POSITIVE EXTERNALITIES IN DESIGN FOR SUSTAINABILITY

Bengt Steen

Environmental System Analysis, Dept. of Energy and Environment, Chalmers University of Technology, Göteborg, Sweden

bengt.steen@chalmers.se

Human concern for environment began as a reaction to single episodes of damage to environment and human health. As a consequence, today, the assessment of environmental impacts consists mostly of negative externalities. When social and economic aspects were considered together with environmental aspects to assess sustainability, the tradition of looking for negative externalities has continued. However, when considering satisfaction of human needs, which is the ultimate goals for sustainable development, it becomes obvious that there are many positive externalities that are not taken into account. Capacity and efficiency to satisfy basic human needs characterize such externalities.

Keywords: Externalities, sustainable development, indicator, design for sustainability

1. INTRODUCTION

Human concern for environment began as a reaction to single episodes of damage to environment and human health. Excess mortality in London from smog, infertile birds, acid lakes, muddy waters and dead fish on the shores were visible examples of environmental impacts. As a consequence, the public and expert interest was focused on who and which emissions that were responsible for these impacts. The assessment of environmental impacts consists today mostly of such negative externalities. When social and economic aspects were considered together with environmental aspects to assess sustainability, the tradition of looking for negative externalities has continued. Economic aspects are often considered as life cycle costing (LCC) and social aspects through negative aspects like child labor and accidents at work. However, when considering satisfaction of human needs - the ultimate goals for sustainable development - it becomes obvious that there are many positive externalities that are not taken into account. Capacity and efficiency to satisfy human needs characterize such externalities. For example, in satisfying basic human needs for nourishment via food, fertility of land, transports, food storage and processing are necessary prerequisites. Some of the costs for this are paid for by the customer, but there may be optional values of capability and efficiency for future customers that are not paid for. Other positive externalities have to do with technology for housing, clothes, information transfer, environment and energy. There is, of course, sometimes a trade-off between positive and negative externalities that has to be made, but to do this an identification of them is a necessary first step.

2. METHOD

The method used here is outlined in figure 1. First, the sustainability has to be defined and the needs to be addressed identified. Then, for each need a number of satisfiers are identified, and for each satisfier, a number of safeguards subjects, which are critical for the supply of satisfiers. The state of safeguards subject are described by state indicators. Impacts on these indicators may then be identified, based on historic or projected data. These impacts are then used, or grouped, in impact categories and described by impact category indicators, which in turn can be linked by models to external intervention like emissions, use of resources, other human activities or natural phenomena. These indicators are often called “pressure indicators”, or in LCA contexts “inventory parameters”. The models (characterization factors in LCA) linking inventory parameters to impact indicators and changes in state indicators will be the base for identifying which human intervention that significantly may contribute to changes in the state indicators and which indicators that should be selected in an inventory. The inventory parameters may be used directly in sustainability management or transformed to more practical indicators, like fossil fuel consumption or solvent use. C.f. “significant aspects” as mentioned in ISO 14001. When applying these indicators in real cases, sensitivity analyses will show which ones that are most important for decision making, and which data quality that is needed. This will give new information on which indicators to choose and to which quality that is required. The procedure outlined in figure 1 is simplified. In reality several iterations may occur. This paper will cover the process down to selection of state indicators.

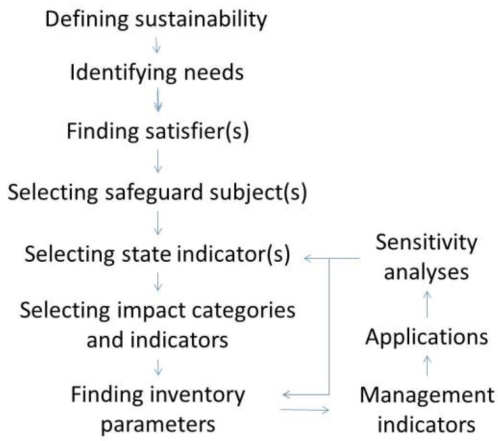

Fig. 1. Method for selecting safeguard subjects, impact categories, category indicators, and indicators for external interventions in life cycle sustainability assessment.

