Life Cycle Impact Assessment Programme
of the Life Cycle Initiative

Final report of the LCIA Definition study

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1. Introduction

1.1 Objectives and process

The Life Cycle Impact Assessment (LCIA) Programme is one of the programmes of the UNEP/SETAC Life Cycle Initiative. This report was prepared by one of the working groups that was convened by UNEP/SETAC to develop guidelines for the development of LCA. Other working groups are addressing LCI (life Cycle Inventory) and LCM (Life Cycle Management. The major goal of the LCIA DAT in preparing this report is to identify the deliverables of the LCIA program consistent with a set of objectives identified in prior efforts. A second goal is to ensure that the deliverables identified are appropriate to the needs and concerns of all LCA “stakeholders”. The objectives used by the DAT were developed in a “Terms of Reference (ToR)” study (REFERENCE) that was carried out prior the start of the current effort. Based on the ToR study the objectives of this report are, in priority order, the following.

According to the predefined Terms of Reference, this definition study aims in priority:

1) To identify user needs for Life Cycle Impact Assessment (LCIA)
2) To provide a clear picture of an overall LCIA framework and of the impact categories to address as high priority, including different impacts than the one typically applied in "OECD country LCAs", like e.g. erosion or biodiversity
3) To identify the main research needs and to produce a 2 years detailed plan, with a prospect of 4 years for the LCIA programme.
4) To identify worldwide experts from relevant fields, as potential candidates to ask for peer review, workgroups or task forces

The present programme builds on the ISO series of LCA standards, in particular ISO 14042 (ISO, 2000) on Life Cycle Impact Assessment (LCIA) and the related Technical Specification 14047. Important predecessors of the present programme are the more than ten years of effort by SETAC in advancing LCA, in North America, Asia and in Europe. More specifically the working groups of SETAC-Europe on Life Cycle Impact Assessment have established a crucial basis for the identification of best available practice in this field. Also, the initiative builds on the ongoing national projects on LCIA, e.g in Japan, Denmark, Holland, Switzerland, USA and on multinational initiative such as the OMNIITOX European project. The LCIA Programme complements and strengthens these important international initiatives. It will be designed to avoid duplicating their goals and deliverables, addressing the remaining needs.

In order to meet its goals in preparing this report, the authors made use of a user needs survey, works shops, and extensive collaboration. The team developed, executed, and evaluated a user needs survey in order to enable worldwide participants to make proposals, suggestions and constructive criticism. The user needs survey provided input for setting priorities among the information and approach needed for an LCIA. The report authors also collected input from workshops that were held May and December 2002 to obtain both inputs and feedback. These workshops were held at the launch and finalization of this definition study. In preparing this report, the author team has collaborated via email, teleconferences and small group meetings to work on both this report and its background documents.

The present document will now be submitted for review to an external panel. It will also be widely published for comments through an Internet Forum.

1.2 Report status and structure

This document consists of an extended summary of the definition study as elaborated by the appointed Draft Author Team, focusing on the initial definition of an encompassing LCIA framework and on activities to be carried out in different impact categories. It is supported by several background documents, which provide additional details and background information on each impact category, but will require further work and elaboration within the Life cycle Initiative itself to reach consensus.

The present report summarises the main results of the LCIA definition study, starting with the results of the user needs survey and the update of the LCIA programme aims. A preliminary framework is then proposed structuring both midpoint and damage approaches of LCIA in a consistent way. Analysis of midpoint impact categories and damage categories are finally discussed in a workplan looking at scientific challenges and proposed activities. Definitions of terms like LCI results, midpoint and damage categories and indicators are given in Appendix I, detailing the used terminology.

Three different background documents complement this approach:
- Background document I presents the full needs analysis report (the user need questionnaire itself can be downloaded from the LCinitiative website).
- Background document II presents a summary report on three LCIA workshops in Vienna, Tsukuba and Barcelona.
- Background document III provides complementary and important analyses for 12 midpoint categories.

2. User needs

The user needs analysis provided important input to the authors about issues, categories, values, and priorities for LCIA. Background document I describes the user development, execution and evaluation of the user needs survey (Background I_LCIA needs analysis report1a.doc). This report contains a full analysis of the responses gathered for the LCIA element of the UNEP/SETAC Life Cycle Initiative survey, based on 91 independently completed surveys that had been received by 15 February 2003.

The complete needs analysis report details:

- A **background to the survey respondents** which includes an indication of the regions from which surveys were received, a breakdown of the industrial sectors in which respondents work, details of the departments (marketing, R and D etc) in which the respondents work, the manner in which they use LCA, and the confidence which they place in the information delivered by LCA.
- **Selection and Prioritisation of Issues in LCIA** in which specific issues in LCA were presented and respondents' agreement and/or concerns with these issues gauged.
- **Impact Categories to be included in LCA** which investigated the perceived significance that respondents placed on both existing and potential new impact categories. This section of the report contrasts differences in perception between the entire respondent group, and those responses received from resource extraction (or non-traditional LCA) countries
- **Environmental Values** highlights the end-points which are of concern to the respondents
- **Specific Requirements of LCIA** discusses requirements of specific industrial sectors and global regions
- **Conclusions** includes remarks on the potential limitations of the survey results, as well as the expectations that respondents have of the initiative.

The survey was structured in such a manner as to elicit additional information from respondents if they wished to supply further details. This information is also presented in the detailed report. There is significant information in the final report and the interested reader is encouraged to read it.

2.1 Regional analysis of responses

Specific attention is paid to the regional split of the respondents and its influence on the different issues highlighted in the survey, with special emphasis on the significance of different impact categories.

Table 2.1 Regional split of the survey respondents.

UN Regions	**Number of Respondents**
Africa	5
Asia and the Pacific	7
Europe	61
Latin America and the Caribbean	5
North America	11
Not Specified	2
Total	**91**

Figure 2.1 highlights the manner in which the respondents use LCA information. This information has the potential to inform the link between the LCI, LCIA and LCM elements of the UNEP SETAC Life Cycle Initiative. Specifics were supplied for “Other” by the respondents who were assessing the potential for the methodology to support programmes within an intergovernmental agency; and research into, and the development of, LCA methodology. This figure demonstrates that the majority of respondents either conduct LCAs in isolation, or use LCAs to support decision making processes. The largest class of decisions supported are industry decisions.

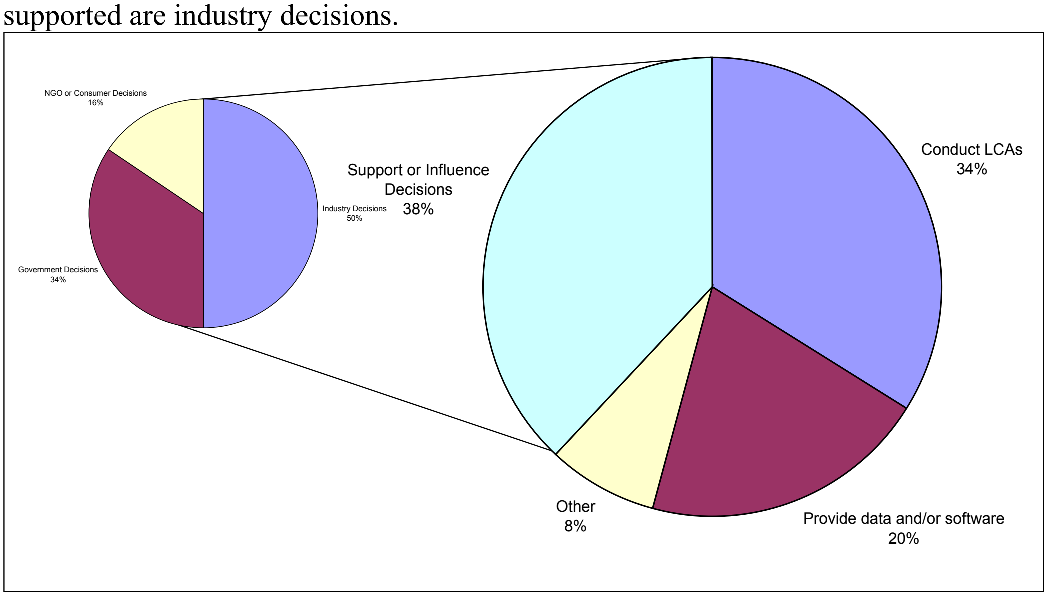

Figure 2.1 Breakdown of how respondents use LCA, with further resolution on decisions supported

Respondents were also requested to highlight the stage of LCA which most often informs their decision making (Figure 2.2). This information should be used in integrating planning between the LCI, LCIA and LCM elements of the Life Cycle Initiative. This figure demonstrates that a significant majority of the respondents use a combination of LCI and LCIA in their work. The percentage of respondents basing decisions on LCIA (24%) should also be used to support the significance of developmental work in LCIA.

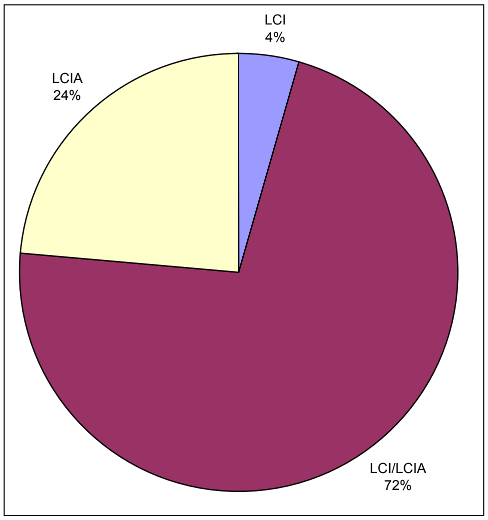

Figure 2.2 Stages of LCA used to inform decision making by respondents

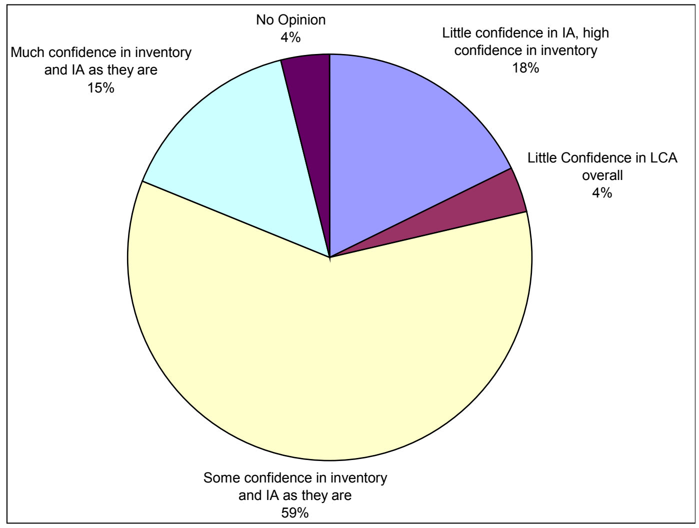

Figure 2.3 Details of respondents' confidence in LCI and LCIA information

Respondents also described their perception of the credibility of LCA methodology. Figure 2.3 details these perceptions. It indicates that, while the users of LCA have some confidence, they are also conscious of the limitation of LCA outputs, especially in industry according to specific comments. Additional comments are included in the background document on User Needs.

2.2 Issues in LCIA

The user needs survey provided the user with the opportunity to select important issues among a set of 13 listed issues. Background report I describes in detail each of the issues included in the survey.

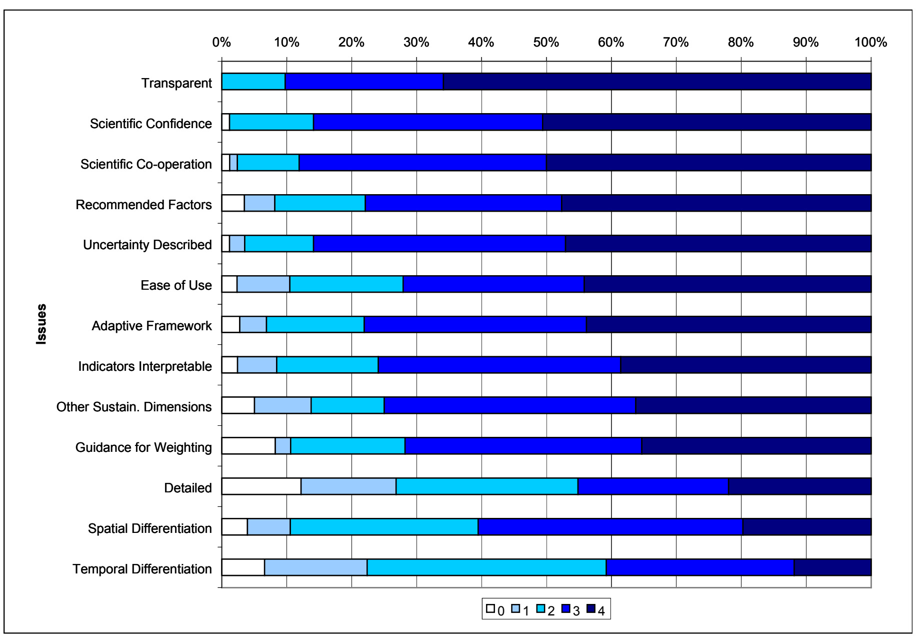

Figure 2.4 Agreement with the stated Issues in the survey: a score of 0 expresses complete disagreement and a score of 4 complete agreement with the issue as stated.

