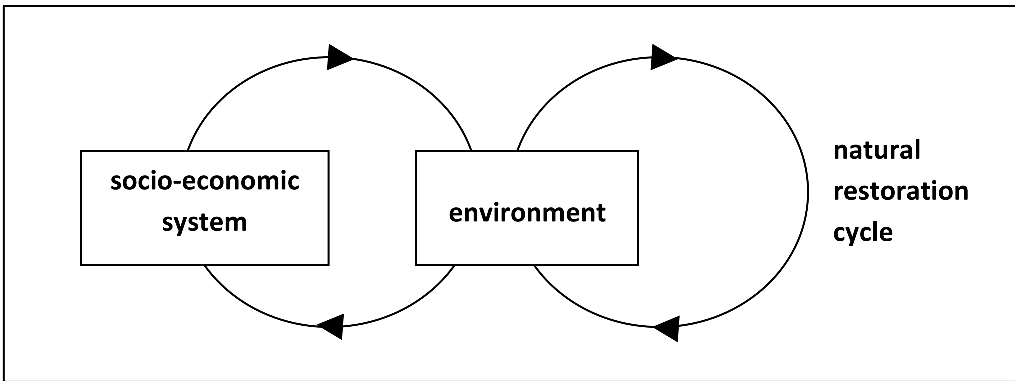

Figure 3: The environmental cycle

If the natural restoration processes of the environment and the carrying capacity of the supporting ecosystem are not able to outweigh the human disturbances, "sustainable development" cannot be attained (WCED, 1987).

The human presence is the centre of important and specific relationships with the environment and with other socio-economic factors. Therefore, in Figure 4, Bakkes et al. (in UNEP/RIVM, 1994) distinguish population from other socio-economic factors. A similar model has been published by Hamilton (1991).

The three resulting sub-systems (objects) each have a two way relationship with one another. The environment is the physical living space for the population, in which space, people are exposed to physical, chemical and biological factors. Population causes disturbances to the environment directly and via the socio-economic system. The environment provides space, raw materials and energy to the socio-economic system and receives physical changes and pollution in return. Societal response leads to recycling and repair (arrows between socio-economic system and environment). The population receives goods and services from the socio-economic system, in exchange for human resources and organization.