Besides considering relevance in the choice of safeguard subjects, impact categories, category indicators, and indicators for external interventions, operationality is also important. Data has to be available with sufficient accuracy. Sometimes, there is a trade-off between relevance and accuracy, but in order to make that trade-off experience from sensitivity analyses in case studies is needed.
Via its concepts, terminology, models etc., the method proposed here is a simplification of reality. There is a trade-off between simplification and accuracy to be made. A simple method is easy to understand and use. A complex method may give a more precise answer, but only the initiated will know. Hopefully, at least the backbone of this method will be easy to understand.

3. DEFINING SUSTAINABILITY

In the Brundtland report “Our common future” (Brundtland et al 1987), the concern is directed towards human well-being and avoiding poverty. So, in this study, well-being, in the sense of non-poverty will be the goal for sustainability. In case of irreversible changes, sustainability should have the dimension of time, and may be defined as 1/P time units, where P is the probability per time unit of an indicator value being less than the critical value. Such a sustainability concept is illustrated in figure 7 for an irreversible change. In case of reversible changes sustainability becomes dimensionless and may be described as $1-p_{poverty}$ where $p_{poverty}$ is the average probability of being poor in the surveyed time period for a person belonging to any generation on the globe. If the present conditions on earth stay unchanged, and we use the UNDP data on multidimensional poverty, the well-being sustainability today is 0.78 (1.56 billion live in multidimensional poverty of the total population of 7.14 billion).

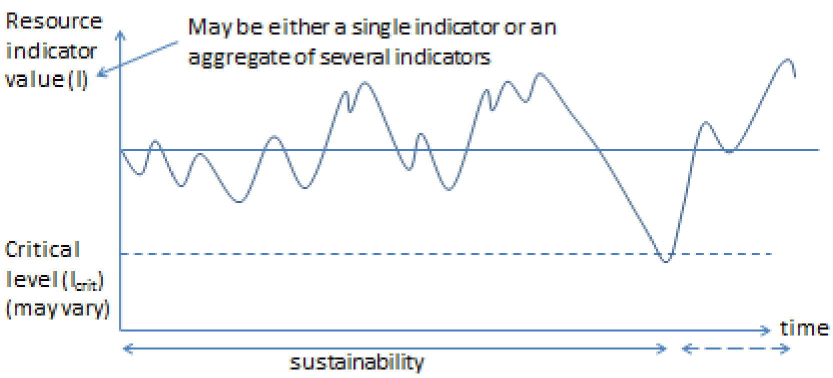

Fig. 2. Sustainability at irreversible change.

4. DEFINING NEEDS

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Having chosen well-being and poverty as sustainability subjects, the needs to focus on would be those called “basic needs”. This concept was originally made public by ILO (Jolly, 1976). Since then several lists of basic needs have been suggested, (Lütkenhorst, 1982), (Galtung, 1996), (UNDP, 2010), (Litwack, 2007). They vary in the names, which are chosen for the needs and in what are seen as needs and satisfiers. In table 1, some of these needs are listed, which are believed to be relevant for product development. There are also a number of psychological needs to be identified that could be of interest, but they are omitted here, as it is not likely to find good models for how they are influenced by product design, or how they influence sustainability. The list is chosen to give as little redundancy as possible and as basic as possible. The exact names of the needs are probably not so decisive in identifying safeguard subjects and indicators, but it is important that no basic need is left out.

Table 1. Basic human needs.

Need	**Function**
Nourishment	Source of energy for life functions and building materials for the body
Water	Solvent, a component in metabolisms, heat control
Oxygen	Used for energy release when combining with food
Excretion	Exhalation, urine, feces, sweat
Proper temperature	Certain temperature range to maintain living processes
Body Integrity	Protection from physical and psychological intrusion and from infections and toxic substances
Reproduction, sex	Enables future generations
Sleep, rest	
Movement	For satisfying other needs
Identity	Ensures social belonging and role
Planning	For the management of future needs satisfaction
Love, attachment	For personal development and cooperation

Besides being in line with the Brundtland commission’s ideas of sustainability, basic needs are easier to describe and manage, than spiritual and instrumental needs.