From these results the top four issues can be identified to be:

- Need for transparency in the methodology

- Need for Scientific confidence
- Need for Scientific co-operation
- A recommended set of factors and methodologies should be developed

In second priority, the initiative should look at developing an adaptive framework compatible with other dimensions of sustainability, easily interpretable indicators provide recommended factors and guidance for weighting enabling an improved ease of use. The development of models with spatial and temporal differentiation and higher level of details come as last priorities, although around half of the surveyed persons still gives scores of 3 and 4.

2.3 Impact categories to be included in LCIA

The participants in the survey were asked to set priorities among multiple impact categories. Figure 2.5 summarizes the significance that respondents placed on impact categories included in the survey.

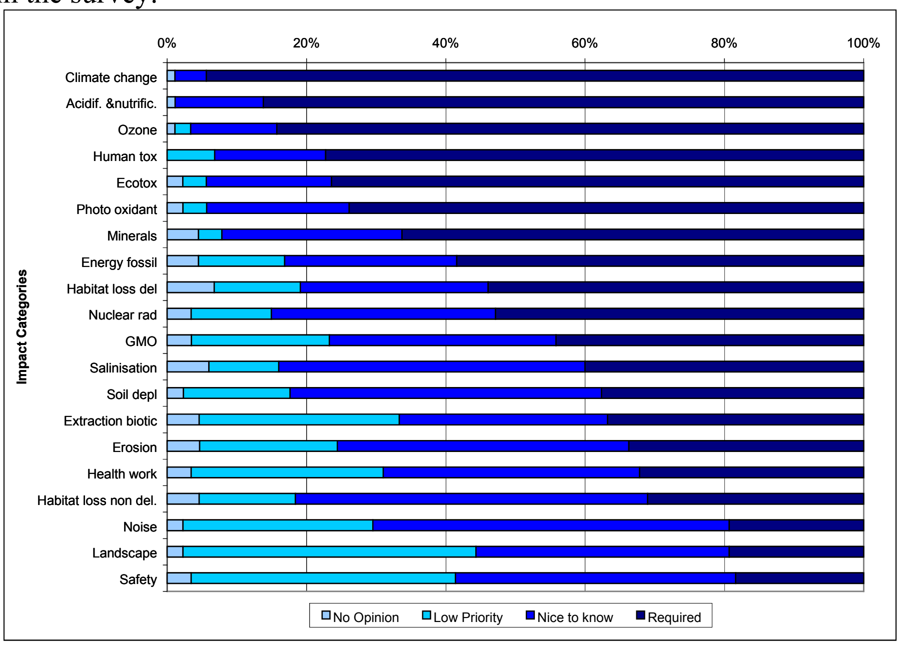

Figure 2.5 *Importance of Impact Categories included in Survey*

This implies that the traditional impact categories are preferred and have been prioritised. However, when this data set is contrasted with that obtained from the non-traditional LCA countries concerns did differ. In forming this conclusion the responses received from Africa; Latin America and the Caribbean; and Asia and the Pacific have been contrasted with the overall set of responses. In developing Figure 2.6, only those impact categories where the difference in the sum of scores for "Required" and "Nice to Know" between the overall survey respondents and the regional survey respondents was greater than 10% have been included. These impact categories have been arranged according to the magnitude of the differences in scores. This figure demonstrates that the concerns of these regions do differ quite significantly from those expressed by the overall survey respondents. From this information it can be seen that the most significant difference between the overall results and the region specific results were recorded for **salinisation** and **erosion**.

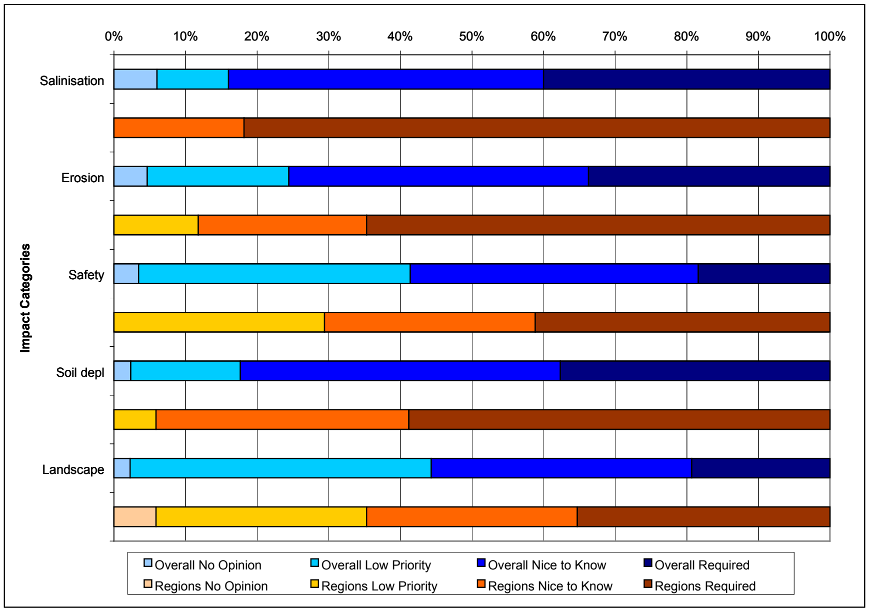

Figure 2.6 Specific concern to regions previously not engaged with the development of LCA (red) compared to concerns in the overall user need assessment (blue)

It has been noted that survey responses are dominated by those from academia. In order to determine whether this has skewed the results presented in this section a similar process was conducted as has been described above for the non-traditional LCA regions. In general, responses from the non-academic audience presented with similar results as the overall audience. Figure 2.7 shows restricted differences for a few categories, the non-academic audience being less favourable to the inclusion of non traditional categories such as safety or landscape.

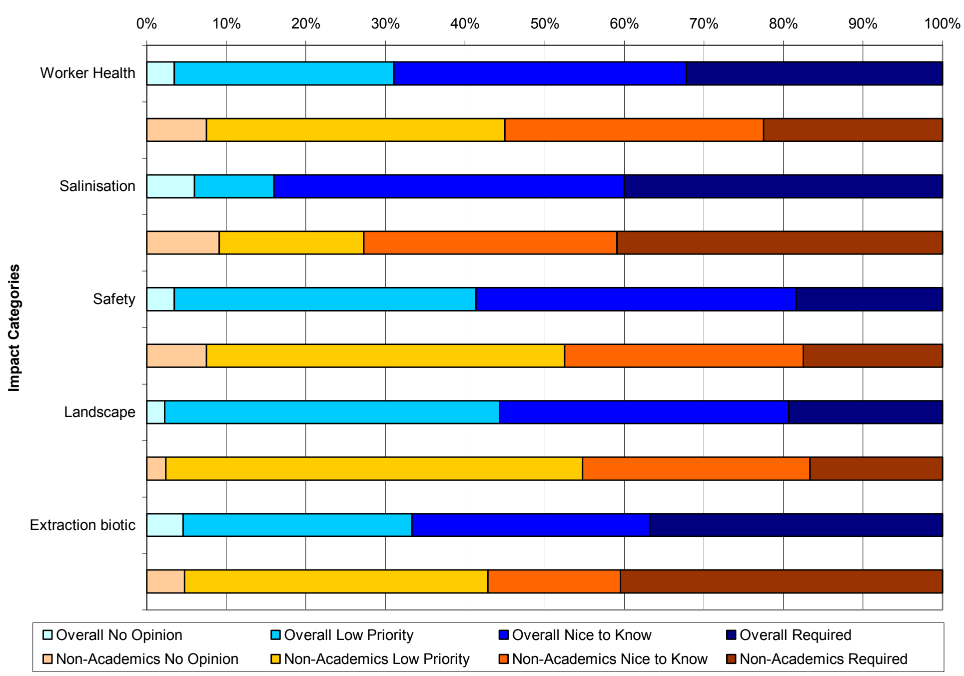

Figure 2.7 Issues of Specific concern to non-Academic respondents (red) compared to concerns in the overall user need assessment (blue)

Table 2.2 Significance of impact categories. *"Required column": more than 50% Required; impact categories which scored 70% when "Required" and "Nice to Know" are added in the "Nice to Know" column*

Required	Nice to know	Low priority
• Climate Change • Ozone Depletion • Habitat loss as result of deliberate actions • Human toxicity • Eco-toxicity • Acidification and Eutrophication • Photo-oxidants • Extraction of Minerals • Energy from Fossil Fuels • Nuclear Radiation • ***Water usage	• *Salinisation • *Erosion • *Soil Depletion • Habitat loss as a result of indirect actions • Noise • Use of GMOs	• *Health of workers • **Safety • Landscape • Extraction of biotic resources

* classified as "required" if only answers from non-traditional LCA countries are considered
** classified as "nice to know" if only answers from non-traditional LCA countries are considered
*** Not in the initial list, but explicitly asked for by a number of respondents

A summary of the prioritisation of impact category results is included in table 2.2. In addition, water pollution, water usage is seen as a significant focus for a number of respondents. Requirements specific to different industries and regions are detailed in the survey report: A conclusion drawn from this section is that the specific needs of developing countries, especially salinisation and erosion need to be addressed by the UNEP/SETAC Life Cycle Initiative, and that specialists from the developing countries (and industries typically found in these countries) need to be included in this development.

2.4 Outcome of the LCIA workshops

During the definition study, different workshops have been organised within or in collaboration with the Life Cycle Initiative to enable direct inputs of a broad range of participants from different continents to the definition of the LCIA work programme:
- The Montreal Workshop in collaboration with the mining industry (ICMM) and APEC (Asia-Pacific economies) brought together specialists from different fields related to minerals and metals, to discuss how to improve the relevance of LCA (including LCIA) in this field (15 to 17 April 2002).
- The Vienna workshop focused on the establishment of a flexible LCIA framework, including midpoint and damage (16 May 2002).
- The Tsukuba Workshop was organized by AIST open "Gateway to Life Cycle Impact Assessment for APEC Member Economies (7 November 2002).
- The Barcelona LCIA workshop enabled to present the main proposal of the Draft Author Team to a larger audience including industry partners, providing interesting feedbacks.

Main inputs are summarized below, the Background document II presenting a more detailed report on these LCIA workshops (Background II_Overview of the LCIA work meeting results1a.doc), while a book reports main results of the Montreal workshop (Dubreuil et al., 2003).

For LCIA, the Montreal workshop addressed metal mining and lifecycle impact assessment of human and environmental toxicity. For resource depletion it emerged that, as a result of the availability, recyclability and substitutability of metals, the depletion of resources is not of the highest priority; the expression resource availability or access to resources may be more helpful. For physical impact and land use, volumes alone is not an appropriate indicator in LCA. Surface used and other impact categories such as acidification (acid mine drainage) and salinisation are much more relevant and are site specific. Metals-specific research issues need to be investigated to improve current approaches for addressing toxicological impacts in LCA. These issues include: transformation / speciation, fate and transport, bioavailability, background conditions and effects.

In conjunction with developments in different initiatives, the ***Vienna workshop*** opened new possibilities to reconcile approaches based on classical impact category indicators (sometimes called midpoint) and damage oriented approaches (sometimes called endpoint):
- The structure proposal for the LCIA framework was perceived as an interesting and sound basis to build up a flexible framework for LCIA within the life cycle initiative.
- The framework should offer a good flexibility to enable to choose different levels of sophistication, to select different points for weighting and to incorporate different values & worldviews. The level of detail should be restricted to what is really necessary in order to avoid the introduction of debatable statements.
- It is always useful to try to model up to endpoint or damages, but it is essential to quantify and specify related uncertainties.
- Case studies are needed to test new indicators, method feasibility, etc.

Finally three working group addressed the three above described aims:
I) The first working point provides initial inputs to define a consistent LCIA framework, including area of Protection.
II) The second working group gives a first proposal of impact categories and of potential indicators both at midpoint and endpoint levels.
III) The third working group provides a preliminary list of new impact categories, especially for developing countries with first comments on their scope.

