Areas of Protection

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The Areas of Protection in Life Cycle Impact Assessment

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This chapter is based on a broad discussion, which started within the Task Group on Resources and Land use, but later involved the full Working Group and also outside participants. Written contributions have been received from Jane Bare, Göran Finnveden, Edgar Hertwich, Patrick Hofstetter, Gjalt Huppes, Norihiro Itsubo, Walter Klöpffer, Wolfram Krewitt, Ruedi Mueller-Wenk, Willie Owens, David Pennington, Bengt Steen and Bo Weidema. Although the text where possible aims at consensus, and on many issues includes differing viewpoints, personal standpoints can well deviate from the below text.

1 Introduction

This book* reports on new developments in Life Cycle Impact Assessments, and aims to contribute to the development of best available practice in this field. These new developments not only concern technical knowledge about the fate and effect of substances but also regard conceptual issues. This chapter focuses on the latter. Examples concern terminology, the way to define impact categories and category indicators. We do not have the pretence to identify best available practice in this area. Instead, the goal of this chapter is to identify new issues, to clarify differing viewpoints, but also to make our own suggestions.

Two trains of thought can be identified regarding the identification of best available practice on conceptual issues. Leaving intermediate standpoints for the moment out of consideration, one train is, that choices in this field should all be dependent on the goal and scope of the study. The other is that also here best available practice should be identified, as far as appears to be possible. We follow the latter train of thought. Without a common conceptual framework it is hardly possible to define a best-practice set of impact categories with their category indicators, and precisely these should be the basis for the work on LCIA in the coming UNEP-SETAC Life Cycle Initiative. So, if the LCIA community is afraid to identify best practice in this conceptual area, it will be hard to set out for the LCIA sub-programme in the Life Cycle Initiative. But it is clear that this in itself is a value choice, with a respectable counterpart. The latter will be exemplified in the epilogue of this chapter.

As stated above, the main aim of this chapter is to clarify questions regarding the framework for LCIA. A next question is what the implications of such a framework would be for the preceding LCI phase: different impact categories and category indicators require different LCI results. How true this is in itself, this will not be a guiding principle of the present chapter. Consequently, the implication can be that the identification of best practice in the field of LCIA will set requirements on LCI, which at present cannot or not fully be fulfilled. It will be the task of the UNEP-SETAC Life Cycle Initiative to define best practice in LCIA in such a way, that it can already be implemented at the present moment.

The structure of this chapter is as follows. Section 2 deals with the terminology regarding the environmental mechanism of an impact category. Some options for adaptation of this terminology are presented, but for the rest of the chapter the terminology of the first report is used. Section 3 presents differing viewpoints on three critical issues in LCIA: the compatibility of LCA as a tool for decision making, with LCA as an example of systems analysis; the scope of LCIA; and lastly the comparison of a bottom-up vs. a top-down approach in LCIA. Section 4 and 5 explore two different ways to structure the so-called Areas of Protection in LCIA, i.e. classes of endpoints which society wants to protect. In section 6 a visual representation of these two approaches will be presented and discussed.

2 Terminology on the Envionmental Mechanism of Impact Categogies

In this section we will discuss and define a number of terms related to the environmental mechanism of an impact category (being). In the rest of this chapter the terminology will, for continuity reasons, be followed as used in the first report of the Working Group (Udo de Haes et al. 1999). Where alternatives are provided, the possibility to define new terms is in the hands of the UNEP-SETAC Life Cycle Initiative, and later on in a possible revision of ISO 14042. The terms to be discussed are in particular: environmental mechanism, environmental intervention, midpoint, endpoint and Areas of Protection.

The *environmental mechanism* of an impact category is, according to ISO 14042, the total of environmental processes which link the environmental interventions to the

* The final outcome of the debate will be documented in Chapter 8 (The conceptual structure of Life Cycle Impact Assessment), written by Helias A. Udo de Haes and Erwin Lindeijer, in the book 'Towards best practice in Life Cycle Impact Assessment', eds. Udo de Haes et al., SETAC, Pensacola, 2002 (in print).

endpoints of that given impact category. The concept in itself is clear. In practice, the term 'mechanism' causes confusion, as it seems to refer to a single environmental process (for instance the degradation of a compound or the response of the vegetation to eutrophication). A possible alternative is 'impact chain'. The term 'chain' does not show the branching of the inter-linked processes, but this confusion seems small compared to the term 'environmental mechanism' which seems to be hardly used.