5. IDENTIFICATION OF SATISFIERS

For nourishment the satisfier is normally food. Although nourishment could be supplied direct into the blood, like in hospitals, food is likely to be the dominant satisfier. Food has to supply energy and building blocks for the human body. Energy may be measured in terms of calories, while building blocks are more diverse, like proteins, vitamins, minerals etc. For water the satisfier is clean water. Drinking water has to have a certain quality. Requirement on water quality is given by WHO. The satisfier for oxygen is clean air. Like for water, WHO issues quality guidelines for air. The satisfier for excretion is primarily available space for it. Hygiene installations like toilets and showers are considered basic in most cultures. Proper temperature may be satisfied through shelter, heating/cooling and through clothing. There are several satisfiers for body integrity: quality requirements on food, water and air, clothing, shelter, hygiene, healthcare and safety from violence. Reproduction is a very basic need for any species. Shelter, safety and quiet environments and relations are some of the satisfiers for reproduction. Shelter, safety and quiet environments are also satisfiers for sleep and rest. Movement requires space. Identity is developed through relations, knowledge and culture. Relations, knowledge and culture are also satisfiers for planning and love.

6. SELECTING SAFEGUARD SUBJECTS FOR THE SATISFIERS IDENTIFIED

6.1. Food

For all types of food fertile land is required to produce the food, i.e. we need to safeguard the fertility of land. So, *ecosystem production capacity* is a logical safeguard subject. In the TEEB project (Kumar, 2012), this is seen as a "provisioning" ecosystem service. But, when addressing sustainability it is the capability of provisioning services that is of primary interest, not the service for the moment. Considering that systems seldom collapse from changes in the normal conditions, but rather from extreme events, the surplus production capacity relative to the service output would be an alternative safeguard subject. However, at present it is not clear, whether this sophistication is worth the extra complication it introduces.

There are several other factors required for making the satisfier *food* available on the table such as agriculture, transports, storing and processing. Again, it is not the actual services performed in agriculture, transports, storing and processing that is of prime interest, it is the capability. For the individual, an income is also necessary to be able to buy food. And, not the least, human health is necessary for transforming food into nourishment. To summarize, there are six safeguard subjects identified for food: ecosystem services, transport technology, food technology, land availability, income and human health.

6.2. Clean water

In order to be able to drink clean water, we need to have access to it. Even if we find water that, smell and taste well, we cannot know that it is suitable for drinking. Many toxic substances and infections may not be detected this way. Chemical and biological methods are also needed. Often, water needs to be purified before drinking. To a large extent this is done through ecosystem services, but may also be made in purification plants using environmental technology and various abiotic resources. The safeguard subject chosen here are thus: access to clean water, ecosystem services, environmental technology and abiotic resources.

6.3. Clean air

The requirements for supply of clean air differ somewhat from those for clean water. Whereas we can avoid drinking low quality water, we can only for a very short time avoid breathing bad air. And whereas we can have problem of finding a supply of water, air is always present. The quality of air depends on natural processes, such as ecosystem services, of air and flue gas control technology and of materials from abiotic resources. The safeguard subjects identified are thus: ecosystem services, environmental technology and abiotic resources.

6.4. Clothes

The supply of clothes relies on fibers, to some extent from ecosystem services, and to some extent from industry. A textile industry, transports, abiotic resources, and income are other resources needed for making clothes available.

6.5. Shelter

Several building materials depend on ecosystem services: wood, grass, leaf, tar, fibers. etc., some depend on abiotic resources, like cement, steel, copper, paint, glass etc. Housing technology is important for the supply of appropriate shelter, like energy technology.

6.6. Heating/cooling

Energy technology and abiotic resources are required for heating/cooling in buildings.

6.7. Hygiene

In order to maintain a good personal hygiene, we need clean food, water and air, cleaning equipment for surfaces and sanitary installations like toilets, showers, washing equipment etc. So technology for food processing, water purification, air cleaning, waste gas cleaning, surface cleaning, washing and sanitation (environmental technology) are safe guard subjects. These technologies require water access and abiotic resources. Besides having a direct value for the user, there is a social value in control of spreading of infections and a cleaner environment.

6.8. Quiet
A quiet environment requires a good sound environment and shelter from outer disturbances, i.e. housing technology. So the main concern is to safeguard sound environment and housing technology.