The Tsukuba Asia-Pacific Economic Cooperation (APEC) workshop showed that there is some convergence between damage and midpoint impact modelling and there is potential to adapt much of what has been done in Europe for countries in the APEC region, possibly based on environmental "archetypes" rather than strict geographical areas.
- Resources are needed to further this work, however a network of scientists has been initiated, willing to assist and promote the development of an LCIA model(s) for the region.

In the Barcelona LCIA workshop, the discussion on the preliminary framework clearly shows two main points of view:
- On the one hand, several users emphasize the need to stay at midpoint level, further developments and methodological improvement being clearly needed at that level (a midpoint level approach was not considered old fashioned). It is therefore important not to put all effort on damage assessment, but to keep action for midpoint method development. There is also a risk of loosing confidence if methods with too high uncertainties are recommended.

- On the other hand, some users emphasize an interest in damage assessment, e.g for communicating to governments, for understanding relevance or answering industrial needs. The survey reveals that these two points of view do not occur preferentially among academia or industry, but are held almost evenly among the groups.

Thus, the proposed framework should enable both possibilities at midpoint and damage levels in a consistent way. Care must be taken to keep actions at both midpoint and damage level. It must be clear that having an encompassing framework does not mean that we will indeed recommend to model up to damage level or address all mentioned points (e.g. man-made environment), but it is useful to be able to incorporate further knowledge and methods in the future. Recommendations will be developed further in the LCIA programme itself, a quantitative approach to damage assessment being retained only if additional uncertainty is not too high. In addition, it is of high priority to develop the basic criteria to select and eventually recommend in later stages method and for the best point to stop the quantitative assessment. Value choices should also be well identified and documented (natural science based parts and social science based). The framework should also enable the user to consider not only damages but also benefits (negative damages !) of LCI results.

The proposed framework has to be flexible enough to enable the incorporation of new categories or of different value systems without major change. However, it has to be rigid enough to enable a consistent structuring of the way impact categories will then be described. A point of attention is that the relevance for application and management of the results should be made clearer. For a first step the interest of the application-orientated experts is to have an established set of indicators that can be used by industry and government in their decision-making, covering a broad number of LCI results (e.g. ability to cover a large number of chemicals). Moreover, the concerns of different regions in the world should carefully be taken into account and the link to inventory-based life-cycle performance indicators like waste per product output should be considered.

3. Objectives of the Life Cycle Impact Assessment Programme

The LCIA Programme aims at the enhancement of the availability of sound LCA data and methods and at guidance on their use.

The guidelines for the life-cycle initiative must be based on a recognition that the scientific development for LCIA is ongoing, must avoid establishing one very specific method or dataset, and must stimulate innovation. On the other hand, the guidance needs to discourage a situation in which “anything goes”, as this can lead to confusion and misuse of the methodology. Therefore guidance and recommendations are needed. Because the ISO 14042 framework leaves room for a very wide variety of approaches and interpretations, the LCIA application is rather difficult for non-experts to interpret or apply. Furthermore, since the publication of the ISO standard, new developments like the concept of Midpoint and Endpoint or Damage approaches have emerged. These methods need to be better explained and better integrated.

In parallel, the LCIA programme will stimulate input of specialists of different fields into LCA, at least for review work and bring scientist and industrialists to collaborate closer in addressing practical and scientific challenges, leading to better quality and easier application of LCIA methods.

In this context and according to the user needs survey, the LCIA programme has the following objectives:

1) **A consistent conceptual framework for LCIA, including the relationships with the LCI results on the one hand, and damages on the other hand**
   This framework will describe how impact pathways (composed of environmental processes) link the LCI results to the midpoint indicator(s) and the damage indicator(s), based on impact pathways. Preferably this framework can be the same for the midpoint

and the damage approaches. The initiative leaves it up to the user to decide if midpoint indicators or damage indicators are used for the decision. The initiative intends to provide sufficient guidance to the user to base this choice on. This framework can at best be represented in a flow diagram, in which impact pathways as well as their (intermediate) results are modeled in series of modules requiring specific input and output. In this way the framework provides a modular structure that provides a transparent basis for researchers with specific expertise to develop appropriate models that fit into the framework using the same inputs and outputs.

This flow diagram enables the choice of category indicators at different midpoint levels (like global warming potentials for climate change) and at damage level (like forecast indicators for impacts on human health in term of years of life lost: see Appendix 1 for definitions).

2) **Recommended** list of impact categories and category indicators, possibly consisting of sets at midpoint and at damage level, including new ones for developing countries**
"Generic situation dependency*" can be introduced to account for those main archetypical situations leading to important variations in characterisation factors and therefore justifying a differentiation.

3) **Recommended methodologies for the calculation of characterisation factors for different impact categories**
Models of impact pathways used to calculate characterisation factors will be recommended for the different impact categories, including transparent and documented descriptions of main assumptions and model choices. The initiative intends to describe assumptions and choices and give recommendations on how to handle and document them, as this will also provide guidance to both users and model developers on how to increase consistency and transparency.

4) **Recommended characterisation factors for the different impact categories, to be included in the database on LCIA**
These factors (with the option of generic situation dependency*) for the different impact categories include documented uncertainties and limitations (with a link to weighting procedure) and cover a broad range of LCI results. These will be incorporated in an LCIA database to facilitate application by users.

5) **Stimulation of collaboration between scientists and industrialists**
The LCIA programme will stimulate input of specialists of different fields into LCA, at least for review work, and bring scientists and industrialists to collaborate closer in addressing practical and scientific challenges, leading to better quality and easier application of LCIA methods.

* Generic situation dependency: different situations where LCA is used in different types of application are identified. The different situations may pose different requirements to the LCIA methodology. For each of these situations, generic recommendations on LCIA methodology are given. The recommendations are thus generic for each situation. **Recommended Practice: Practically, we are facing an interesting challenge: the need to bring together science and pragmatism, to obtain characterization factors and data sets that are scientifically defendable, relevant to the decision endpoints, and practical.

4. Presentation of the initial general framework and of general tasks

Section 4.1 develops an initial proposal for the framework, needed as a basis to develop a work plan. This preliminary proposal will itself be further developed through later activities proposed in section 4.2.

4.1 Framework initial description

a) Background

LCIA methods aim to connect, as far as possible, each life cycle inventory (LCI) to its potential environmental damages, on the basis of impact pathways (impact pathways are composed of environmental processes like a product system consists of economic processes).

According to ISO, LCI results are classified in impact categories and the category indicator can be located at any place between the LCI-results (interventions) and the category endpoint. Based on this format, two main schools of methods developed:
a) Classical impact assessment methods (e.g. CML: Guinée et al., 2002, , EDIP: Hauschild and Wenzel, 1997) which stop quantitative modeling relatively early in the cause-effect chain to limit uncertainties and group LCI results in what we call here midpoint categories, according to common themes: i.e common mechanisms (e.g. climate change-global warming) or commonly accepted grouping (ecotoxicity).
b) Damage oriented methods such as Ecoindicator 99 (Goedkoop and Spriensma 2000) or EPS (http://eps.esa.chalmers.se/download.htm), which try to enhance relevance by modeling (sometimes with high uncertainties) the cause-effect chain up to the endpoint or damage.

In conjunction with developments in different initiatives (the Recipe project: http://www.leidenuniv.nl/interfac/cml/ssp/publications/recipe_phase1.pdf; Impact 2002: http://gecos.epfl.ch/lcsystems/), the Vienna workshop opened new possibilities to reconcile these two approaches. Building up from the ISO framework (ISO, 2000) and from these new developments, the present framework takes advantage of both approaches, by grouping similar category endpoints in a structured set of damage categories. At the same time, it keeps the concept of midpoint categories, each midpoint category relating to one or several damage categories. This flexible framework is presented below in a somewhat encompassing way, whereas the definite choice of midpoint and endpoint categories can be adapted or restructed to choose different levels of sophistication, to select different points for weighting and to incorporate different values & worldviews.

b) Principles

To achieve the connection between LCI results and environmental damages, types of LCI results with similar impact pathways (e.g. all substance flows influencing stratospheric ozone concentrations) have been grouped into impact categories at midpoint level, also called midpoint categories. A midpoint indicator per midpoint category is defined in view of comparing and characterizing the substance flows and/or physical changes tabled as LCI results, which contribute to the same midpoint category. The term 'midpoint' expresses that this point lies somewhere on the impact pathway as an intermediate point between the LCI results and the damage or end of the pathways. In consequence, a further step may allocate these midpoint categories to one or several damage categories, the latter representing quality changes of the environment being the ultimate objects of human societies concern. A damage indicator is the quantified representation of this quality change. In practice, a damage indicator is always a simplified model of a very complex reality, giving only a coarse approximation to the quality status of the item.

Definitions of LCI results, of midpoint and damage categories or indicators are given in Appendix I, which details the used terminology.

c) The overall scheme of the proposed framework

Figure 4.1 shows the overall scheme of the proposed framework, linking all types of LCI results via the midpoint categories to the damage categories. An arrow means that a relevant impact pathway is known or supposed to exist between the two corresponding elements.

It would be desirable to draw reliable quantitative impact pathways connecting each "relevant" type of LCI results to midpoint indicators and eventually to the corresponding damage indicator. This ambitious task cannot be attained for the time being for all types of impacts, mainly due to current limits of scientific knowledge. Since midpoints are often chosen at the point where further modeling becomes too uncertain, currently available information on the last sections of some impact pathways, between midpoint and damage levels, is sometimes particularly uncertain (dotted arrows). This causes a dilemma between certainty and completeness of LCIA. An answer to this dilemma is to model quantitative impact pathways only where reasonably reliable information is available (full arrows). Adequate scientific information may often be unavailable for the links between midpoints and the damage categories: It is then desirable to provide information on the connection of these midpoint indicators to quality changes at damage level at least by supplying a verbal statement describing the expected relationships. The LCIA framework will therefore contain a coordinated mix of a) fully quantitative links from LCI results to damage indicators going through midpoint indicators and b) both fully quantitative links to midpoint and simple verbal information on the possible influence from the midpoint indicators to the respective damages. When only semi-quantitative or verbal information is available, interpretation (and weighting, if any) is to be performed at the level of midpoint indicators.

It should be pointed out that, in some cases, there can be significant interactions among different midpoint indicators. Soil erosion will in turn have strong effects on global warming. Thus, it is very important to define whether overlap or any links among to midpoint indicators will be taken into account in the definition of pathway at the LCI level. Otherwise, it will be necessary to introduce some explicit overlapping pathway between two different midpoint indicators. This is important when the interpretation is only performed at the level of midpoint indicators. If damage indicators are used for the interpretation of the results, then the overlap effect can be taken into account in the links between midpoints and damages. However, some specific synergic effect should probably be considered which enhances or reduces the damage related to a specific midpoint, just as health effect of contaminants should be analyzed together and not separately.

Traditionally, LCA was mainly related to those environmental damages which are mentioned in figure 4.1 under human health (Morbidity & Mortality), biotic natural environment (occurrence of species) and abiotic natural resources (ores, energy carriers, water and soil depletion). Though not compulsory, the framework could also enable inclusion of the damages to the Man-made abiotic & biotic environment (Buildings and crops). Until now, only very limited attention was paid in LCA to damages on the biotic natural resources (caused by extraction of wild animals and plants), as well as on the abiotic natural environment (by degrading and destructing materials, structures and non-living landscape elements). Though probably not a priority at the present stage of the Life Cycle Initiative to keep the framework simple and to avoid effort dispersion, it will be required to find out to what extent it is desirable and practical to also include these categories. Each of these damage categories is treated in more detail in the discussion of section 6.

Similarly, the midpoint categories shown in figure 4.1 provide an initial view of most significant impacts but are not compulsory and could be either simplified or complemented. Possibly, some midpoint categories currently cause negligible effects at the level of the damage categories selected, so that their modelling can be delayed. It is also conceivable that it is practical to merge certain midpoint categories. Each of these midpoint categories is discussed in the work plan of section 5 and in more detail in the related background document III.