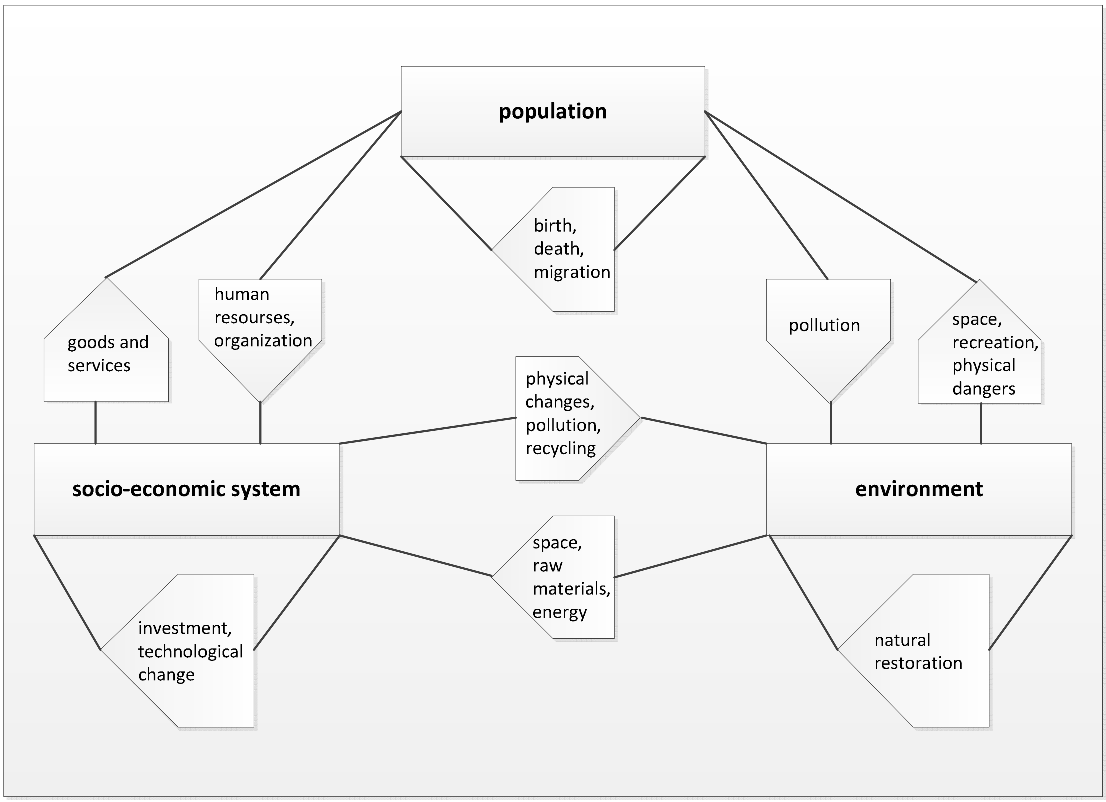

Figure 4: Environmental, socio-economic and population sub-systems

The diagram also shows processes relating to just one subsystem, such as the natural restoration cycle for the environment presented in Figure 3, demographic processes (birth, death and migration) for population, and investments and technological changes for the socio-economic system.

The state of a sub-system is changed by processes belonging to the sub-system itself, of which the most important are indicated, as well as by driving forces from the other sub-systems. This implies that a systematic description of environmental change has to consider not only the state of the environment but also the driving forces in the other sub-systems, and the societal response to the changed environment.

This model can be expanded again. For example, Figure 5 (UNEP/RIVM, 1994) shows the main conceptual parts of the environment: environmental compartments, ecosystems and natural resources. The flow of waste is also shown. This simple model has been used on a national scale to organize environmental data (Hamilton, 1991).