Environmental interventions (or possibly 'antropogenic interventions') are the physical elements which cross the border between the product system and the environment (for these terms see section 3). The environmental interventions first of all consist of the extraction of natural resources which enter the product system, and the emission of hazardous substances (or other types of physical elements like radiation), which leave the product system and enter the environment. But they also involve other types, like in particular different types of land use, i.e. physical changes in the environment caused by activities in the product system (cutting of trees, shooting of animals, lowering of groundwater table, etc.). ISO 14042 uses the term 'elementary flows' in this context. These elementary flows cover the extraction of resources and the emissions of substances; but they do not cover land use. In addition, this term seems to focus on chemical elements and not on compounds. Another term which is used in this context is 'exchanges' with the environment, or 'environmental exchanges' (Weidema). In itself this is probably a very good term which covers all three types of elements mentioned above. However, the term 'exchange' is also used involving the relationship between LCI databases; for instance there is the term 'exchange format', which has nothing to do with passing the system boundary between product system and environment. A last possibility is the term 'stressor', as was originally coined in the Sandestin workshop on LCIA. Also this term ca be a good candidate; but the it should be limited to elements passing the boundary of the product system, and not also include elements at midpoint level (see below) as was originally the case.

Midpoints concern all elements in an environmental mechanism of an impact category between environmental interventions and endpoints. This leads to the necessity to define endpoints. We define *endpoints* as those elements of an environmental mechanism which are in themselves of value to society. ISO 14042 mentions forests and coral reefs as examples. Other examples are physical aspects of human health, like lifetime or bodily functions; plant or animal species, or natural resources like fossil fuels and mineral ores.

Regarding the terms 'midpoint' and 'endpoint' a number of issues have to be clarified. It is important to note that the meaning of 'endpoint' as used by ISO 14042 is different from that in Environmental Risk Assessment. There, it is any physical element in the analysis which is regarded as the dependent variable. In ISO-LCA language endpoints are at the physical damage level, i.e., the level of elements which in themselves of value to society. We write 'physical damage level' as distinct from 'monetary damage level', as we should recognise that the term 'damage' can be used at these two different levels. A further point regarding the term 'endpoint' concerns the distinction between an element itself, and an effect on an element; for instance, a forest versus damage to a forest. It is advisable to keep to ISO terminology, meaning that endpoints are the physical elements themselves, not their changes caused by environmental interventions.

Another question is whether also elements like DALYs (Disability Adjusted Life Years) or QALYs (Quality Adjusted Life Years) are to be regarded as endpoints in LCIA terminology. Like monetary damage, these do not involve physical elements, but are value constructs. As close as possible to ISO 14042, the term 'endpoint' will be further used here for the physical elements themselves; then DALYs and QALYs are derived from endpoints, or weighted endpoints, but are not the endpoints themselves. As a last point regarding 'endpoints' we want to add that the phrase 'of value to society' can refer both to *intrinsic* values, such as elements related to human life, to biodiversity, or to works of art, and to *functional* values, like elements related to abiotic resources. Although this distinction is not absolute (we can look at works of art, and thus they have of course also a function), with 'functional values' rather a physical, or practical use is meant.

The last term in this context is *Area of Protection*. In the first report of the Working Group (Udo de Haes et al. 1999), an Area of Protection is defined as a class of endpoints. In ISO three of such classes are mentioned, be it in a rather implicit way: human health, natural environment and natural resources. In this chapter another classification of AoPs will be discussed, as well as two possibly additional AoPs: the Man-made Environment (first introduced by Udo de Haes et al. 1999), and the Life Support Functions (first proposed in LCIA context by Udo de Haes 2000). Another term which describes classes of endpoints is the expressive term 'safeguard subject', introduced by Steen and also used in the Swiss literature by Beltrani. It is important to note that these two terms exactly convey the same message: they relate to the endpoints as physical elements, not to the societal values behind. So, following this terminology, consumer welfare cannot be an AoP or a safeguard subject; and neither can be respect for nature, or cultural values. We propose to keep to the term AoP because it is more in line with the discussion in ISO (although not strictly defined in ISO 14042), and also because this term is used in the earlier publication of the working group.

3 Viewpoints on and Approaches in LCIA

In this chapter a number of contrasting viewpoints on LCIA will be discussed which are relevant for the definition of impact categories and category indicators. We will discuss three topics. The first deals with the role of LCA as a decision support tool, vs. LCA as example of systems analysis. Subsequently, the second topic is what types of problems should be part LCA, and LCIA in particular. The third topic concerns the distinction between a bottom-up and top-down approach in LCIA.