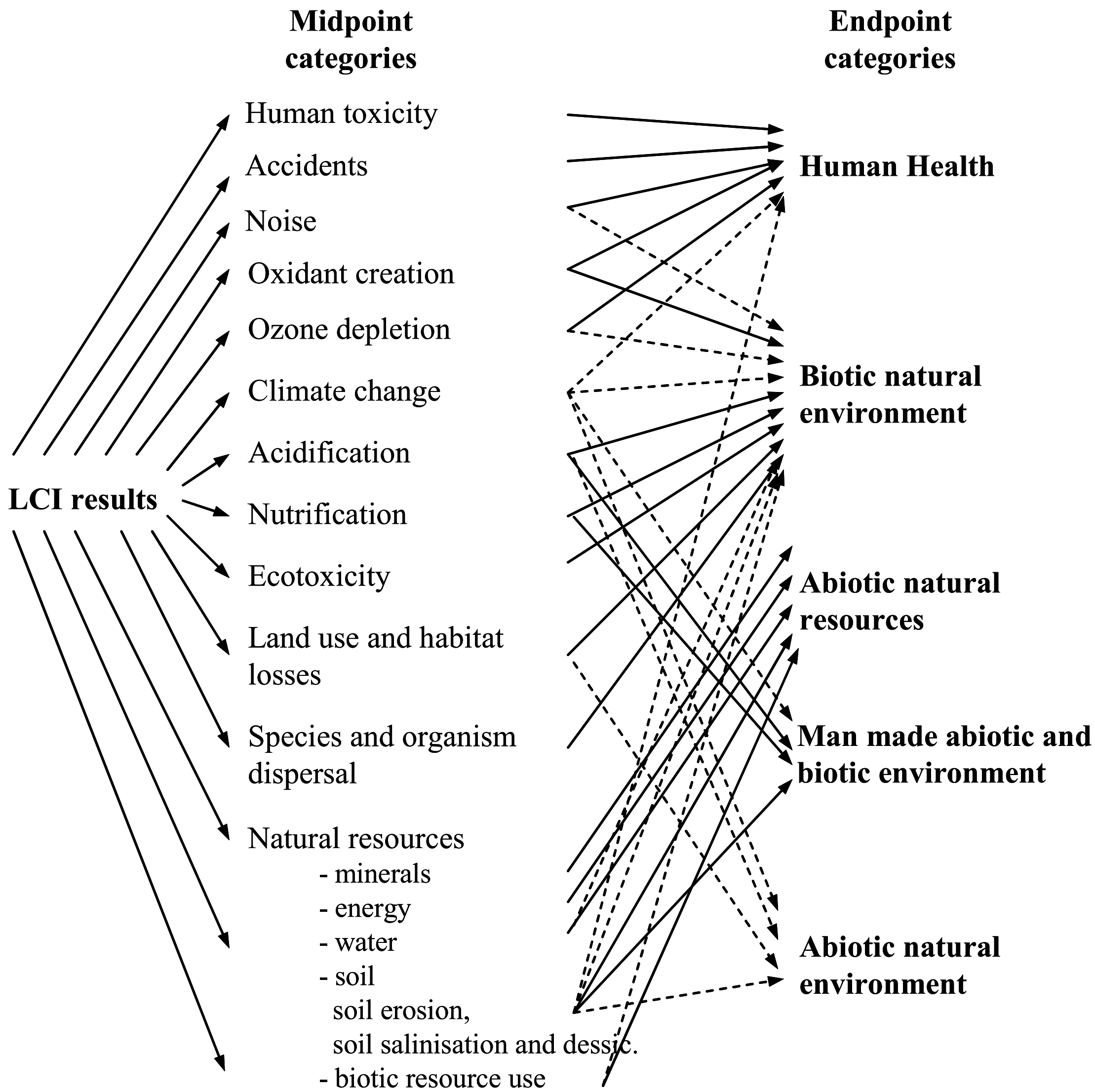

Figure 4.1 General structure of the LCIA framework. Dotted arrows: currently available information between midpoint and damage levels is particularly uncertain according to preliminary analyses.

An alternative view of midpoint categories and damage categories is presented in table 4.1. Table 4.1 is based on an adapted version of the conceptual structure of LCIA contained in chapter 8 of H.A. Udo de Haes et al. (2002), where damages are grouped in the upper part of table 4.1 according to several dimensions:

- According to physical objects, in horizontal axis (human life, biotic and abiotic environment);
- According to different sets of values corresponding to different damages, in vertical axis (intrinsic and functional values: vertical axe); and
- According to different Areas of protection, in different colors or letter-types (Human health, natural environment, natural resources, man-made environment).

These areas of protection, also called safeguard subjects, represent operational groups of items of direct value to human society. The different damage categories are damages to these areas of protection. Whereas, an initial attempt was made to retain the area of protection as the main basis for grouping damage categories, it proved very difficult to reach consensus with an international team on the definition of these areas of protection. Agreement on definition and concept of damage categories proved easier and was retained as the basis for discussion and classification.

Life Support Functions are introduced for climate equilibrium and for 'soil fertility & bio-geochemical cycles' to help understanding the values behind a midpoint category. For example climate equilibrium can be considered as having an intrinsic value to be protected from damages. (For further explanations referring to 'life support functions', see Udo de Haes et al. 2002).

The lower part of table 4.1 lists the midpoint categories, with 2 different types of links. On the right side, symbols X mark the impact pathways to the damage categories, whereby the number of X represents the importance of the link. Towards the left side of table 4.1, the link between midpoint categories and the 'life support functions' is shown. A more detailed discussion of midpoint and damage categories is presented in chapters 5 and 6, the damage category biotic natural resources being discussed together with biotic natural environment (6.2).

Table 4.1 Classification of damage and midpoint categories according to physical objects, societal values and the following areas of protection: Human health (HH), Natural Environment (NE), Natural resources (NR), Man-Made environment (MME). Elements that have often not been considered in LCA are ***in italics***, elements that could be considered outside the scope of environmental LCA or related to other dimensions of sustainability are in ***small italics.*** **Damages are ordered with the most natural at the top and the most man-made at the bottom.**

*** also linked to biotic environment**

X link of lower significance, XX significant link, XXX highly significant link

Life Support Function	Objects considered	Humans	Biotic environment	Abiotic environment
			Plants and animals, species	Freshwater, ores & energy carriers Built environment
	Damage categories:			
	Damages related to intrinsic value and corresponding indicator.	**Human health** Morbidity & Mortality (DALY's)	**Biotic natural environment,** Species* (PAF or PDF)	***Abiotic natural environment*** *Natural materials and structures, landscapes elements* *Man-Made environment: Cultural heritage***
	Damages related to functional values	*Human resources (e.g. labour loss due to illnesses)*	**Biotic natural resources** e.g fish (Net productivity?) ***Man-made biotic environment:*** *crops, aquaculture ($)* Domestic animals	**Abiotic natural resources**: ores & energy carriers, soil quality. (MJ Energy to close cycle) ***Man-made abiotic environment:*** *Materials, buildings, etc. ($)*
Life Support Function	**Midpoint categories:**			
'Climate Equilibrium'	Climate change	XX	XX	X
'UV protection'	Stratospheric ozone depletion	XX	X	-
	Human toxicity, *incl. Work environment, indoor pol.*	XX		
	Ionising radiation	XX	X	
	Non-ionising radiation	X	X	
	Accidents	XX	X	
	Photo oxidant formation	XX	XX	X
	Noise	XX	X	-
	Acidification		XX	X
'Soil fertility & bio-geochemical cycles'	Eutrophication		XXX	
	Ecotoxicity		XX	
	Land use & habitat losses		XXX	XX
	Species &organism releases	X	XX	X
'Soil fertility & bio-geochemical cycles'	**Abiotic resource use**: Energy extractions Mineral extractions Water resource use Soil quality Biotic resource use		 XX XX XX	 XX XX XX XX

d) Impact pathway descriptions

Table 4.2 shows a checklist with the desirable properties of the description of impact pathways.

Table 4.2 Checklist for impact pathway descriptions

Clarity and documentation:
- clearly described beginning point for the analysis (LCI results or indicator values of another impact pathway)
- clearly described end point for the analysis (nature of the output, its indicator, and its target recipient)
- explicit documentation provided of models and variables including the conditions under which the model is valid, in terms of temporal and spatial validity and other boundary conditions

Technical characteristics:
- adequate description provided of key aspects of the impact pathway (different types of information covered)
- describing marginal impacts rather than average
- applying continuous variables rather than discontinuous
- relevant for the further integration and modelling towards the damage indicators
- modular rather than aggregated
- quantifiable rather than qualitative
- open to validation by combining bottom-up processes with top-down partitioning of observed global results over their causal factors
- validated by comparing the model result to verifiable outcomes

Availability of data
- feasible through availability of the needed data for the most frequent contributors encountered in LCIs

Uncertainty characterisation:
- uncertainty resulting from modelling assumptions,
- uncertainty of available data for variables and background data
- uncertainty of model relationships
- uncertainty introduced as a result of model aggregation and the allocation of impacts (for example uncertainty related to spatial (and temporal) differentiation)
- inclusion of all significant parts of the environmental process, its inputs or outputs
- sensitivity analysis to identify the importance of different causes of uncertainty
- suggestion of ways for reduction of uncertainty through collection of more relevant data or improvements in modelling

e) Relation to weighting

In order to support his judgement, the decision maker can obtain from LCIA a set of figures indicating midpoint or damage impacts together with standardised statements describing the possible influence of such indicator quantities on the extent of damage on Area of Protection.

If the decision maker needs to come to a comprehensive environmental judgement including all damages and/or other sustainability dimensions, he has to execute an implicit or explicit weighting of the various impacts or damages, which involves a number of value judgements: There is no scientific procedure for finding the "right" exchange ratio between a lost year of human life and the loss of a plant species through extinction.

On the one hand, providing recommended weighting factors is clearly not part of the Life Cycle Initiative project, as UNEP missions explicitly leave value judgments to users. On the other hand, the user need survey confirms the desire to provide guidance to users on how to derive consistent weighting procedures and sets of weighting factors for LCIA results (see activities under 4.2)

f) Relation to other sustainability dimensions and to other environmental tools

LCA can give an important contribution to the environmental dimension of the concept of sustainability towards better clarification and operationalisation. So far, LCA has rarely included the economic and societal dimensions of sustainability. Nevertheless, the high level of structural consistency and transparency of the LCA framework makes this a potentially useful framework for the future modelling of potential impacts and consequences within the economic and societal parts of the sustainability concept. Appendix 1 illustrate this by providing a parallel between the above presented framework and framework more broadly used in sustainability assessment such as the DPSIR framework (http://esl.jrc.it/envind/theory/Handb_03.). The DPSIR framework assumes cause-effect relationships between interacting components of social, economic, and environmental systems, which are

D Driving forces of environmental change (e.g. industrial production)
P Pressures on the environment (e.g. discharges of waste water)
S State of the environment (e.g. water quality in rivers and lakes)
I Impacts on population, economy, species and ecosystems (e.g. water unsuitable for drinking)
R Response of the society (e.g. watershed protection)

It is proposed to develop this further in synergy with the LCM programme (see 4.2 below). It must be acknowledged that other environmental tools can complement LCA and LCIA in to addressing specific decisions. Main specificities of LCIA consist of:

a) enabling a comparative characterisation of LCI results expressed in terms of a guantity such as a functional unit but not localised (this is typical in many LCA studies where location of emissions only have to be roughly characterised for a site-dependent characterisation; [see Udo de Haes et al., 2002].
b) covering the large range of known impacts to avoid generating a new problem once solving another one.

LCA can be complemented by other tools within a Life Cycle Management toolbox, such as e.g. Risk Assessment for the maximal Risks due to localised emission of chemicals, and Environmental Impact Assessment for local impact due to a new construction or a new production facility.

4.2 Summary of the proposed tasks

This section defines the general activities, whereas more detailed actions are described in chapter 5 for the midpoint categories and at the end of each subsection of chapter 6 for the damage categories.

a) framework development

To develop further consensus on the different elements of this framework, a workshop is foreseen on framing LCIA, organized by Jane Bare, US-EPA, on May 1, 2003, at the SETAC Hamburg conference. It will also enable a more detailed study of what should be the scope of damage and midpoint categories to consider in priority.

The framework elements are detailed in a complementary report looking in more detail at the definition of area of protection and damage categories, which can serve as a basis for further developments.

In addition, it is of high priority to develop first the basic criteria and guidelines to select and recommend methods for the later stages and adequate points to stop the quantitative assessment. Guidelines should also cover the starting points and the decision-making framework (e.g. how to deal with time integration, spatial integration, population distribution, etc.).

b) relation to LCI, LCM and other sustainability dimensions, guidance for weighting

In all activities related to midpoint categories (section 5), the different interfaces with LCI and the requirements on LCI data should be clearly identified and listed. This is especially important for flows that are often not fully modelled down to elementary environmental flows.. In priority waste treatment processes should be treated as unit processes in LCI.. To facilitate the assessment, it would be of high interest for industry, to elaborate process models for a series of most common waste treatment alternatives and technologies (landfill, waste incineration, cementary incineration, etc.) which would enable to translate mass of waste into emissions. Long term emissions of e.g. metals for landfill need special care to deal with in LCIA, as releases and impacts can take place over thousands of years. This emphasizes the need to take e.g. bioavailability and effective residence time into account for very persistent substances, whose impact could be strongly overestimated otherwise.