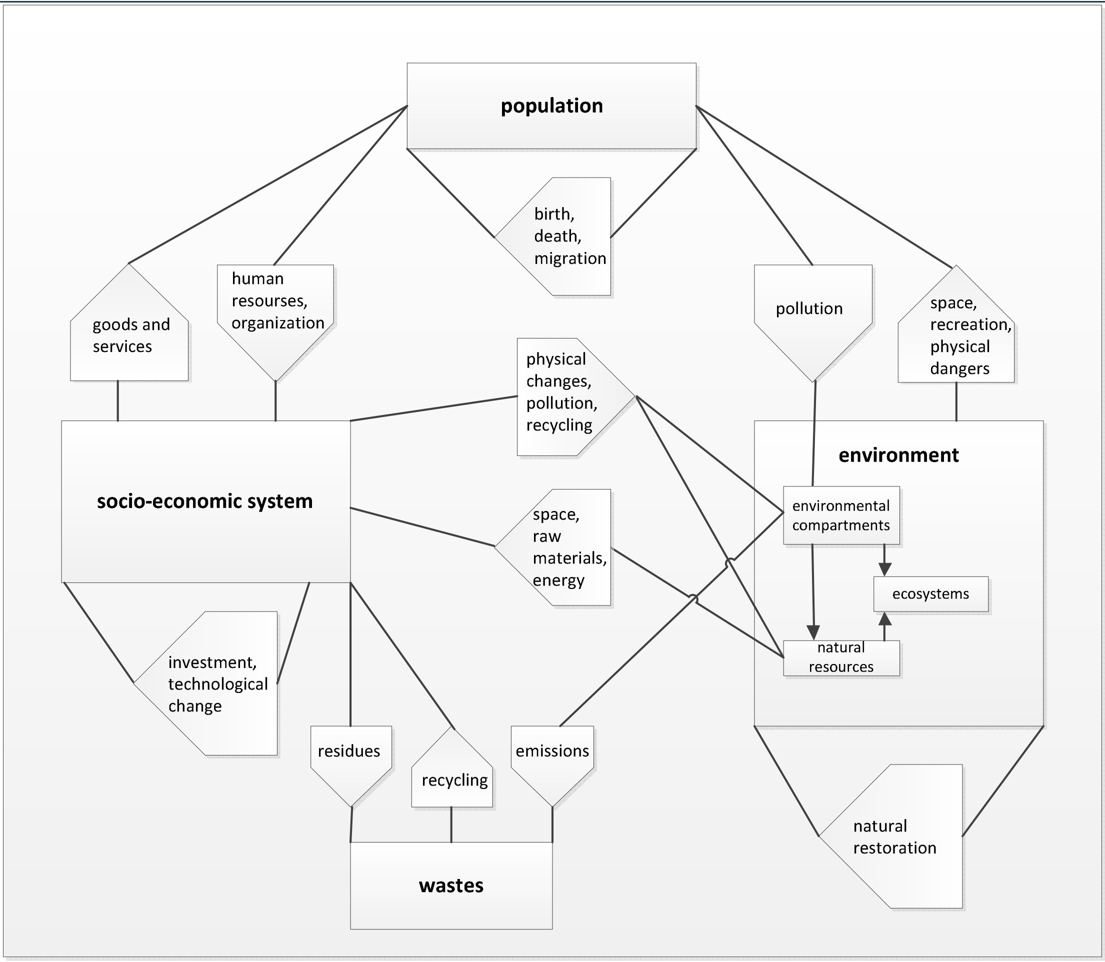

Figure 5: Environmental compartments, ecosystems and natural resources

3.3. The most common causal chain frameworks

In order to clarify the inter-relationships between human beings and the environment, the OECD, the EEA, Eurostat and many other institutions have adopted conceptual frameworks for the derivation of indicators. While a number of conceptual frameworks are used within the context of environmental assessments (for example EPA (1998) ecological risk assessment framework), the most common frameworks used in indicator based studies are the pressure–state–response (PSR), the driving force–state– response (DSR) or the driving force–pressure–state–impact–response (DPSIR), conceptual frameworks, which organize and structure indicators in the context of a so-called causal chain (e.g., Hammond et al., 1995; OECD, 1998, 1999; Smeets and Weterings, 1999; EEA, 2000; Wascher, 2000; Bridges et al., 2001; OECD, 2001). In the causal chain, social and economic developments are considered driving forces that exert pressure on the environment, leading to changes in the state of the environment. In turn, these changes lead to impacts on human health, ecological systems and materials that may elicit a societal response that feeds back on the driving forces, pressures, or on the state or impacts directly (Smeets and Weterings, 1999). Where the frameworks mainly differ is in the degree in which they subdivide the steps in the causal chain. EEA, Eurostat and European institutions tend to use the DPSIR framework, while OECD uses PSR and the UN Commission on Sustainable Development favours DSR.

3.3.1. The PSR and DSR frameworks

The pressure–state–response (PSR) framework (Fig. 6a) divides indicators in pressure, state and response indicators through the following logic: ‘‘pressure on the environment from human and economic activities, lead to changes in the state or environmental conditions that prevail as a result of that pressure, and may provoke responses by society to change the pressures and state of the environment’’(OECD, 1999).

The driving force–state–response (DSR) framework is illustrated in Fig. 6b. In this framework the ‘‘pressure’’ component is replaced with the concept of ‘‘driving forces’’. This concept, in the words of OECD (1999), ‘‘recognises that agricultural activities can both produce beneficial impacts to enhance environmental quality [. . .] and also have harmful impacts on the environment.’’ The concept of driving forces also accommodates ‘‘a broader coverage of the influences affecting the environment in agriculture and sustainable agriculture, including farmer behaviour, government policies, economic, social, and cultural factors’’ (OECD, 1999).

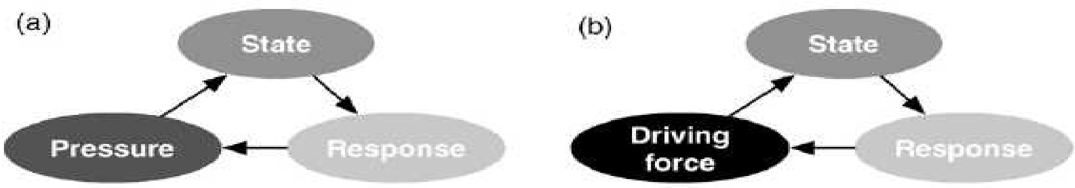

Figure 6: The PSR (a) and DSR (b) frameworks

3.3.2. The DPSIR framework

The driving force–pressure–state– impact–response (DPSIR) framework follows essentially the same general pattern as the other two frameworks but distinguishes more steps along the way. It distinguishes between indirect driving forces such as social and economic developments and pressures such as emissions that directly influence the environment. It further distinguishes between the state of the environment (for example concentrations of pollutants) and the impacts of (changes in) the environmental state on human health, ecological systems and materials (Smeets and Weterings, 1999).

According to this systems analysis view (Fig. 7), social and economic developments exert Pressure on the environment and, as a consequence, the State of the environment changes, such as the provision of adequate conditions for health, resources availability and biodiversity. Finally, this leads to Impacts on human health, ecosystems and materials that may elicit a societal Response that feeds back on the Driving forces, or on the state or impacts directly, through adaptation or curative action.