3.1 Decision support vs. systems analysis

LCA is an analytical tool for decision support. At the same time it is often seen as an example of systems analysis, a scientific discipline which structures the analysis of complex systems. There can be a friction between these two statements. One may argue that systems analysis and decision support set different requirements. Thus, one can perform a systems analysis study without any relevance for decision support. And, conversely, one can provide decision support regarding a complex system like a product system without doing a systems analysis study. However, if one selects relevant input variables which can be steered by society, particularly including the selection of alternative products to provide a predefined service, and output variables which are regarded as good indicators for damage and benefits, then a systems analysis study can become very relevant as a means for decision support. As long as LCA meets these requirements, we argue that it can be directed at decision support, and at the same time follow the requirements of the environmental systems analysis framework.

Taking this as a starting point, it is important to define what is the system, what the surroundings of the system are, and consequently what is the boundary between system and its surroundings. For the moment we use the neutral term 'surroundings' of the system, because the term 'environment' has a specific meaning in environmental management, and will be introduced below.

Starting point for LCA is the product system, consisting of all processes related to a given product from cradle to grave. The surroundings of this product system consist of processes in other product systems, but also of processes in what is usually called 'the environment' (for instance in the ISO framework of the standards on environmental management). In the context of LCA, this 'environment' can also be seen as the surroundings of a system, i.e., of the total of all product systems together. We will call the letter system 'the economy'. So in fact a distinction between a system and its surroundings is relevant at two levels, the level of a single product system, and the level of the economy, i.e. the total of product systems in a given area (**Fig. 1**).

At the level of the product system the relationships with other product systems (so, inside the economy) are the field of multiple processes and of allocation. The relationships with the environment consist of the environmental interventions as described in section 2. At the higher level, the economy and the environment, also other terms are possible. Instead of 'economy' one can also use the term 'technosphere' (Hofstetter 1998). This term is not proposed here, because its limits the types of processes which are to be analysed within this system. 'Technosphere', as introduced by Hofstetter, is opposed to 'ecosphere' (the environment) and 'valuesphere'. In our view the processes which form the economy and which are to be analysed in LCA (particularly LCI), may well surpass the physical level. For instance, the function which is provided by a product is of a non-physical nature. In addition, allocation based on system extension explicitly includes the analysis of market processes, just as economic allocation involves monetary values. The physical level has to be the basis for the analysis of processes, but this analysis may very well go beyond that.

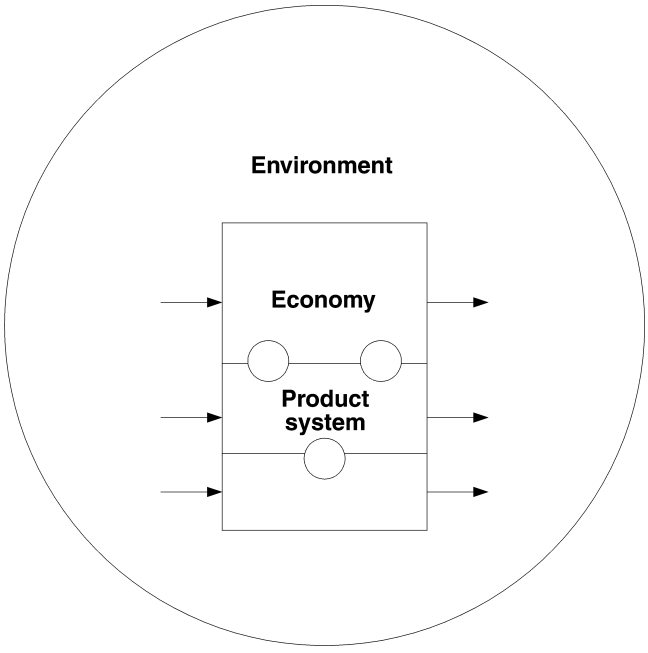

Fig. 1: Product system and economy: two levels of system definition. Circles indicate multiple processes at the boundary of the product system and the rest of the economy

There are also alternatives for 'environment'. Thus, one may think of 'nature' or 'ecosphere'. However, the term 'environment' is used in the ISO standards of the 14000 series, and in environmental management in general, for that matter; another term with roughly the same meaning will introduce confusion.