6.9. Health care
Ecosystem services, water access, abiotic resources, transport technology, environmental technology, housing technology, IT and knowledge are prerequisites for a good health care. IT is meant in a broader sense than just digital communication via PC and internet, even if these are dominant information technology today

6.10. Safety
IT, human health, peace and social security are needed for a person to be and feel safe.

6.11. Space
Space is a satisfier for movement and excretion. There is thus a need to safeguard land availability for everyone and housing technology to be able to supply housing.

6.12. Relations
In order to develop relations, many psychological prerequisites need to be fulfilled. There is a whole branch in psychology dealing with relations. One of these prerequisites is particularly of interest for a simplified method like this, and that is continuity, which in turn is dependent on jobs and knowledge. In particular continuity is important for children attaching to parents and other close persons. Human health is also important in an instrumental way to develop relations.

6.13. Knowledge
Knowledge in itself is a safeguard subject for the satisfier "knowledge", in particular useful knowledge. Human health, in particular mental health, is needed to acquire knowledge. Knowledge is made available through IT. Knowledge is extremely difficult to quantify, but so important for a sustainable development that even a rough method is to prefer compared to omitting it from a sustainability assessment.

6.14. Culture
Culture is a satisfier for planning and identity, for love and attachment. By culture is here understood something that promote widening and deepening of perspectives, not frozen habits. Culture in such a meaning, is seen as a safeguard subject. It is related to knowledge, but contains also largely subconscious issues like feelings, values, attitudes and motivation. Cultural values are often seen as a part of ecosystem services. Human health in a wide sense has an instrumental value to culture. Culture is made available through IT.

7. SELECTING STATE INDICATORS FOR SELECTED SAFEGUARDS SUBJECTS

7.1. Ecosystem services
TEEB categorize ecosystem services in provisioning, regulating, cultural and habitat services. Provisioning services for agricultural areas are crop production capacity of the soils in intensive agriculture and meat production capacity in extensive agriculture. For forests provisioning services are wood production capacity, and for water it is fish production capacity. Regulating services are climate and hydrological regulations, influencing precipitation and flooding. Cultural values may be measured by time spent in nature (physical or mentally) for recreation. Habitat services may be measured by biodiversity indices and by number of endangered species. Table 2 summarizes state indicators for ecosystem services.

Table 2. State indicators for ecosystem services.

State indicator types	State indicators	Unit
Provisioning	Crop production capacity	mass/area,time
	Meat production capacity	mass/area,time
	Wood production capacity	mass/area,time
	Fish production capacity	mass/area,time
Regulating	Precipitation	mm/time
	Flooding	area*time

Cultural	Recreation	persons*time
Habitat	Biodiversity	Index
	Endangered species	Species*area*time

7.2. Access to clean water

There are two dimensions in access to water: amounts and quality. Two quality categories are of particular interest: drinking water and irrigation water. The state indicators therefore are production capacity of water with drinking quality and production capacity for irrigation water. These indicators are not about the production or consumption per se, but about the production capacity. This means that if a well, that can produce 1000 liter per hour of clean water is polluted, there will be a decrease in the state indicator regardless of whether it is used or not. Extracting water from nonrenewable water stocks means that the production capacity decrease with the same amount as extracted. When extracting water from a flowing river, no change in production capacity takes place on a global scale. Locally, downstream, there may be a decrease.

7.3. Abiotic resources

Abiotic resources are both environmental and economic issues. Their state indicators may be given similar structure as economic indicators: capacity and efficiency. Capacity is about how much there are and efficiency is about how many person-hours we need to invest to obtain a mass unit of the resource. However, the total amount of abiotic resources on atomic level cannot be changed, only their availability. Beside insignificant amounts added or subtracted by nuclear reactions, the total amount of, for instance Cu atoms will be constant. And, the maximal amount of any molecule will be determined by its atoms. Therefore concentration is chosen as the state indicator for abiotic resources.