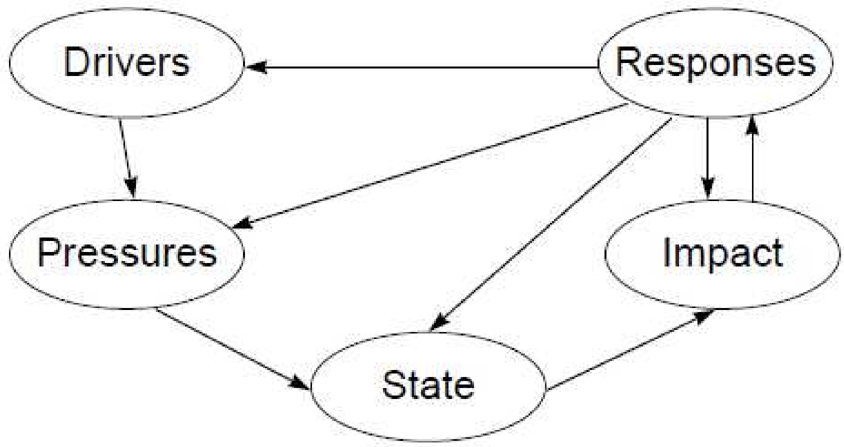

Figure 7: The DPSIR framework

The DPSIR framework is useful in describing the relationships between the origins and consequences of environmental problems, but in order to understand their dynamics it is also useful to focus on the links between DPSIR elements. For instance, the relationship between the 'D' and the 'P' by economic activities is a function of the eco-efficiency of the technology and related systems in use, with less 'P' coming from more 'D' if eco-efficiency is improving. Similarly, the relationship between the Impacts on humans or eco-systems and the 'S' depends on the carrying capacities and thresholds for these systems. Whether society 'Responds' to impacts depends on how these impacts are perceived and evaluated; and the results of 'R' on the 'D' depends on the effectiveness of the Response (Figure 8).

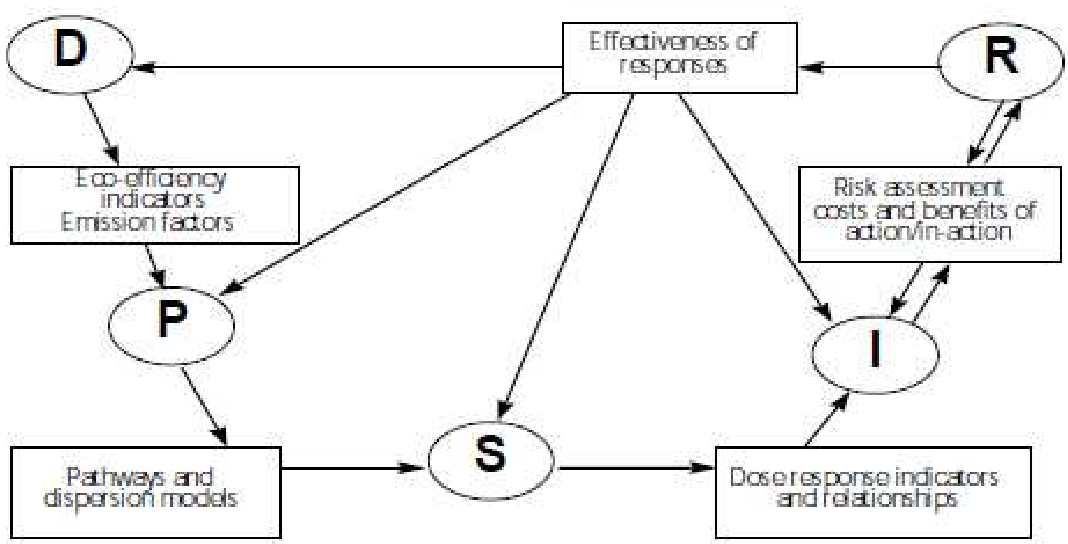

Figure 8: Indicators and information linking between DPSIR elements

4. Indicators used across various countries

Hass et al. (2002) in an overview prepared for OECD, concerning Sustainable Development Indicators, compared different sets of indicators used across various countries. Although this overview does not provide any evaluation of the indicator sets used by different countries, cross-country comparisons highlight both similarities and differences. All of the national sets of sustainable development indicators that were accessible to the authors were examined. Tables 1 and 2 highlight the major similarities and differences.

The categories (or themes) shown in the rows of Table 1 are those identified in the United Nations Commission for Sustainable Development (UNCSD) core set of indicators (UN, 2001). The comparison is made by theme rather than at the indicator level. A "✔" indicates that the indicator set of a given country contains at least one indicator that is relevant to each specific theme. Assessing whether a country has an indicator pertaining to a certain theme is not always easy because of the diversity of indicators, their different definitions and the different descriptions of the national indicators. There are also classification problems, for example when a country (e.g. the Netherlands) has a multi-dimensional index that is relevant to several themes.