3.2 What types of problems should be included in LCIA?

LCA can include any type of problem, which can be related to the functional unit of a product system. The choice then can be made in the Goals and Scope definition phase. A question is however, what types of problems are to be included in *environmental* LCA, that is, LCA as an *environmental* analytical tool as is part of the 14000 series of ISO. This question is particularly relevant for the coming UNEP-SETAC Life Cycle Initiative. If one aims to identify best practice in a given area, one should know what is and what is not part of this area.

The most straightforward answer is: problems concerning damage to elements in the environment (like damage to biodiversity or the depletion of natural resources), and problems related to elements which are damaged via environmental processes. There is a difference between these two categories of damage. The latter also includes damage to elements within the economy, which is due to an environmental pathway. Examples concern acid rain damage to buildings or climate change damage to crops. Also damage to human health can be seen as an example, if one regards humans to be part of the economy.

The above guideline excludes damage to elements within the economy which do not involve environmental processes. In fact, these types of impact are part of the product system itself. A product system therefor not only fulfils a function, but also can lead to internal damage without any involvement of processes in the environment. Examples are car accidents and possibly health impacts in the work environment, depending on the definition of the system boundary, i.e., whether the indoor environment is seen as part of the environment or of the economy. We would like to stress again that LCA can include also the analysis of these types of impact, but that these are additional to the *environmental* impacts which are part of the scope of an *environmental* management tool.

3.3 Top-down vs. bottom-up approaches

LCIA deals with damage on endpoints, either in the environment or back in the economy, caused by environmental interventions. This not necessarily implies that the full chain of processes from interventions up to the endpoints needs to be modelled quantitatively. In this context two approaches can be distinguished: a bottom-up approach and a top-down approach. The *bottom-up approach* starts from the environmental interventions and takes these as input to models which bring us further along the environmental mechanism of accepted impact categories. Given the acceptance of such categories, also the results, often (but not always) expressed in terms of midpoint variables, can be regarded as relevant for decision making. On the other hand, the top-down approach starts at the other end of the environmental mechanisms: the endpoints which directly matter to society, and the societal values behind. Then, models have to be constructed which have to link the interventions with these endpoints, which are chosen as category indicators.

Historically, the midpoint approaches have set the scene in LCIA, taken as prominent examples the critical volume approach, the Nordic LCA guide, the CML thematic approach (Heijungs et al. 1992), the EDIP model (Hauschild) and the Sandestin workshop on LCIA. They also have mostly structured the work of the Working Group (see Udo de Haes et al. 1999), the way of thinking and examples chosen in ISO 14042.

Since the middle of the nineties the top-down approach was set on the agenda. It had already a longer history, particularly in the EPS approach from Steen and Ryding (Steen and Ryding 1992, Steen 2000), but got strong impetus from Switzerland (Mueller-Wenk) and again from the Netherlands in the Eco-indicator approach (Goedkoop and Spriensma 1997, 1999). At the moment also in Japan impect assessment models are developed according this approach (Itsubo, pers. comm.). This approach starts from the main values in society, connected with so-called Areas of Protection, or Safeguard Subjects: groups of endpoints which are linked to these societal values. From these values and connected endpoints the modelling goes back to the environmental interventions. In line with ISO 14042, three main Areas of Protection were generally identified in these approaches: human health, natural environment (particularly involving non-human life or bio-diversity) and natural resources.

A first real discussion between the bottom-up and top-down approaches took place at a workshop in Brighton in 2000, organised under the auspices of UNEP-DTIE (Bare et al. 2001), and is known under the term 'midpoint-endpoint discussion'. The conclusions of this workshop can be summarised as follows:

- both types of approaches have their specific value
- bottom-up approaches, often choosing midpoint variables as category indicators, give results which are relatively certain (although sometimes still quite uncertain), but which generally are less environmentally relevant because they focus on variables which are generally far removed from the endpoints which directly matter to society
- top-down approaches on the other hand, choosing endpoints as category indicators, give results which are expressed in very relevant terms, but are relatively (to extremely) uncertain
- it would be an important step further if one encompassing framework could be developed, including the most important variables of both types of approaches, thus enabling modelling along the two approaches and comparing the results with each other.

In the preparation of the UNEP-SETAC Life Cycle Initiative, which in fact started from the bottom-up approach, the latter conclusion has recently been incorporated as one of the leading principles for the LCIA sub-programme. The required encompassing framework must on the one hand include a broad picture of the environmental interventions concerned, and on the other hand a clear picture of the relevant types of endpoints and their underlying societal values. This second requirement is the basis for the next chapters on the Areas of Protection.