The compatibility between the three LC initiative programmes should be tested through appropriate case studies going through all three programmes and proving the usefulness of latest development for decision-making.

On the one hand, providing recommended weighting factors is clearly not part of the Life Cycle Initiative prospect as these are linked to personal value judgement. On the other hand, the user need survey confirms the need to provide guidance to users to derive consistent weightings procedures and sets for LCIA results. The writing of such a guidance document on consistent weighting procedure is therefore an important activity.

c) Facilitating application and data availability

In cases where the development of an LCIA method is relatively complex, its application can still be made relatively easy so long as adequate characterization factors are made readily available. One main task is therefore to make recommendations and results of the LCIA programme widely available for users. This should include the creation of a worldwide accessible website including:

- LCIA guidelines, as described under the framework development.
- Downloadable recommended factors in midpoint and damage categories (in an easily worldwide accessible format, e.g. excel spreadsheet), for a wide range of LCI results.
- Downloadable models to calculate new characterization factors.
- An adequate description of key aspects of the impact pathway (different types of information covered), and proper documentation of the applied models.

Strong attention should be given to data availability and accuracy, as data reliability is at least as important as model selection.

Until recommended factors and models are defined, the website could provide links to currently used methods and characterization factors at midpoint and damage levels, enabling users to easily access state-of-the-art methods and to fill-in the different parts of the LCIA framework. Once, recommended methods have been retained, the initiative should lay out a clear process for revising the framework, e.g. on a triannual basis.

In addition, the three programmes together should provide a library of case studies illustrating good/successful and bad/unsuccessful uses of LCA methodologies in practice, including LCIA.

5. Workplan per midpoint category

This section summarizes scientific and practical challenges and proposes further activities for 12 different midpoint categories. **Background document III** provides complementary and important analyses of these midpoint categories by describing the impact category and the related impact pathways and by carrying out a short and non-exhaustive review of the state of the art. It also considers some existing bases and resources to address these challenges, leading to proposed actions toward recommended practice. The link to damages is shortly analysed for each midpoint categories, whereas the more detailed discussion on damage categories and indicators is presented in chapter 6.

For each midpoint category there are tasks that relate to required achievements as noted in the matrix below and there are activities linked to these tasks. These tasks and activities can differ according to the following dimensions:
a) The time-span and amount of effort needed: short-term achievements, as well as middle- and long-term research
b) Their expected achievements such as
- review on state of the art of existing projects and actions,
- initiation of new fields and definition of the analysis framework for further method development,
- development of base models by identification of improvements to individual modules,
- recommendations on models and characterization factors, and

c) The type and format of activities: punctual workshops involving experts of different fields or middle term task forces to arrive to recommendations.

The required approaches depend on the state of the art in the considered categories:
a) For domains where factors are mostly determined outside the LCA community, such as ozone depletion (5.1), climate change (5.2) and photo-oxidant formation (5.5), model selection could be mostly based on the review of outputs of related projects, with organization of a state of the art workshop leading to recommended models and eventually factors (e.g. in the first half of 2004 for these categories).

b) For other domains where a significant level of activity has been carried out in LCIA for a long time, such as for human- and ecological toxicity impacts (5.3 and 5.9), there is a need for more specific changes and incremental improvements. Once a specific area of improvement is identified, progress could be initiated by issuing a challenge to the community of practitioners. For example, starting from a base model developed by a group of experts, other scientists can be invited to present alternative models or partial improvements of individual modules within a common framework. In short, the Life Cycle Initiative could stimulate the process of using a base model developed in ongoing projects opened up to other international teams providing inputs.

c) For categories where middle term developments are typically needed such as for land use (5.10) or new categories in natural resources (5.12), initial workshops could be run to create the basis and initial consensus on the impact pathway framework, then leading to more defined and dedicated tasks.

d) Finally, long term research is needed for categories that to date have received little attention in LCA and for which the scientific foundations are still limited. Examples are exposures to non-ionising radiation or dispersal of invasive species. For these categories workshops could also be adequate to initiate new fields and define the analysis framework for further method development.

The 12 categories are addressed according to the order of figure 4.1, summarizing scientific and practical challenges together with proposed tasks and activities.

Category	**5.1 Ozone depletion**
Challenges	It is desirable to improve the scientific knowledge regarding the impact pathways between LCI results and the reduction of stratospheric ozone concentration as a function of time and geographical area. Although it is well known that issue exists, as mentioned for climate change below, the largest uncertainties result from modelling relations between impacts at midpoint level and damages. We note here that LCIA for ozone depletion must build on the expertise from other scientific fields rather than taking over the tasks from these fields. So the challenge here as well as for other categories is to learn how to extract from complex assessments in other fields the information that is relevant and informative for LCIA.
Activities	Acceptable propositions for modelling the full network of impact pathways regarding stratospheric ozone depletion are available, e.g. Goedkoop and Spriensma (1999: http://www.pre.nl/eco-indicator99/default.htm), Steen (1999: http://eps.esa.chalmers.se/download.htm), Hayashi et al. (2000 and 2002) who list a number of primary references that they used in developing their approach. In comparison to other parts of the LCIA impact network with a higher priority, it appears defendable to allocate, within the LC-Initiative, only limited resources for stratospheric ozone depletion. In consequence, we propose only activities of level 0 (i.e. reviewing ODP-related projects). One important activity is to model or at least describe the related damages on the ultimate area of protection. To date quantitative modelling only exists for damages on human health and are not readily available for damages on the biotic natural environment. Here again, inputs from WMO/UNEP could be highly relevant to help interpreting the generated damages.
Category	**5.2 Climate change**
Challenges	There is a need for the consistency of approach with the various impact categories, especially for time horizon and background level.
Activities	In comparison to other parts of the LCIA impact network with a higher priority, it appears defendable to allocate only limited resources for climate change within the LC-Initiative, as this is covered by IPCC (Intergovernmental Panel on Climate Change). In consequence, we propose only review activities (i.e. reviewing IPCC-related projects) and suggest that LCIA efforts build on existing national projects to arrive at the most suitable proposal on methods and related factors. We therefore suggest to: - Follow new IPCC developments and analyze the different options offered by the latest results of IPPC. - Consider consistency with fate & effect modelling in other categories (time horizon, background levels) - One important activity is to model or at least describe the related damages on the ultimate area of protection. Here again, inputs from IPCC and from the Japanese national LCA project could be highly relevant to help interpreting the generated damages. There are a number of climate change models that characterise what we in LCA call damage. An important challenge here is how

	to best use these models for LCIA.
Category	**5.3 Human toxicity**
Challenges	- Calculate best-estimate fate factors (intake fractions), including accurate estimates of exposure pathways, especially through food intake. At low and median values of intake fraction, inhalation tends to be the dominant route of intake, but at the high end, ingestion tends to dominate. Thus, the question of bioconcentration in plants and animals is of central importance for substances leading to high intake fractions. - Address essentiality and speciation of metals - Quantify uncertainty (model, parameter, and scenario) associated with different estimates (possibly adopting the categories of Hofstetter 1998 as a starting example for parameter uncertainty and including estimates for the screening methods). - Study the feasibility to identify morbidity endpoints for humans and to extend consequence measures, such as DALYs per incidence, to non-cancer effects. - Address the ability to deal with multiple effects which occur from single chemicals. (e.g., the most severe effects vs. the lowest concentrations causing effects). Address the combined effects of various mixtures – some common (asphalt mixtures, gasoline mixtures) and some less common. - Address the development of simplified methods that can be readily applied for screening with low quality/amounts of data, in a compatible way with more advanced models.
Activities	The following activities are foreseen mostly short to middle term a) Stimulate collaboration between OMNIITOX (http://www.omniitox.net/) model development, TRACI (http://www.epa.gov/ORD/NRMRL/std/sab/iam_traci.htm) development and scientists active worldwide (e.g. Lausanne workshop, December2003), including: - Open challenge to improve individual modules (2003-2004) - Workshops on comparisons between modules and with other models (beginning 2004) - Selection of recommended models and calculation of generic factors corresponding to typical emission situations (end 2004). This could include - Proposal of a modular framework for the estimation of toxicological human health characterisation factors – providing modules for the fate of chemicals, human exposure pathway models, and toxicological (cancer + non-cancer) effects. - Peer review of sub-modules of proposed approach by domain experts to identify clear areas for improvement or modification. - Invitation to specific domain experts, as well as open public invite, for specific proposals to suggest further improvements/additions. Due to data and model availability, recommended practice could lead to different models for different situations and substances, still integrated in the same framework (e.g. for organic substances, metals and primary and secondary particles). b) Data collection and supply for a wider range of chemicals, with the support

	of US-EPA (make their own effort known and widely available) c) Further investigation on the scope of the category regarding indoor emissions, worker health, ionizing and non ionizing radiations. This should all tie in well with the taxonomy discussion which should be carried out on the entire document (see section 3.2). Discussions on the relevance of and strategies for including indoor and worker health are needed. Some practitioners consider these issues outside of the scope of LCA.
Category	**5.4 Accidents**
Challenges	Statistics of the impact of accident on human health are often directly available in term of mortality and morbidity. This could then be eventually compared to other damages on human health if these can be modelled up to damage. Environmental impacts due to unexpected events or accidents in industrial activities or big storage tanks are obtained by multiplying the probability of risk by the corresponding environmental effects. Emissions to the environment could often be already be considered in the Life Cycle Inventory, based on e.g. tanker accident statistics compared to the total volume of fuel transported.
Activities	- As a first step: further investigation on the scope of the considered impact on human health and on the environment, together with the need to include accident statistics (taxonomy workshop). - Eventually elaboration of typical damage factors on human health for screening LCA
Category	**5.5 Photochemical Oxidant Creation**
Challenges	The POCP (Photochemical Oxidant Creation Potentials) approach has the advantage that it provides different scenarios, and the disadvantage that it does not evaluate non-Northern European situations. The MIR (Maximum Incremental Reactivity) approach is a simpler one to use, but its results have not been verified outside of North America. None of these approaches include the impact of NOx which often accounts for more than 50% of the total ozone formation impact. Development based on the RAINS model specifically for use in LCIA includes the NOx contribution at the expense of loss of substance specificity among the VOCs. On a more basic level, it is not clear that measuring or estimating the ozone in smog is the best indicator of the overall effects of smog. For example peroxyacetyl nitrate and other photochemically produced substances may cause damage to human health and the environment. This raises the question of whether the impacts of smog could be covered by the human health and ecotoxicity categories. These methods should be evaluated regarding specific LCIA requirements, leading to recommendations eventually dependent on generic situations and data availability. As the MIR and POCP approaches are based on specific situations, it should also be studied how far this is consistent with the comparative approach required in LCIA: how this relates to other impact categories, also in term of mean versus extreme responses of time horizon? The Danish development and consensus project should be analyzed to determine if the conclusions drawn by this study concerning spatial differences can be used to simplify LCIA.