The revised UNCSD themes were used as a starting point since many countries have used it as the starting point of their national effort to develop sustainable development indicators. When countries have grounded their work in the UNCSD framework, there is often a close correspondence between the UN and national sets, and many check marks will appear for that country.

Table 4 highlights specific country features with regard to sustainable development indicators. All countries include indicators for climate change, agriculture, forests, ecosystems and economic performance. Several include indicators for poverty, gender equity, education, crime, water quality and quantity, species, financial status and material consumption. Only one country has a proposal to have an indicator relevant to desertification.

However, beyond themes included in the UNCSD's core set of sustainable development indicators, several other themes were identified by this review. Table 5 lists some among the most common of these (non-UNCSD) themes, and the countries where they occur. Acidification and toxic contamination are two of the themes most often covered in national sets. Other countries include indicators relating to ethnic minorities, either with a focus on indigenous peoples or on integration of immigrants. Several countries also used indicators for illness due to pollution and life style factors. Coverage of such health issues seem to have increased alongside higher awareness of these health risks among the general public.

Table 4: Comparison of different SD indicator sets

UNCSD Categories and themes	**Australia**	**Denmark**	**Finland**	**Korea**	**Netherlands**	**Portugal**	**Sweden**	**Switzerland**	**UK**	**US**	**EU struct. indic.**
SOCIAL											
Equity											
Poverty		✔	✔	✔	✔	✔		✔	✔	✔	✔
Gender Equality	✔		✔	✔	✔		✔	✔	✔		✔
Health											

Nutritional Status				✔							
Mortality	✔	✔	✔	✔	✔	✔			✔	✔	
Sanitation				✔		✔		✔			
Drinking Water		✔	✔	✔		✔			✔		
Healthcare Delivery				✔		✔			✔		
Education											
Education level	✔		✔	✔	✔	✔		✔	✔	✔	✔
Literacy						✔		✔	✔		
Housing											
Living Conditions		✔		✔	✔			✔	✔	✔	
Security											
Crime			✔	✔	✔	✔	✔	✔	✔	✔	
Population											
Population Change	✔		✔	✔			✔		✔	✔	
ENVIRONMENTAL											
Atmosphere											
Climate Change	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Ozone Layer Depletion		✔	✔	✔		✔			✔	✔	
Air Quality	✔		✔	✔		✔		✔	✔	✔	✔
Land											
Agriculture	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	
Forests	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	
Desertification						✔					
Urbanization	✔	✔	✔	✔				✔	✔		
Oceans, Seas, and Coasts											
Coastal Zone	✔		✔	✔	✔	✔			✔		
Fisheries	✔	✔	✔	✔		✔	✔		✔	✔	
Fresh-Water											
Water Quality	✔	✔	✔	✔	✔	✔		✔	✔	✔	
Water Quantity	✔	✔	✔	✔	✔	✔		✔	✔	✔	
Biodiversity											
Ecosystems	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	
Species	✔	✔	✔	✔	✔	✔	✔	✔	✔		
ECONOMIC											
Economic Structure											
Economic Performance	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Trade		✔		✔	✔	✔		✔	✔		
Financial Status	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Consumption & Production Patterns											
Material		✔	✔	✔	✔		✔		✔	✔	

Consumption											
Energy Use	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔
Waste Generation and Management		✔	✔	✔		✔	✔	✔	✔		✔
Transportation		✔	✔	✔		✔	✔	✔	✔		✔
INSTITUTIONAL											
Institutional Framework											
Strategic Implementation of SD		✔		✔					✔		
International Cooperation		✔				✔		✔	✔		
Institutional Capacity											
Information Access			✔	✔		✔		✔			✔
Communication and Infrastructure			✔	✔							
Science and Technology			✔	✔	✔	✔	✔	✔			✔
Disaster Preparedness and Response				✔				✔			

Table 5: Other common themes and indicators identified from country-level sustainable development indicators

Categories and themes	Denmark	Finland	Netherlands	Portugal	Sweden	Switzerland	United Kingdom	United States
SOCIAL								
Life styles and Illnesses		✔				✔	✔	
Health (pollution related illnesses)	✔				✔		✔	
Ethnic Minorities		✔	✔			✔	✔	
Cultural Heritage		✔					✔	
Participation in arts and recreation			✔					✔
ENVIRONMENTAL								
Acidification	✔	✔	✔				✔	
Toxic contamination	✔	✔		✔	✔	✔	✔	✔
Alien species								✔
ECONOMIC								
Tourism	✔			✔			✔	