Abiotic resources are not generally exchangeable. Silver, e.g., cannot be replaced by aluminum. But different ore grades with silver may be exchanged and be used to produce pure silver. This means that state indicators have to be substance specific. In the long run, the number of atoms of each kind of elements on the globe is practically constant, and the only kind of resource we can deplete is the availability, i.e. high concentrations of elements or minerals. The state indicator for elements and chemical compounds is therefore simply its concentration. Pure substances have the state indicator 1 and when diluted they are measured in terms of their weight share.
The state indicator of a certain abiotic resource will thus be described by its concentration.

7.4. Sound environment

Environmental and sustainability assessments normally focus on noise levels, although there are positive aspects like bird singing and music. The intensity of noise is normally described in terms of dBA or similar measures. Population exposure may be described by person-hours above disturbing levels.

7.5. Transport technology

The sustainability value of different technologies lies in their respective capacity and efficiency. Capacity and efficiency represents a kind of capital made available for the future.
A possible state indicator for transport technology may be one describing the capability of transporting a certain mass a certain distance between two points in a certain time, for instance in ton km/day. An indicator for the efficiency could be the cost per tonkm or person-hour per tonkm. So, we chose transport capacity e.g. in tonkm/day and transport efficency e.g. in person-hours per tonkm as state indicators.

7.6. Environmental technology

The sustainability value of environmental technology is to some extent covered by reduced environmental impact, but as for transport technology, there is also a value in the capacity and efficiency of the technology. So the volume and labor per improved quality of controlled mass and person-hours/mass unit controlled for different flows is chosen as a measure. Labor is preferred rather than costs, but knowing the cost for labor allows for transforming one measure into the other. In table 3, some specific technologies are listed.

Table 3. State indicators for environmental technology capability.

	Capacity units	Efficiency units
Purification for drinking water	ton	personhour/ton
Municipal waste water treatment	m3	personhour/m3
Flue gas cleaning, SO2	ton	personhour/ton
Flue gas cleaning, CO2	ton	personhour/ton
Flue gas cleaning, NOx	ton	personhour/ton

Flue gas cleaning, particles	ton	personhour/ton
Gas cleaning, VOC	ton	personhour/ton
Indoor air cleaning	m3	personhour/m3
Clean room air	m3	personhour/m3

7.7. Textile technology

The sustainability value of textile technology, not covered by sales, lies in the capacity and efficiency of producing clothes, such as total mass of production and person-hours/mass unit of clothes.

7.8. Housing technology

The sustainability value of housing technology, not covered by sales, lies in the capacity of supplying housing measured by m2 of available housing and by efficiency in person-hours/m2 and year for supplied space.

7.9. Food technology

The sustainability value of food technology, not covered by sales, lies in the capacity and efficiency of producing food, such as total calories of production and person-hours/calorie of food produced.

7.10. Information technology

The sustainability value of information technology, not covered by sales, lies in the capacity and efficiency of transferring information, measured by Mb and person-hours per Mb

7.11. Energy technology

The sustainability value of energy technology, not covered by sales, lies in the capacity and efficiency of producing delivering energy-ware, measured by MJ and person-hours per MJ. The capacity and efficiency of transportation of energy-ware may be measured as MJkm and person-hour per MJkm.

7.12. Human health

Human health is the ultimate goal for sustainable development and the satisfaction of needs. But human health has also an instrumental value for making satisfiers available. WHO defines human health as "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity". Human health is often described in terms of excess mortality and various types of morbidity and nuisance or discomfort. In LCA, DALY is often used as an indicator. DALY is an economic measure of human productive capacity for the affected individual, and consequently do not capture other aspects of diseases.

7.13. Land availability

The land area on earth is constant, with exception for transformation to or from sea areas or inland waters. Land availability is therefore more of a social issue, where basic need of sufficient space to every person is of interest. So, appropriate state indicators would be population density and number of persons not having access to sufficient space covering the equity issue. At present, it is not known to us what sufficient space is and how to monitor it, so number of persons living in poverty will be used as an indicator.

7.14. Income

Common state indicators are GNP/person and number of persons living in poverty. There are several ways of measuring poverty. The World Bank uses 1.25 $ a day as a limit for absolute poverty. The number of people living on incomes below 1.25 $/day (or any updated limit) is chosen as a state indicator.