4 AOPs in the Bottom-up Approach of LCIA

4.1 General

Areas of Protection are, as described in section 2 of this chapter, classes of endpoints. They enable a clear link with the societal values which are the basis for the protection of the endpoints concerned. **Table 1** gives an overview of the AoPs with underlying societal values as presented in the first report of the Working Group.

As the AoPs aim to conect the environmental interventions with endpoints and their underlying societal values, their definition implies value choices. Thus, there is not one correct way to define a set of AoPs. In this chapter we will

Table 1: Areas of Protection and underlying societal values (from Udo de Haes et al. 1999)

Areas of Protection	Societal values
1. human health	intrinsic value of human life, economic value
2. natural environment	intrinsic value of nature (ecosystems, species), economic value of life support functions
3. natural resources	economic and intrinsic values
4. man-made environment	cultural, economic and inrinsic values

discuss two different possibilities: one connected with the bottom-up approach of LCIA (this section), and one connected with the top-down approach in LCIA (section 5). Diagrams of both approaches will be presented in section 6.

In the bottom-up approach the AoPs are distinguished according to environmental characteristics. After that, the resulting classes are connected with the relevant societal values. In the top-down approach the opposite route is chosen: starting from societal values, classes of endpoints are defined.

4.2 Bottom-up definitions of AoPs

A possible bottom-up classification of AoPs is:

- atmosphere
- hydrophere
- pedosphere
- geosphere
- biosphere
- plants
- animals (including man)

The problem with such an ecological classification is that it deals with the planet earth as a whole, without the distinction between the economy system and its environment, and without a specific place for antropogenic interventions and societal values. It is therefore not compatible with a systems analysis view on LCA.

Another classification of endpoints, according to their environmental characteristics, is the following:

- Abiotic environment
- Biotic environment
- Human health

A further subdivision is possible. For instance, within the abiotic environment one can distinguish between abiotic resources (like fossil fuels, minerals, water and soil (in part)), natural structures (like glaciers and mountains), man-made structures (like materials, buildings and works of art), and possibly land. Likewise, within the biotic environment one can distinguish between biodiversity, biotic resources and a man-made structure like crops.

The advantages of the latter classification is that it can be linked rather well with existing disciplines. Also the link with the societal values is somewhat more clear, particularly at the level of the subdivisions. But still, also the latter AoPs are quite heterogeneous regarding their connection with societal values.

5 AOPs in a Top-down Approach

5.1 General

The three AoPs which are included in ISO 14042, i.e., human health, natural resources and natural environment, in fact are classified according to societal values. This line will be further elaborated in this section. Two dichotomies will be taken as guiding principles. Firstly, there is the distinction between human (or man-made) on the one hand and natural on the other. Secondly, there is the already made distinction between intrinsic values and functional values. Thus, the distinction between natural resources and natural environment lies in the latter dichotomy: the natural resources being of functional value, the natural environment being of intrinsic value.

Two issues regarding the AoPs in this top-down line will particularly be discussed. Firstly, there is the Man-made Environment, which was already proposed in the first report of the Working Group (section 5.2). Secondly, it will be suggested to split up the AoP 'Natural Environment' into two AoPs: Biodiversity and the Life Support Functions (section 5.3).

5.2 Exploration of man-made environment in relation to the system boundary

In the first report of the Working Group (Udo de Haes et al. 1999) it was suggested to include the 'Man-made Environment' as a fourth AoP, covering crops, production forests, buildings and materials. The reason is that without this AoP we would not have a basis to include impacts into the analysis of acid rain on silviculture or monuments, or of ozone impacts on agriculture. The inclusion this AoP links up with top-down reasoning, but it is not without problems. The main problem is that, for consistency reasons, the inclusion of this AoP may open up the analysis to all kinds of impact which traditionally do not belong to LCIA and which may divert it from its original aim. Examples are: car accidents, impacts on commercial elements like buildings or materials, positive impacts from river dams, etc.

We will explore three different options which may set limits to and avoid undesirable expansion of the scope of LCIA. The first concerns the position of the system boundary. In section 3.2 we argued that environmental LCIA should focus on damage to elements in the environment, and on elements back in the economy which are affected through environmental processes. As was already said, this means that elements *within* the economy, which are affected by processes *within* the product system, are no part of environmental LCIA. They can be added to the study, but are additional to the *environmental* analysis. The example is: casualties and physical damage caused by car accidents. Also human health impacts due to accidents in the work environment could be out of the scope, depending on how the boundary between economy and environment is drawn.