5. Environmental indicators for the RECLAIM project

5.1. Methodological approach

Taking into consideration the analysis presented in previous sections, the conceptual model of the LFM process presented in Figure 9 (Claydon, 2012), as well as the particular needs and concerns of the RECLAIM project, a set of suitable environmental indicators is established. The proposed indicators are related to the following environmental sustainability issues:

- Recovery of recyclable Materials
- Recovery of energy materials
- Land reclamation and rehabilitation
- Life-time extension for landfills
- Water use
- Air emissions

In addition, the indicators monitor a number of impacts, i.e.:

- Waste minimization
- Material resources
- Soil degradation
- Climate change
- Energy resources
- Water resources
- Human health/Environmental quality/Quality of life
- Land use

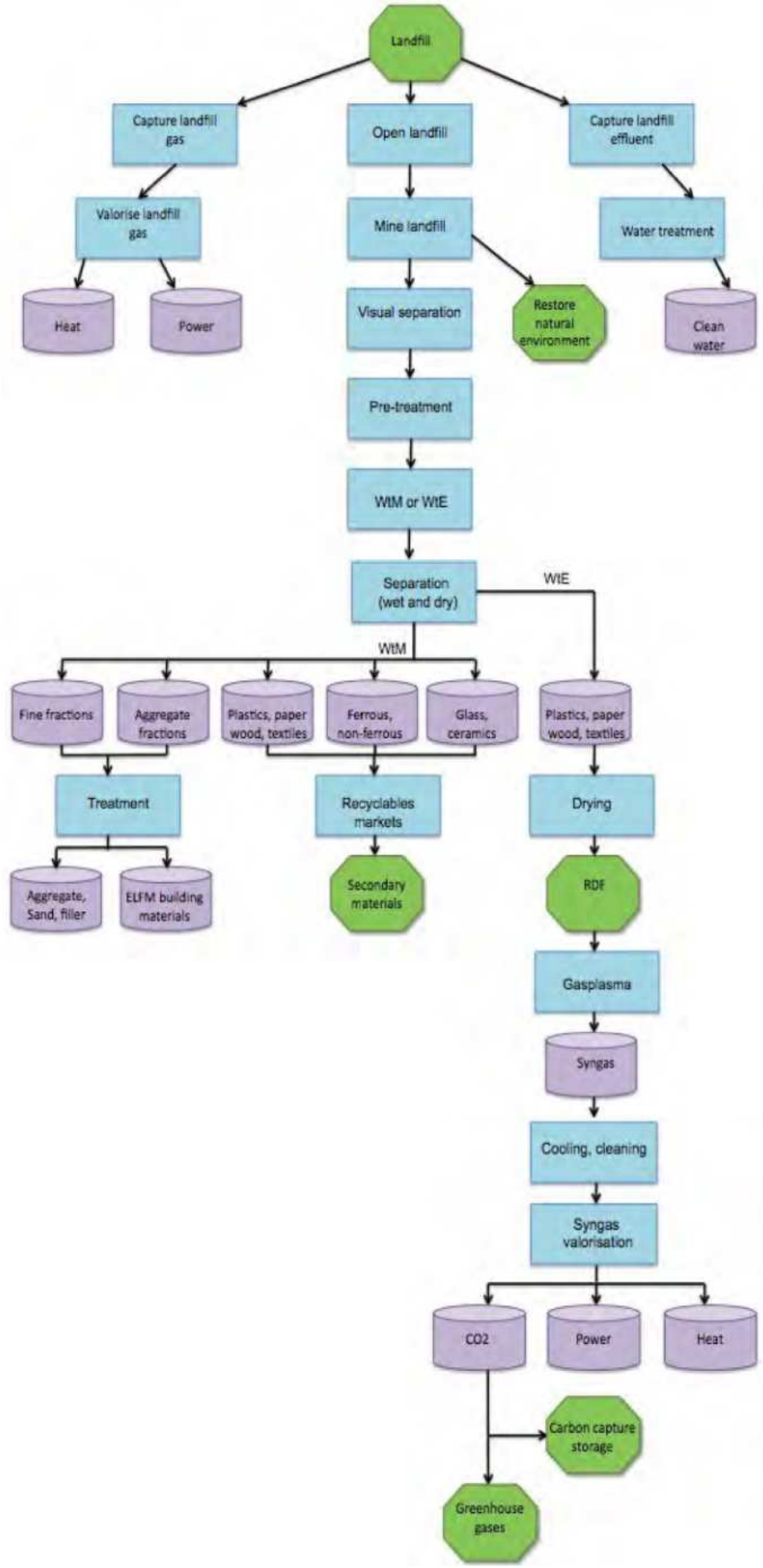

Figure 9: The conceptual model for the LFM process (source: Claydon, 2012)