	The challenge for summer smog is not only the difference between the single VOCs but the actual contribution to an increase in ozone formation. This increase in ozone formation needs then to fit with what has been used in epidemiological studies to get an idea on human health damages.
Activities	Inquiries to the developers of POCP, MIR, and RAINS-based approaches should be made to determine if they are able to or willing to expand the coverage of these indicators and to examine how a comparative assessment can be achieved, as a basis for further recommendation.
Category	**5.6 Traffic Noise**
Challenges	In comparison to chemical emissions, the inclusion of noise emissions into LCA methods has not received much attention so far, in spite of research studies that show that noise may have significant effects on the health of humans. Within the LCA-Initiative, it is an important task to fill this gap - by studying the available literature on health effects of noise - by studying the available calculation models connecting vehicle-kilometers with the increase of continuous noise levels - by evaluating the possible choices of LCI results and midpoint categories.
Activities	Proposed actions are: A proposition for modelling the full network of impact pathways regarding health damages due to road traffic noise has been worked out by Müller-Wenk R.: Attribution to road traffic of the impact of noise on health, BUWAL SRU 339, 2002 Bern CH. This proposition should now be tested on case studies to examine the potential impact of traffic noise on human health compared to other impacts. Alternative proposals for assessing road, rail and air traffic should be identified and possibly developed to a level where an evaluation of available concepts can be made. Traffic and/or industrial noise can be expressed as local impact and measured as an equivalent intensity of noise over certain threshold, per individual.
Category	**5.7 Acidification**
Challenges	For midpoint approaches, there are international collaborative studies like RAINS (Regional Acidification Information and Simulation) and EMEP (Co-operative Programme for Monitoring and Evaluation of the Long-Range Transmission of Air pollutants in Europe) in Europe, related activities that are both established and maintained under the UNECE Convention on Long Range Transboundary Air Pollution. For North America, TRACI took advantage of the significant NAPAP (National Acid Precipitation Assessment Program) data and models to develop acidification fate and transport. It seems an effective approach to begin from these results and examine the feasibility to apply them to other regions or bring compatibility between approaches. For damage approaches, although damages to aquatic life and soil organisms are the likely most important damages, consideration of these damages alone may not be sufficient. If the man-made environment is considered, damage to

	materials and crops also has to be taken into account as one of the major impacts. ExternE has already considered assessing the impact on materials. LCA national project of Japan take the impact on aquatic life and crops into account in the program. But these above considerations should be reviewed.
Activities	Proposed activities: There are many activities internationally that can be applied to tackle these problems. Research to solve the above problems are required based on these contributions.
Category	**5.8 Eutrophication**
Challenges	It should be noted that there is a specific characteristic of eutrophication. There is a minimum amount of nutrients (P/N) required to support life, but the state of a given environment reflects the nutrient-balance. If input is increased relative to output of nutrients, a gradual eutrophication will occur and the species composition and other characteristics will change. It may still be nature but a different type of nature. Such changes also occur naturally over time and it is thus quite difficult to consider this balance of negative and positive effects in LCIA. Both aquatic and terrestrial eutrophication need to be addressed (Udo de Haes et al., 2002) In addition, eutrophication appears at very local scales such as inland sea, lake, river, and marsh. In order to reflect the characteristics of local area, significant information sets will have to be collected. For North America, TRACI took advantage of the significant NAPAP program data and models to develop fate and transport, similar to acidification. Agriculture and Agri-Food Canada also developed a model for the risk of water contamination by nitrogen and phosphorus. http://www.agr.gc.ca/policy/environment/eb/public_html/pdfs/aei/fullreport.pdf In Europe, similar work has been performed using the RAINS model for airborne eutrophication. It seems an effective approach to begin from these results and examine the feasibility to apply them to other regions or bring compatibility between approaches. For midpoint approaches, it should be discussed how to reflect the differences in sensitivity between locations and how to generate a representative values from localised information. Several studies, including fate modelling, have already been developed covering the transportation from air to water and soil. There has been much discussion on the issue of transfer from soil to water, but there has not been sufficient debate and consensus on how to address this issue.. For damage approaches, the consideration of damage on aquatic life and fisheries is insufficient. Damage to forest and ecosystems biodiversity also still have to be considered adequately as one of the major impacts in eutrophication.
Activities	Proposed actions: Unlike the circumstance of acidification described in the previous section, there is little international collaborative study on eutrophication in LCIA. Further efforts to collect background information are required. A few years are required to solve the problems described on under damage approaches in the specific

	challenges. Specific actions proposed for this impact category are: - Collection of background information available on a region or country-specific basis; this should incorporate a workshop to jumpstart international collaboration on the development of this impact category; care should be taken to incorporate input from non-traditional LCA countries whose background levels of nitrogen and phosphates differ significantly from traditional LCA countries. Some attention should be paid to the potential of each of the three groups of modelling (simple Redfield ratio, fate+Redfield ratio or damage modelling: see section 8 of background doc. III) methodologies described in this section to deliver outcomes desired in this impact category, looking both at the benefits and the limitations of these models. Attention should be paid to similarities which exist between this impact category and the acidification and eco-toxicity impact categories, modelling of impact pathways selected should (if possible) be consistent between these groups (this suggestion is made in support of the stated desire for a transparent and flexible LCIA framework). - Further refinement of existing modelling methodologies in-line with the outcomes of the workshop and consistent with developmental work in the eco-toxicity and acidification impact categories.
Category	**5.9 Ecotoxicity**
Challenges	The following scientific challenges are especially relevant to ecotoxicological effects to help advance the current state-of-the-art (for fate, challenges are mostly the same as for human health): - Make use of the tools that have been developed for environmental risk assessment and for comparative risk assessment of chemicals to develop measures appropriate for LCA - Address bioavailability and speciation of metals and of persistent substances, in freshwater and marine environments - Enable an accurate estimation of effects indicators in terrestrial species looking at bioavailable fractions (e.g. total soluble, etc.). - Model the food chain in terrestrial and aquatic species - Develop simplified methods that can be readily applied for screening with low quality/amounts of data, in a compatible way with more advanced models. - Quantify uncertainty (model, parameter, and scenario) associated with different estimates. Practical challenges: - Data availability and reliability of LCI results - Data availability for terrestrial ecotoxicological testing has to be strongly improved or extrapolation from existing (aquatic) data validated and, if needed, improved.
Activities	The following activities are foreseen, in parallel to human toxicity for fate modelling: a) Stimulate collaboration between OMNIITOX model development, TRACI development and scientists active worldwide (e.g. Lausanne workshop in December 2003), including: - Open challenge to improve individual modules (2003-2004)

	- Comparison workshop between modules and with other models (beginning 2004) - Selection of recommended models and calculation of generic factors corresponding to typical emission situations (end 2004) b) Based on the 2002 Montreal Workshop on LCA and Metals, which was co-sponsored by UNEP, SETAC, APEC, Natural Resources Canada and the metals industry (ICMM), a specific group of participants could be asked to prepare a document on how to consider bioavailability and speciation of metals for ecotoxicity assessment in LCA. This could be of interest to metal industry (ICMM) within a case study. c) Data collection and supply for a wider range of chemicals, with the support of US-EPA (make their own effort known and widely available)
Category	**5.10 Land Use/Habitat Conservation/Biodiversity**
Challenges	Although many indicators have been suggested, based on scientific knowledge about the relationship of land use and biodiversity, few if any of them can truly be identified as having been tested in any scientifically rigorous fashion. Part of the problem is that biodiversity itself is not a clear concept when looked at in detail. For example, zoological and botanical gardens have very high species diversity, but no one is suggesting that the world should resemble a zoo. On the other hand, there is a growing consensus that conservation of ecoregions is a much better way to conserve biodiversity than efforts aimed at a particular species or list of species. This supports the concept that land cover should be used as a primary indicator of terrestrial biodiversity, taking into account the vulnerability or scarcity of different habitats. Although there are numerous approaches for assessing biodiversity in aquatic systems, relatively little has been done to monitor biodiversity in aquatic systems. This is unfortunate, since by some estimates 20% of all freshwater teleost fishes are endangered, and about 80% of marine fish stocks are considered to be either over-fished or significantly degraded.
Activities	- As a minimum, the area used by a product system over time can be used as an indicator of the land use impacts. The way to deal with land transition within the LCA structure (linear relationship to functional unit, etc.) has to be further examined. - At the secondary level, land use inventory data should be identified as to its location (latitude and longitude). There are many sources of satellite based information about the different habitats around the globe so that the location of the land use can be included in both current weighting schemes and any future weighting schemes to be applied. - More work needs to be done to reach some consensus about appropriate indicators at different levels of detail. A workshop may be an appropriate way to approach this issue. Aquatic indicators are not well developed, and a great deal more effort needs to be put into this area of research. - Indicators need to be tested against different definitions of biodiversity to assure that they are effective indicators of the impact category.
Category	**5.11 Species and organism dispersal**

Challenges	The problem of dispersal of invasive species has not hitherto been described systematically in the context of life cycle impact assessment. Thus, initial efforts should focus on: - describing a generic model that can be applied to the different vectors of introduction and in a compatible way with the LCA structure (linear relationship to functional unit, etc.) - collecting data and quantifying the relationships in the model. The further modelling from the midpoint indicator to the damage indicators is similar to that described under physical impacts from land use (category 5.10). Thus, the required activities for the last part of the impact pathway is identical to the biodiversity assessment of the receiving environments.
Activities	Short to middle term activities (within 2 years) include: - Workshop to identify important model parameters and ensure agreement on model. - Literature study to identify sources of data and cases where quantification has been attempted for the factors that enter into the model. - Initial quantification of the model and the uncertainty on each of its parameters, in order to provide initial characterisation factors and priorities for further refinement. Middle term activities (2-4 years) include: - Testing of the initial model on a number of case studies. - Further refinement of the data basis.
Category	**5.12 Use of natural resources**
Challenges	The impact linked to the depletion of energy, water, metallic and non-metallic resources is a subject of high debate in LCA, as pollution has been up to now a much stronger limiting factor than resource availability. There are a number of concepts that are common to impact assessment of all groups of functional resources, be they biotic (wild or domesticated plants and animals) or abiotic (metallic or non-metallic minerals, energy minerals, water or soil). These common concepts place the emphasis for the definition of this impact category on the ultimate form of the resource leaving the system and its remaining potential to deliver the functionality for which it is desired; as opposed to focussing on resource extraction. They are explained in the introduction part of chapter 12A) in Background document III, based on the alternative technology (called “backup technology”) applied when reaching the ultimate quality limit for these output flows. Links to other existing methods are discussed. We deal here mainly with the functional values of natural resources as opposed to intrinsic or existence values, since most resources have only functional value to humans, i.e. they are valuable because they enable us to achieve other goals.
Activities	Specific issues and activities are detailed below for each subcategory.

- Energy, metallic and non-metallic resources

Short to middle term activities (within 2 years) would include:

- Workshop to check and enhance agreement on the proposed model for resources as given in chapter 12A of the background document III. Literature study to identify sources of data for the ultimate resource limits and technology scenarios to identify possible backup technologies for specific *metal and non-metal* minerals, including scenarios for future energy technologies. Due consideration will be given to the other existing methodologies, possibly in determining the ultimate limits and technology scenarios.

- Water

- The current inability of LCIA to account for water usage (and thus the loss in quality and availability) is a significant deficiency, which needs to be addressed in the short term. The definite challenge with this category lies in the region specificity: Freshwater resources availability is geographically variable, i.e. between countries, and between catchments or eco-regions within countries, and freshwater resources availability is time variant, i.e. impacts may be seasonal dependent. It may therefore be required to define focussed regions at a global level. Some propositions have been made to characterise and weight freshwater usage. However, these may be limited, especially to differentiate between surface- and groundwater reserves, and further approaches should be proposed and reviewed within the LCIA community. In this context it is suggested that a literature study be conducted in the short term to identify sources of data for describing freshwater quality (and reserve availability) and water technology scenarios, possibly differentiated per geographical region, and also identifying possible pathways towards intrinsic impact categories. The use of water from sensitive coastal or marine water systems, e.g. estuaries, must also be investigated further. In the longer term workshops should be considered to facilitate and coordinate ongoing research in this respect.

- Soil quality

- Literature study to identify sources of data for describing *soil* quality and technology scenarios for soil maintenance and other backup technologies, possibly differentiated per geographical region, also identifying possible pathways towards intrinsic impact categories. This review should include a consideration of soil qualities in different global regions. A panel of experts should be convened to determine the basis for developing backup technology arguments for soil quality. Further action on this impact category should include consideration of the proposals below on salinisation, dessication and erosion. As yet there is no clarity on whether these are mid-point impact categories in their own right or whether they form part of the resource depletion set of impact categories; this clarity will only result from a clarification of the "division" between emissions and resources. They have been retained within Abiotic Resources at present, but will be the subject of specific analyses.

- Erosion

The impacts of erosion depend very much on site specific conditions, like soil type, average rainfall and evaporation, wind speed, slope and vegetation. By using the extent of available area that has received high, medium or low erosion as the LCI parameter, part of the modelling problems is moved to the LCI part of LCA. Modelling efforts for these types of impacts are already available in the USA and has been adapted for Canadian conditions. The model is available at:
http://topsoil.nserl.purdue.edu/nserlweb/usle/USLEqn~1.htm
The LCI experts will need to gather data on the seriousness of the erosion and describe the impacts.
In order to keep this new impact category manageable both for LCI and LCIA practitioners, we propose to develop LCI and LCIA parameters for a limited set of archetypical conditions, that are characterized by the factors like wind, rainfall, slope, etc. The benefit of this approach is that many agricultural products will in practice only grow in one or two of these archetypical conditions. So in an LCA for coffee, one will need to study only a limited subset of these conditions to develop default LCI and LCIA parameters. This approach also has the advantage that one can start with relative coarse models and refine later.