A second option for limiting the scope in a generic way concerns the distinction between *intrinsic* and *functional* values. Thus one may choose to include monuments, but to exclude materials or commercial buildings. However, also in the natural environment we regard both elements with functional and with intrinsic values. So a limitation of the scope on this ground within the Man-made Environment would be rather inconsistent. But it remains very advisable to split up the Man-made environment according to precisely this criterion. Crops, materials and buildings predominantly fall under the functional values, monuments, works of art and man-made landscapes predominantly under the intrinsic values.

A third option for limiting the scope of LCIA concerns a possible distinction between *damage* and *benefits*. We may argue that LCIA should focus on damage, and should exclude benefits. If so, the positive economic impacts of a dam would not be included in environmental LCIA. But there are strong arguments against such a limitation. Why only include the acidifying impacts from SO_2, and exclude its mitigation of climate change? Why exclude possibly positive impacts of NO_x emission on the limitation of tropospheric ozone? So in fact, we think that the exclusion of positive impacts would lead to biased results.

A last alley may lie in the distinction between *intended* and *unintended* impacts. Intended impacts should be part of the function of the system, and consequently not be also part of LCIA. If we choose for a limitation of LCIA to unintended impacts only, then the positive economic impacts of river dams, or of measures aiming at the enhancement of biodiversity, should not be part of LCIA but should be included in the definition of the function of the product system.

The above reasoning leads to a somewhat sharper focus, but still the resulting scope of LCIA may be seen as too large. If so, one can choose to define *positive* and *negative* lists of types of impact which should and which should not be part of LCIA. So one should be able to say: 'Strictly speaking, damage to commercial buildings be regarded as part of LCIA, but given the attention which is given to this issue in other contexts, LCIA should not include this type of impact in its scope.' One step further, this focus can be application dependent, or even case dependent. In the latter case the limitation would be part of the Goal and Scope Definition, and therefore outside the present argumentation.

5.3 The splitting up of the Area of Protection 'Natural Environment'

The other issue which is at stake in the top-down line concerns the splitting of the natural environment into two AoPs, i.e.: 'Biodiversity and Natural Landscapes' and 'Life Support Functions'. This possible splitting up would find its ground in the distinction between intrinsic and functional values. The biodiversity part of the first AoP mentioned is defined here according to the Biodiversity Convention and includes genetic diversity, species diversity and ecosystem diversity. True, these classes of endpoints can also have functional values. But if these are predominant in a given case, the given elements can rather be grouped under Natural Resources. The natural landscapes are in fact ecosystems on a higher scale level. They have, just as the above mentioned man-made landscapes, predominantly intrinsic values related to recreation and aesthetics.

The Life Support Functions concern the major regulating functions of the natural environment, which enable life on earth. These particularly include the regulation of the earth climate, hydrological cycles, soil fertility and the biogeochemical cycles. Like the Natural Resources, the Life Support Functions are of functional value for society. These two are therefor of a fundamentally other nature than the AoPs with intrinsic value to society, such as in particular those connected with human health, with biodiversity and with works of art.

The question whether or not to include the Life Support Functions as a separate AoP is not only of academic significance. Suppose, one wants to follow a top-down approach and to choose the category indicators at endpoint level (i.e., at the level of physical damage). If one would only include AoPs which have intrinsic value to society, then it would suffice to select indicators for human health and for Biodiversity, just as for instance is done in the Eco-indicator approach (Goedkoop and Spriensma 1997, 1999). But if one also wants to include functional values, then it is required to also include indicators for the Natural Resources and the Life Support Functions.

A few remarks will be added about the possible AoP 'Life Support Functions'. Firstly, it should be clear that it is composed of a number of subclasses, which cannot easily be represented with one indicator. To be more precise, this AoP will cover more impact categories, each with its own category indicator. Secondly, it is interesting to compare this AoP with the AoP 'Unknown Damage', as introduced by Hofstetter (1998). Although there is resemblance, there are also differences. Hofstetter's 'Unknown Damage' is in fact based on a negative definition; his AoP shrinks with increasing knowledge. Here a positive description is used, based on the natural regulation functions, which in principle are independent from the amount of knowledge. Thirdly, it should be recognised that the inclusion of an AoP 'Life Support Functions' implies, that the elements involved are to be regarded as endpoints. Climate regulation or soil fertility, midpoints in the context of other AoPs, are here to be regarded as endpoints.