Finally, it is noted that the establishment of indicators fulfills four criteria, as follows (Jackson et al., 2000):

- Conceptual relevance, i.e. the indicator must provide information that is relevant to concerns about environmental condition. The selection of an indicator is obvious from the assessment question and from professional judgment. However, a conceptual model is helpful to demonstrate and ensure the indicator's relevance.

- Feasibility of implementation, i.e. adapting an indicator for use in a large or long-term monitoring program must be feasible and practical. Methods, logistics, cost, and other issues of implementation should be evaluated.

- Response variability, i.e. it is essential to understand the components of variability in indicator results to distinguish extraneous factors from a true environmental signal. Total variability includes both measurement error introduced during field and laboratory activities and natural variation, which includes influences of stressors.

- Interpretation and utility, i.e. a useful indicator must produce results that are clearly understood and accepted by scientists, policy makers, and the public. The presentation of indicator results should highlight their relevance for specific management decisions and public acceptability.

5.2. Proposed environmental indicators

The environmental indicators selected are summarized in the following Table 6. Furthermore, each indicator is discussed in more detail below.

Table 6: Environmental indicators used in RECLAIM project

Impact category	Environmental Indicator	Unit
Waste minimization	Quantity of waste excavated	kg and/or m^3
Waste minimization	Waste residues	kg and/or m^3
Material resources	Recovery of paper	kg and/or % of waste
Material resources	Recovery of glass	kg and/or % of waste
Material resources	Recovery of aluminum	kg and/or % of waste
Material resources	Recovery of ferrous materials	kg and/or % of waste
Material resources	Recovery of other metals in metal concentrate	kg and/or % of waste
Soil degradation	Recovery of soil	kg and/or % of waste
Climate change	Reduction in greenhouse gas of recycled materials compared to use of new materials	kg CO_2 eq.
Energy resources	Reduction in energy consumption of recycled materials compared to use of new materials	% reduction in energy
Water resources	Reduction in water consumption of recycled materials compared to use of new materials	lt of water saved or % reduction in quantity and/or water pollution
Material resources	Reduction in raw materials consumption of recycled materials compared to use of new materials	kg of raw materials saved
Human health/Environmental quality/Quality of life	Reduction in air emissions of recycled materials compared to use of new materials	% reduction in quantity and/or air pollution
Human health/Environmental quality/Quality of life	Air emissions associated with the proposed activities in Polygyros Landfill	kg of pollutants emitted
Human health/Environmental quality/Quality of life	Noise emissions associated with the proposed activities in Polygyros Landfill	Number of people annoyed
Human health/Environmental quality/Quality of life	Wastewater emissions associated with the proposed activities in Polygyros Landfill	lt of wastewater produced
Land use	Potential land reclamation and rehabilitation	ha of land
Land use/Green space	Available landfill lifespan	years

- E.I.1. Quantity of waste excavated: This indicator refers to "Waste minimization" and its aim is to monitor and assess the waste that will be excavated during the RECLAIM project and it will be measured in kg and/or m^3.

- E.I.2. Waste residues: This indicator is related to "Waste minimization" and its aim is to monitor and assess the waste residues that will be re-disposed to Polygyros Landfill during the RECLAIM project. It will be measured in kg and/or m^3.

- E.I.3. Recovery of paper: This aim of this indicator is to monitor and assess the impacts on "Material resources" throughout the duration of RECLAIM project. More specifically, it will measure the quantity of paper recovered by the waste treatment process and It will be measured in kg and/or % of waste processed.

- E.I.4. Recovery of glass: This aim of this indicator is to monitor and assess the impacts on "Material resources" throughout the duration of RECLAIM project. In particular, it will measure the quantity of glass recovered by the waste treatment process and It will be measured in kg and/or % of waste processed.

- E.I.5. Recovery of aluminum: This aim of this indicator is to monitor and assess the impacts on "Material resources" through the duration of RECLAIM project. More specifically, it will measure the quantity of aluminum recovered by the waste treatment process and It will be measured in kg and/or % of waste processed.