The following activities are foreseen:
- Organize a workshop with experts
- Check literature on the relevance of the link with PM10
- Participate in the two erosion conferences in 2003
- Build a scratch model of one or two archetypical conditions that can be used as a basis for further discussion and refinement

- Salinisation & dessication

The impacts of salinisation depend very much on site specific conditions, like soil type, average rainfall and evaporation, wind speed and vegetation. One important factor is the amount of salt that is deposited. By making this the LCI parameter, this problem is moved to the LCI part of LCA. The LCI experts will need to gather data on the salts deposited; the LCIA experts will describe the impacts.
In order to keep this new impact category manageable both for LCI and LCIA practitioners, we also propose to develop LCI and LCIA parameters for a limited set of archetypical conditions, also according to management practices, for example: well managed, restoration planned, to badly managed, no restoration. The Green Mining initiative could be a useful framework. . Similarly, it may be possible to link such conditions to different types of ores, as some ore types (oxides) create much lower acid mine drainage compared to others (like S), and in case the ore concentration is low (gold) the potential emission is even bigger.

	As a starting point, a workshop should be organized with experts, e.g. from the Mine Environment Neutral Drainage (MEND) programme (http://www.nrcan.gc.ca/mms/canmet-mtb/mmsl-lmsm/mend/default_e.htm) the International Network for Acid Prevention (INAP) (http://www.inap.com.au/), the ACMER (Australian Centre for Mining Environmental Research) and the ISHS (The International Society for Horticultural Science), to review this proposal. For desiccation we propose to consult experts within UNEP and its associated groups to develop future actions. For desiccation we propose to consult experts within UNEP and its associated groups to develop future actions.and the ISHS to review this proposal. For desiccation we propose to consult experts within UNEP and its associated groups to develop future actions.
	- Biotic resources Literature study to identify sources of data for describing backup technologies for biotic resources, possibly differentiated per geographical region, also identifying pathways towards intrinsic impact categories. It is likely that sub-surveys should be performed for wild fish, wild mammals, other wild animals, wild plants and wood, and domesticated plants and animals.
	- Unique landscapes and archaeological sites Strictly speaking, these are not part of natural resources, since they should be considered for their intrinsic value and thus are beyond the scope of most existing LCIA methods. No specific activities are foreseen in a first period, until scope is clearly defined in the framing & taxonomy workshop (see section 4.2).

6 Discussion on Damage Indicators and activity proposal per damage category

The leading idea of LCIA is to assess the LCI results with respect to quality changes caused at midpoint level and/or at damage level (figure 4.1). In order to describe such quality changes at damage level in a practicable form, damage indicators are used. For the sake of consistency of a LCIA framework, it is important, for each damage category, to select and to define properly the corresponding damage indicators, so that the modelling of the various impact pathways in different midpoint categories can be oriented towards common damages. In addition, the link to damages is shortly analysed for each midpoint categories in the Background document III.

Here, we start from the overall structure drawn in figure 4.1 and table 4.1 and discuss, for each damage category,

- a short review of potential indicators
- an initial proposal of indicators to be retained at present to ensure consistency
- scientific challenges, further work and investigation needed in this area and proposed actions

The modelling of impact pathways between LCI results and midpoint indicators or damage indicators is discussed at the level of each individual impact category (see chapter 5).

6.1 Damage to humans

Definition and review of potential damage indicators

Environmental damages to the human population could be expressed in several ways: Diminution of joy of life, loss of the production factor 'labour', cost of medical interventions, diminution of the population size, etc. However, there is a reasonable agreement that the environmental damage to humans is essentially represented by the observable or expected damage to individual human health, hereby including all individuals of the present generation as well as the members of the coming generations. Individual human health may be impaired either by a reduction of the number of life years of an individual, compared to some standard life expectancy, or by the deterioration of the years lived, due to diseases or accidents.

The status of health of a human population during a given time period can be described by the number of premature deaths per death cause and per age bracket, and by the number of non-lethal disease/accident cases with their duration. In view of the large number of possible diseases, disease stages, accident types and death causes, attempts have been made to express the status of health of a human population in a more aggregated way.

The World Health Organization (WHO) uses two types of health metrics in order to express the national and global health status, taking account of life years lost as well as life years lived with a disability: DALY (disability adjusted life years) and HALE (healthy years life expectancy), both of which aggregate the severity of different non-lethal disease stage by assigning disability weights (DW). Disability weights have been assigned by international bodies such as WHO and exist for many diseases, but not all of the human health effects of interest in LCIA. In this way, WHO is able to record and publish annual data on health damage in form of mortality and morbidity, due to various non-environmental and environmental causes (see WHO: The World Health Report 2000, annex tables).

Other widely used types of health metric systems including the damage due to premature death and/or disabilities exist, like QALY (Quality Adjusted Life Years. There is also a large number of monetarisation proposals to express the value of healthy life (and in consequence the negative value of life years lost or lived with disability) in the form of monetary units; some monetarisation methods aim at the determination of the intrinsic values of human health, whilst other methods are oriented towards the functional value of humans as a production factor of the economic system.

Initial proposal for base indicator at present

This definition study has reemphasized the importance to document very well the objective (natural science based) and subjective (social science bases) choices within the methods applied. It is therefore proposed to report, per death cause and per non-lethal disease/accident type involved, the number of premature deaths per age bracket, and the number of disease/accident cases with their mean duration; whereby the medical conditions of the disease/accident should be described in the form of a generally known system.

In addition it is proposed here to express damages to human health in the form of DALY units as damage indicator. This provides the advantages of coordinating with the WHO data bases to express all environmental health damages to the humans. DALY measures for morbidity and DALY measures for mortality should be reported separately. DALY refers to the intrinsic value of humans, that is to say, humans and their health are seen as a value in itself.

Challenges, further investigation required and proposed actions

A formal coordination with WHO regarding the health metrics system to be preferred in future should be established.

A comparison of the different existing health metrics will be performed to elucidate the model-based uncertainties introduced by the choice of health metrics. There is also a need to examine how the population age structure and the life expectancy influences the metrics of different impacts to elucidate the consequences of spatial differentiation in the damage modelling of human health impacts.

6.2 Damage to the biotic natural environment (wild plants and animals, ecosystems)

Definition and review of potential indicators (biotic natural environment)

The natural environment consists of living parts (animals, plants and others) and non-living parts (earth crust, water bodies, atmosphere, other dead matter and objects). Ecosystems consist of living organisms together with the non-living environment in which they are embedded. The objective is to maintain the variety of species and their ecosystems. Discussion of these issues has been documented in the WIA-2 efforts ("The Areas of Protection Debate"). This debate is fully documented in the "Global LCA Village" to be found (at the website: http://www.scientificjournals.com/lca/.

As far as the living part (wild plants and animals, including all lower organisms) of the natural environment is concerned, this means that a damage indicator should measure how far the anthropogenic processes affect the natural development of the occurrence of species (or habitats). Whilst in the case of human health, each individual's health matters, the focus with respect to animals and plants is rather on the species population dynamics and not on the well-being of the single individual. Occurrence of species, as a damage indicator, includes the global population size of species as well as the geographic dispersion over the globe. Even though increase of population size and geographic dispersion may be considered as a benefit to the biotic natural environment, in the case of species with a historical trend towards extinction, the growth of invasive, ubiquitous species is, in contrast, a damage.

Initial proposal for base indicator at present

An initial discussion is needed comparing different options for category indicators, looking at how to integrate impacts on biodiversity in an LCA. A simplified damage indicator may be perhaps worked out on the basis of data such as those supplied by the 'UNEP-WCMC species data base' with complementary national data, containing the occurrence per region or country of 70,000 animals and 140,000 plant species, together with a indicator of endangerment, representing low or sharply decreasing population density of a species as a coarse indication of its current population dynamics. The "archetypical" conditions concept could be used to arrive to a practical approach based on a variety of situations. In ecotoxicology, indicators such as the PAF (Potentially Affected Fraction of species) or PDF (Potentially Disappeared Fraction of species), both obtained from the SSD (Species Sensitivity Distribution), are currently used and can be applied in LCIA in order to indicate effects on the occurrence of species in a given perimeter.

Challenges, further investigation required and proposed actions

Coordination with UNEP-WCMC and other experts is highly desirable in order to ensure compatibility between the damage indicator selected here and indications of pressure and state regarding plants and animals. Furthermore, the relationship between toxicological indicators and biodiversity data should be studied further.

When wild animals or plants are currently used by humans as a resource (e.g. fish species), it is probably necessary to express this property by a separate damage indicator, based on the importance of this resource to present and coming human generations. A special investigation is needed for this (see also section 5.10). Since fish stocks and other wild animals can be considered renewable resources, this would need to be taken into consideration.

6.3 Damages to abiotic natural resources

Definition and review of potential indicators (abiotic natural materials used as resources)

Depletion of non-renewable abiotic natural resources, due to human use with the resulting destruction or dissipation, is generally considered as a damage to be treated in LCA. The damage consists in the reduced availability of the corresponding type of resource in future. Several specialist show that the total quantity accessible for humans is extremely high for most of the abiotic resources, so that there is little logical justification for short term societal concerns. For others, non reversible dissipation of e.g. fossil could still eventually result in a long term, non-negligible reduction of the easily usable part of resource stocks.

A damage indicator for such depletable abiotic resources should therefore express the two factors quantitatively and the degree of accessibility/usability per type of resource. Various proposals have been made, but an agreement on such a damage indicator is not yet available, and further research is required in order to supply geological data and a scientific background for such an agreement (see also chapter 12A of background document III).

Initial proposal for base indicator at present

As a provisional starting point, the increase of energy requirements for future procurement of the currently used quantities per type of *abiotic* resource could be taken as damage indicator. Energy is used here as a proxy for the “effort” needed to extract lower grade or lower quality resources. This energy requirement needs to be articulated in the context of the functionality required of each class of abiotic resource as described in chapter 12A of background document III and analysed in conjunction other existing methods described in the introduction of this background document.

Challenges, further investigation required and proposed actions

Again, further research is needed to create a scientific basis for a future agreement on damage indicators for natural resources. This research should be based on existing LCIA work on this impact category, but should pay due attention to the fact that it is not the extraction of the resource which poses a problem, it is dissipative use and/or disposal of abiotic resources and this should guide the further development of this impact category.

6.4 Damage to the man-made environment

a) man-made biotic environment (crops and animal cultures)

Definition and review of potential indicators (crops and animal cultures)

The quality status of agricultural and silvicultural crops, domestic animals, aqua-cultures and similar man-controlled living objects can be adversely influenced by environmental impacts, for instance by acidifying emissions or water pollution. Unlike the case of wild animals and plants, the development of the population size of a species would not be an adequate damage indicator, because human activities (like artificial reproduction, feeding and medical prevention of health impacts) can mask the extent of environmental damage.

Assuming that the quantities of man-controlled crops and animals, as absorbed by the markets, will be produced in sufficient quantity to meet market demands, the indicator to represent environmental damage is money spent by the owners of the man-controlled cultures in order to maintain their marketable output in spite of the unfavourable environmental impacts. For example, fish production in aquacultures may be damaged by polluted water, but the marketable output can be held constant by spending additional money in form of increased input of young fish from hatcheries or in form of medical ingredients in the feed.

The issue of well-being of animals in human care is not addressed in this context so far, but would require a specific treatment.

Initial proposal for base indicator at present

Provided that it should be desired to represent environmental damages to man-controlled crops and animals in LCA, the cost in money units for damage prevention activities or to maintain production quantities appears to be an adequate initial proposal for a damage indicator.

Challenges, further investigation required and proposed actions

It is desirable to further investigate the consequences of an inclusion into LCA of environmental damages on man-controlled crops and animals. Other challenges include efforts to investigate methods of accounting for the well-being of husbanded animals and plants. Research on non-monetary indicators that reflect sustainability of the animal/plant population. Often money buys temporary solutions that ultimately may contribute to collapse of the animal or plant population (vaccines and fertilizers can both function this way).

b) man-made abiotic environment (buildings and other man-made structures)

Definition and review of potential indicators

Man-made objects in the abiotic environment are: buildings, equipment, traffic structures, mines, modifications of land surfaces for human purposes, etc. ‘Man-made’ hereby means that materials, land areas and other objects of nature are transformed by man into artefacts, which nevertheless may maintain some content of naturalness; in consequence there may be cases where it is debatable whether an object belongs to the natural environment or the man-made environment. The quality status of non-living man-made objects can be adversely influenced by environmental impacts. For instance, buildings are damaged by acidifying emissions, or crop fields are eroded due to climate change. The damage consists in a physical destruction or impairment of the object, with the consequence of a loss of market value in the case of marketable objects. In the case of non-marketable goods like historical sites, the impairment may reduce their intrinsic values.