6 Overview of the AoPs

In the preceding two chapters a structuring of AoPs has been presented, following two different approaches in LCIA: a bottom-up approach starting from the interventions and structuring the AoPs according to environmental characteristics; and a top-down approach in which the link with the underlying societal values was given priority. In this section we will elaborate both, in a more visual way. Diagrams, as presented in Fig. 2 and 3, can be regarded as underlying paradigm for LCIA. They represent a model from reality, which serves as guidance for the modelling in LCIA.

6.1 Visual representation of the bottom-up viewpoint

Fig. 1 presents a structuring of the AoPs according to a bottom-up viewpoint. Apart from the AoPs themselves, also possible subdivisions are included. As already indicated, an advantage of this way of structuring is that there is a clear link with traditional disciplines. However, the link with the societal values is less clear. To some extent this point can be solved at the subdivision level: the protection of the elements under the heading of the Biotic Environment takes place on basis of different underlying societal values. But there are limitations here. Life Support Functions can not be included easily, as these involve both the Abiotic and Biotic Environment. The same holds true for Biodiversity, which in its broad definition according to the Convention on Biodiversity in fact is wrongly placed under Biotic Environment. And the same holds true for landscapes, which also include abiotic and biotic elements. Also there is no clear room for the distinction between 'natural' and 'man-made'.

6.2 Visual representation of the top-down viewpoint

Fig. 2 presents a structuring of the AoPs according to a top-down viewpoint. Also here, subdivisions are also included.
Fig. 3: Areas of Protection and their relations. Arrows pointing both ways express interactions between economy and AoPs. Intermittent arrows express AoPs with (predominantly) intrinsic values, line arrows express AoPs with (predominantly) functional values. Single arrows express influences from one AoP on the other.