- E.I.6. Recovery of ferrous metals: This aim of this indicator is to monitor and assess the impacts on "Material resources" throughout the duration of RECLAIM project. More specifically, it will measure the quantity of paper recovered by the waste treatment process and It will be measured in kg and/or % of waste processed.

- E.I.7. Recovery of other metals in metal concentrate: This aim of this indicator is to monitor and assess the impacts on "Material resources" throughout the duration of RECLAIM project. More explicitly, it will measure the quantity of other metals recovered by the waste treatment process in metal concentrate and It will be measured in kg and/or % of waste processed.

- E.I.8. Recovery of soil: This aim of this indicator is to monitor and assess the impacts on "Material resources" throughout the duration of RECLAIM project. More specifically, it will measure the quantity of soil recovered by the waste treatment process and It will be measured in kg and/or % of waste processed.

- E.I.9. Reduction in greenhouse gas of recycled materials compared to use of new materials: This indicator is related to "Climate change" impact and its aim is to monitor and assess the reduction in greenhouse gas of recycled materials compared to use of new materials that will be achieved during the RECLAIM project. It will be measured in kg of CO_2 eq. and will be estimated through existing information and data gathered by the project as regards the environmental benefits of recycling compared to use of new materials.

- E.I.10. Reduction in energy consumption of recycled materials compared to use of new materials: This indicator refers to "Energy resources" issue and its aim is to monitor and assess the energy savings during the RECLAIM project owing to the recovery of recycled materials. It will be measured in % reduction in energy consumption of recycled materials compared to use of new materials, based on existing information and data gathered by the project.

- E.I.11. Reduction in water consumption of recycled materials compared to use of new materials: This indicator refers to "Water resources" impact and its aim is to monitor and assess the water savings during the RECLAIM project owing to the recovery of recycled materials compared to use of new materials. It will be measured in lt of water saved or % reduction in quantity and/or water pollution, based on existing information and data gathered by the project.

- E.I.12. Reduction in raw materials consumption of recycled materials compared to use of new materials: This indicator refers to "Material resources" impact and its aim is to monitor and assess the reduction in raw materials consumption during the RECLAIM project owing to the recovery of recycled materials compared to use of new materials. It will be measured in kg of raw materials saved, based on existing information and data gathered by the project.

- E.I.13. Reduction in air emissions of recycled materials compared to use of new materials: This indicator refers to "Human health/Environmental quality/Quality of life" issue and its aim is to monitor and assess the reduction in air emissions of recycled materials compared to use of new materials throughout the duration of RECLAIM project. It will be measured in % reduction in quantity of pollutants and/or air pollution, based on existing information and data gathered by the project.

- E.I.14. Air emissions associated with the proposed activities in Polygyros Landfill: This indicator refers to "Human health/Environmental quality/Quality of life" issue and its aim is to monitor and assess the impacts of air emissions associated with the proposed activities in Polygyros Landfill throughout the duration of RECLAIM project. It will be measured in kg of pollutants emitted, based on existing emission factors and data gathered by the project.

- E.I.15. Noise emissions associated with the proposed activities in Polygyros Landfill: This indicator refers to "Human health/Environmental quality/Quality of life" issue and its aim is to monitor and assess the impacts of noise emissions associated with the proposed activities in Polygyros Landfill throughout the duration of RECLAIM project. It will be measured in number of people annoyed, based on data gathered by the project and suitable models.

- E.I.16. Wastewater emissions associated with the proposed activities in Polygyros Landfill: This indicator refers to "Human health/Environmental quality/Quality of life" issue and its aim is to monitor and assess the impacts of wastewater emissions associated with the proposed activities in Polygyros Landfill throughout the duration of RECLAIM project. It will be measured in lt of wastewater produced, based on data gathered by the project.

- E.I.17. Potential land reclamation and rehabilitation: This indicator refers to "Land use" impacts and its aim is to monitor and assess the area of land potentially reclaimed and rehabilitated in Polygyros Landfill throughout the duration of RECLAIM project due to landfill mining process. It will be measured in ha of land potentially saved.

- E.I.18. Available landfill lifespan: This indicator refers to "Land use/Green space" issue and its aim is to monitor and assess the Polygyros landfill lifespan due to landfill mining process during the of RECLAIM project. It will be reported as landfill lifespan in years, calculated as available airspace/incoming volume per annum (m^3/m^3 per annum).

The above-mentioned indicators will be also expressed per m^3 of waste excavated and treated during the RECLAIM project. The aim is to provide indicators for the assessment of landfill mining process, which will be coherent and compatible with waste management indicators in general and will be transferable to other landfill mining projects.

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