7.15. Peace

Simple state indicators for peace, would be DALY health indicators of excess mortality and injuries. But peace is a broader concept than just absence of physical violence. Psychological factors and oppression may also violence peace, but are more difficult to measure. State indicators chosen are poverty, number of newspapers delivered from a free press and equality as spread in income, measured by the 20/80 ratio.

7.16. Social security

Poverty, equality in income and parental leave are indicators of social security. % of average income guaranteed would be a good indicator, but in most cases this is a distribution and not so practical to use.

7.17. Continuity

Continuity is especially important for children: parental leave and number of separations are chosen as state indicators.

7.18. Knowledge

Knowledge is very difficult to measure, in particular useful knowledge for sustainability. The most common way to measure knowledge today is via education and years in school. But in a modern media and IT life, there is many other ways of acquiring knowledge. A knowledge test would be preferable, but at present the percentage of population having school training more than..x years will at least be relevant for the ticket to further knowledge. This is also used by UNDP as an indicator. Presence of a free press and culture consumption are also indicators of knowledge.

7.19. Jobs, occupation

Jobs are more than just income. It is contribution to wellbeing in society and participation in social life. State indicators are number of people in employment and education.

7.20. Culture

Like knowledge, culture is very difficult to measure, but essential for sustainable development and important to consider. Education, culture consumption and free press will be used as state indicators of culture. At present culture consumption cannot be quantified, and is only brought up at a qualitative level.

8. DISCUSSION, CONCLUSIONS

The positive social and economic externalities, which have been identified in this paper are mainly the capability to satisfy basic human needs developed as a side effect of product and process development. The actual production of products and services for basic needs are accounted for in transactions, but the optional value that lies in an increase in capacity and efficiency is not. Nor is externalities linked to knowledge and motivation.

In practical product development, there will thus be a trade-off between positive and negative externalities. One way to handle this is to use a life cycle assessemnt with monetary weighting of external costs and values. Negative externalities from emissions and resource extractions have been quantified by LCA methods such as Eco-Cost, (Vogtlander and Bijma, 2000) and EPS 2000d (Steen, 1999). Positive externalities like capacity and efficiency in technology may also be possible to estimate in monetary terms, but some of the social externalities may not. In these cases it may still be possible to adress them qualitatively, and estimate whether they incease or decreas compared to some benchmark.

From a bottom-up point of view it may not be possible to make trade-offs between all external impacts, but on the other hand, any design decision results in a trade-off. The question is how consious it will be.

9. ACKNOWLEDEMENTS

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10. REFERENCES

Brundtland et al (1987). Our Common Future, Report of the World Commission on Environment and Development, World Commission on Environment and Development, 1987. Published as Annex to General Assembly document A/42/427

Galtung, J. (1996). *Peace by peaceful means*. SAGE Publications, London, p 128

Jolly, R., (1976). The world employment conference: Tripartite World Conference on Employment, Income Distribution and Social Progress and the International Division of Labour organised by the International Labour Office, Geneva, 4–17 June 1976. Futures, **8**, Issue 4, August 1976, 363–365

Kumar, P. (ed) (2012). *The Economics of Ecosystems and Biodiversity: Ecological and Economic Foundations*, Routledge

Litwack, L.(2007), Basic Needs - a Retrospective, *International Journal of Reality Therapy*; Spring 2007; **26**, 2; ProQuest Central pg. 28

Lütkenhorst, W. (1982). Operationalizing Basic Needs: A Few Fundamental Reflections, *Intereconomics*, September/October 1982, 244-250

Steen, B. (1999) A Systematic Approach to Environmental Priority Strategies in In Product Development (EPS). Version 2000 – Models and Data. Chalmers University of Technology, Centre for Environmental Assessment of Products and material Systems (CPM) Report 1999:5, Gothenburg 1999.

UNDP 2010 http://www.undp.org/content/undp/en/home/presscenter/speeches/2010/08/24/a-better-future-for-all-why-meeting-the-millennium-development-goals-matters.html , accessed at 2014-02-20

Vogtlander. J.G and Bijma.A. (2000). The 'Virtual Pollution Prevention Costs ‘99'. A single LCA-Based Indicator for Emissions. *Int. J. LCA* **5**, 113 – 124