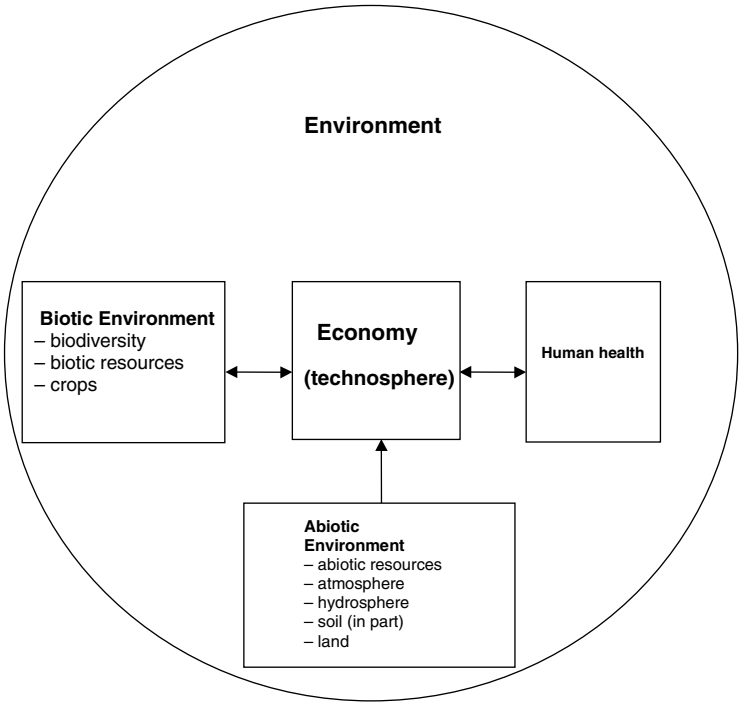

Fig. 2: Areas of Protection, according to the bottom-up approach

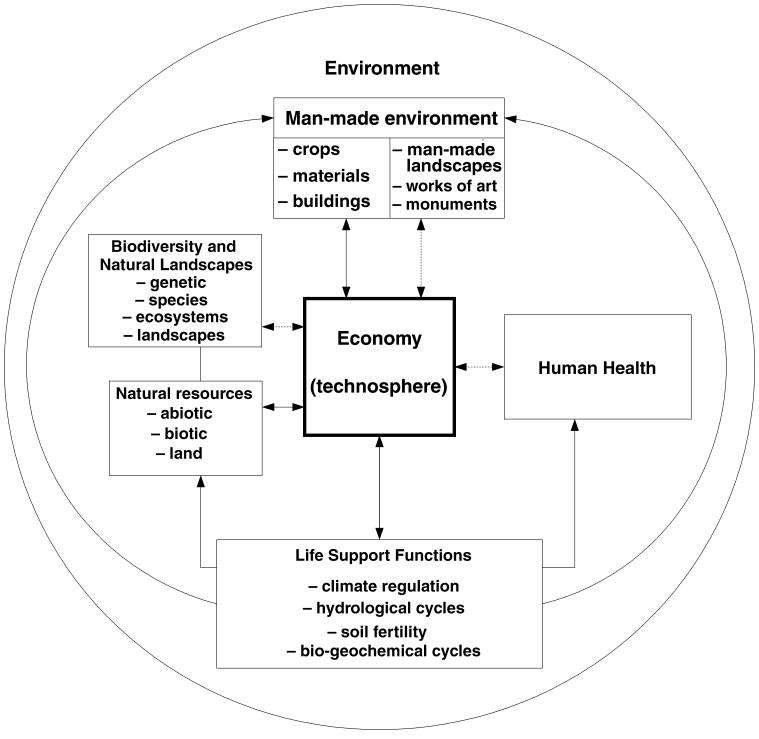

Fig. 3: Areas of Protection and their relations

Table 2: Classification of Areas of Protection, also indicating some groups of endpoints within them

Values	AoPs in the environment	AoPs back in the economy
Intrinsic value	Biodiversity and Natural landscapes – genetic diversity – species diversity – ecosystem diversity – natural landscapes Human health	Man-made Environment – man-made landscapes – monuments – works of art
Functional value	Natural resources – abiotic resources – biotic resources – land Life Support Functions – climate regulation – hydrological cycles – soil fertility – bio-geochemical cycles	Man-made Structures – materials – buildings – crops, lifestock

6.3 Endpoints within the environment and within the economy

The two diagrams have the limitation that they do not show the difference between AoPs inside the environment and AoPs back in the economy. The AoPs all are represented in the environment. This difference rather can be presented in a **Table**. **Table 2** takes the top-down structuring of AoPs as example. In this **Table** two dimensions are distinguished: (1) the distinction between AoPs in the environment, and AoPs back in the economy, and (2) the distinction between intrinsic values and functional values. We realise that the distinction between these two types of values is not sharp. For instance, Man-made Structures can either have functional or intrinsic values. But if we make a more detailed classification of endpoints within these AoPs, as is done in the **Table**, a link along this distinction seems quite well possible.

A next step would be to change the original pathway diagram in the first report of the Working Group (Udo de Haes et al. 1999). However, this is beyond the scope of the present chapter.

7 General Conclusions

This chapter summarises new developments at a conceptual level, regarding Life Cycle Impact Assessment. The aim was to put these on Table 2 in a structured way, in order to clarify different viewpoints and their implications. Two main viewpoints were distinguished right in the beginning. The first is that also at the conceptual level it is necessary to identify best available practice. The second is that the conceptual choices which are at stake should be dealt with on a case-to-case basis in the Goal and Scope Definition phase of a given study. The first point of view is taken as starting point for this chapter. A reason for this is that to the authors opinion a well defined conceptual framework for LCIA should form the basis for the identification of best practice on impact categories and category indicators as will take place in the UNEP-SETAC Life Cycle Initiative. An alternative point of view is presented in the epilogue of this chapter.

A number of issues has been discussed. Firstly, comments were made on the present terminology regarding the environmental mechanism of an impact category, i.e., the chain of processes from environmental interventions up to endpoints. In the further chapter, the terminology used in the first report of the working group has been used. In another context decisions should be made whether or not to adapt the terminology.

After that, a number of differing viewpoints on LCIA have been presented. The first was the compatibility of LCA as a decision support tool, with LCA as an example of systems analysis. Second, the scope of LCIA was discussed: can generic guidelines be established what types of problems should be included in LCIA, and what types of problems should be out of, or additional to LCIA. Third, a bottom-up approach of LCIA was compared with a top-down approach, with the implications thereof for the selection of impact categories.

For both the latter two approaches it was explored what should be the Areas of Protection in LCIA, i.e., the relevant classes of endpoints and their underlying societal values. Taking as starting point the Areas of Protection, as introduced in ISO 14042, two contrasting proposals were presented. These show two ways to structure the endpoints in LCIA. Focal points in this discussion concerned the inclusion of the man-made environment and of life support functions as separate Areas of Protection. Further discussion on this issue is needed. The chapter concludes with a visual representation of the two contrasting ways of structuring the Areas of Protection, together with an overview of the connected advantages and limitations.