It is important to notice that man-made objects or structures may be impaired not only by the impacts of environmental emissions, but also by a discontinuation of certain types of intensive land use. An arable land area, being the result of land use activities like deforesting and shrub-removal, drainage, grading, fertilising, etc., is physically impaired with respect to its man-made properties as soon as the land use type is changed to extensive grazing or fallow. In such situations, a quality decrease of the man-made structure goes in parallel with a quality increase (negative environmental damage = environmental benefit) of the same object as a part of nature. If overlooked, this could cause serious inconsistencies in LCA practice.

If a man-made object is physically damaged, it is normally possible to repair it by an additional human intervention, although even technically perfect reconstructions may be considered as problematic in the case of objects of the cultural heritage. But in general, the economical cost of the repair work is a practicable damage indicator for environmental damages to man-made objects.

Initial proposal for base indicator at present

If it is desired to represent in LCA environmental damage exerted on non-living man-made objects, the cost in money units for the repair work appears to be an adequate damage indicator. In case a repair is not possible or rejected for emotional reasons, the loss in monetary units might be determined by the use of monetarisation.

Challenges, further investigation required and proposed actions

It is desirable to further investigate the consequences of an inclusion into LCA of environmental damages on man-made or man-transformed non-living objects and structures and to specify how to handle interactions between environmental improvements and the degradation for beneficial human use.

6.5 Damage to the abiotic natural environment (Occurrence of natural materials and structures of the non-resource type)

Definition and review of potential indicators (abiotic natural materials and structures)

Anthropogenic processes may exert a degrading influence on non-living natural materials and structures, like geological structures and landscape forms, glaciers, crystal holes, waterfalls, etc.

Considering first the case of materials and structures that are *not* used by humans as a natural resource, the damage consists of disappearance or degradation of materials and structures that have intrinsic value by their existence. This is analogous to the value placed on wild animals and plants of the non-resource type. For example, when glacial relicts or the sediments of a natural river are destroyed in order to prepare the area for building purposes, or creeks are put into underground piping and forests are cut to allow for the use of agricultural machinery.

Inclusion in LCA structure could be difficult. However, a damage indicator expressing the loss of such intrinsic values of non-living natural materials and structures (of the non-resource type) could consist of the development in time of the fraction of non-affected surface units in a region. E.g.: If the area of a region is subdivided into units of 1 km^2, the decrease of the total number of 'un-touched' unit areas could be a reasonable representation of the decrease of abiotic naturalness of this region. A further refining would be to identify 'hot spots of abiotic naturalness', the impairment of which being more serious than the impairment of average surface units..

A different approach would be to assume that a certain degree of correlation exists between the quality of the non-living part of the natural environment and the quality of its living part, because the two components are interlinked by ecosystems. If natural surfaces are homogenised for facilitating the use of agricultural machinery, if coral reef structures are demolished, if river floodplains are cut off by river embankments, this means also that species diversity inside the corresponding perimeter gets reduced. In consequence, the damage indicator for biotic natural environment (as developed above) could also be taken as a coarse proxy of the damage on the abiotic natural environment.

As an alternative, the economical literature proposes methods for monetarisation of existence values. Provided that intrinsic values are indeed well represented by such approach, the money equivalent of the intrinsic value of a lost natural landscape could e.g. be calculated with the travel cost method (TCM), that's to say by finding out how much money people use to spend for travelling to remote places, where they find a replacement for the lost naturalness of their home region.

Initial proposal for base indicator at present

No proposal so far.

Challenges, further investigation required and proposed actions

The problem of environmental damage to abiotic natural materials and structures is a serious issue that has not received adequate attention so far in LCA. In consequence, further investigations are needed with respect to developing and proposing a corresponding damage indicator.

7. Activity plan

The above-described activities constitute an initial basis for proposals among which certain activities will be initiated in priority. Priority setting will be performed later once the review has been carried out and according to ILCP inputs. It will also depend on funding opportunities or synergies with other projects, all activities mentioned being anyway of interest to be carried out as soon as means are available and proper leadership is established according to the LC initiative criteria.

Based on the analysis of the Draft Author Team, on reviewers comments and on inputs at the Hamburg meeting, the following activity plan has been defined by the LCIA programme manager, with input from H. Udo de Haes, M. Hauschild, M. Stewart and J. Potting, in collaboration with the executive committee of the Life Cycle Initiative. Ariving at consistent recommended and widely available characterization factors implies a concerted, well coordinated and continuous effort. Task forces must be created to coordinate the process in different categories in the coming three years, starting with four task forces.

7.1 General motivation: The importance of LCIA for efficient Life Cycle Management

The user needs survey has clearly shown high expectations for the development of transparent and available recommended methods and factors enabling users to perform better impact assessments. This will for instance be important ***for related communities to develop and use sound*** Environmental Product Declarations (EPD), which need to be based on consistent and well defined impact assessment schemes. The Role of the Life Cycle Initiative is also to identify the domains of special interest in developing countries, such as erosion and salinisation (very important issues for North America, parts of Asia and Africa), and to bring environmental assessment together with socio-economic dimensions into one common framework. Finally, such an international effort offers a unique opportunity to bring together scientists specialized in different fields to contribute significantly to more robust and more broadly and easily applicable Life Cycle Impact Assessment.

7.2 Task forces overview

The following four task forces will be established under the Life Cycle Impact Assessment (LCIA) Programme:

1. *LCIA information system*
2. *Natural resources and land use*
3. *Toxic impacts*
4. *Transboundary impacts*

The relationships among these four task forces (and the LCI and LCM programs) and related existing efforts are illustrated in the figure below.

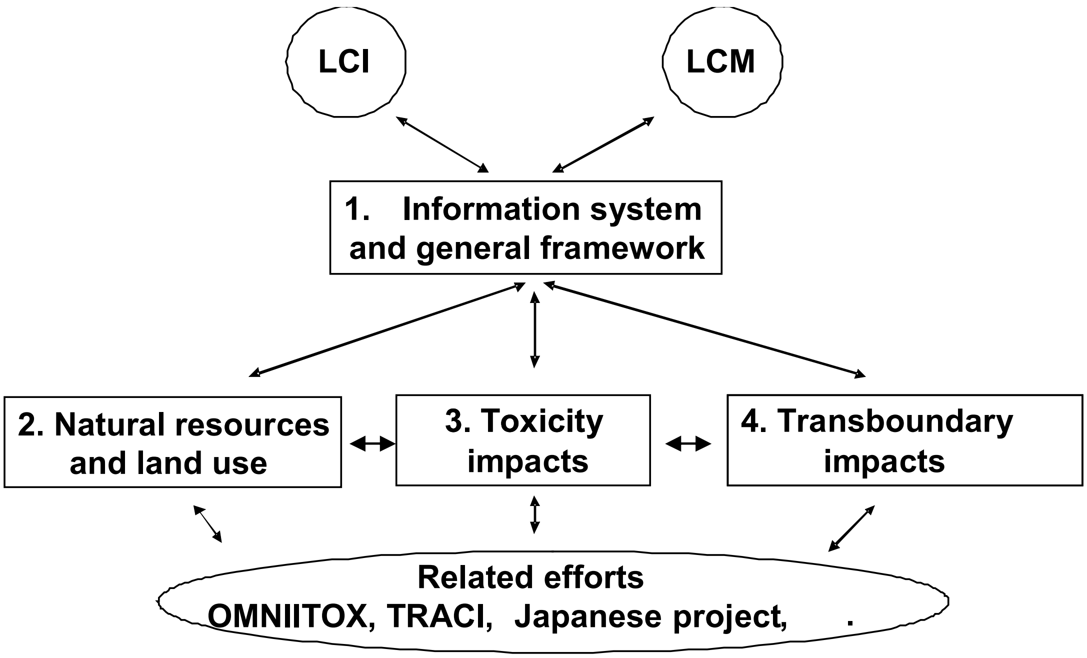

Figure 7.1 Relationship between LCIA task forces the other LC initiative programmes and other related efforts and projects

Two themes driving the design of the entire LCIA program are:

a) The need to integrate information transfer, capacity development and enhancement of good LCIA practice, addressed in priority by TF 1
b) The need for deliverables and products towards recommended practice, carried out in priority by TF 2 to 4, including application.

Linkage with the LCI and LCM programmes will be ensured in priority by TF1, e.g. in the development of the case study library, whereas direct interaction between the TF 2 to 4 and the LCI programme will be established to ensure compatibility between LCI and LCIA needs and developments. TF2 to 4 will also develop strong interactions with related external projects. Common test case studies will be carried out to ensure consistency between all methodologies developed.

7.3 Organisational aspects

The task forces are lead by a chair and a co-chair who are responsible for work progress and quality. They regularly report to the LCIA programme manager to ensure coordination with the other Task Forces and to meet the general programme objectives in a timely manner. As far as possible a small financial compensation will be made available to the chair and co-chair.

Task forces are free to organize their work in the most efficient way, to achieve objectives and to provide high quality deliverables. Participants will work on a voluntary basis, offering about one to two weeks every year to contribute to the task force mission, and should participate regularly by e-mail and in task force meetings. Agenda members can just receive information without having to contribute. The task forces will meet and present their results to the working group on Life Cycle Impact Assessment, in principle twice a year, in conjunction with SETAC meetings or other events.

It is of high importance to rely on the expertise and timely contribution of various experts from different fields. To achieve this we will rely on a series of timely expert workshops (see c) below) to review the state of the art in new fields, to define an analysis framework for further method development and to compare models and characterization factors towards recommendations. For this reason chair and co-chair of each TF need to have access to non-LCA experts in their field.

7.4 Budget & funding

Task force chairs should receive seed funding to acknowledge their important contribution and leadership. For 2003 and 2004, ideally a minimum amount of 36,000 US$ (4000 US$ per TF times 4 TF, 10,000 for programme management, 10,000 US $ for expert reviewers) should be planned to run the LCIA programme and its review. In addition, specific incomes should be found for specific events and workshops. Adaptation of these TORs and budget should be made according to available funding.

The remainder of this document presents draft terms of reference for each TF, built on the basis of the LCIA definition study.

7.5 LCIA Task Force 1: LCIA Information system

Specific aims
Towards the enhancement of the availability of sound LCIA data and methods, Task Force 1 aims to both develop an LCIA information system and to finalize and extend the general framework for LCIA.

A) Information system
Motivation
This task force is of the highest importance as it will provide the necessary tools and guidance to users to take profit of the three task forces on recommended practice. LCA users need to have easy access to recommended practice and new LCIA developments as outdated methods are still commonly applied in practice, potentially leading to misuse of LCA and misinformed decisions.

Work description and programme
In cases where the development of an LCIA method is relatively complex, its application can still be made relatively easy so long as adequate characterization factors are made readily available. One main task is therefore to make recommendations and results of the LCIA programme widely available for users. Based on the work carried out in TF 2 to 4, this will include the creation of a worldwide accessible information system including:
- LCIA guidelines, as described under the framework development.
- Downloadable recommended factors in midpoint and damage categories (in an easily worldwide accessible format, e.g. excel spreadsheet), for a wide range of LCI results.
- Downloadable models to calculate new characterization factors.
- An adequate description of key aspects of the impact pathway (different types of information covered and assumptions made), and proper documentation of the applied models.

Until recommended factors and models are defined, the website will provide links to currently used methods and characterization factors at midpoint and damage levels, enabling users to easily access state-of-the-art methods and to fill-in the different parts of the LCIA framework, highlighting the most significant aspects (generality, assumptions etc) of the considered models ?

In addition, the three programmes together should provide a library of case studies illustrating good/successful and bad/unsuccessful uses of LC methodologies in practice, including LCIA. More generally, this task force will take care of specific interactions with the LCI (e.g. waste, definition of elementary flows, etc.) and LCM programmes.

According to this content, the following work programme is foreseen:
- Prototype for the web information system
- Collection of latest/most widely used LCIA methods, including hyperlinks to respective websites providing characterization factors
- Comparative analysis of impact categories covered by the different methods, including basic hypotheses, based on inputs from TF 2 to 4
- Elaboration of the initial LCIA information system
- Based on recommendations of TF2 to TF4, elaboration of the recommended web information system

Deliverables

The following deliverables are foreseen:

1. A worldwide accessible information systems providing access to:

2003-2004:

Latest/most widely used LCIA methods, including hyperlinks to respective websites providing characterization factors

- Comparative analysis of impact categories covered by the different methods, including basic hypotheses

2005:

- LCIA guidelines, as described under the framework development.
- Downloadable recommended factors in midpoint and damage categories (in an easily worldwide accessible format, e.g. excel spreadsheet), for a wide range of LCI results.
- Downloadable models to calculate new characterization factors.
- An adequate description of key aspects of the impact pathway (different types of information covered), and proper documentation of the applied models.

2. Contributions to the case study library, including examples of good LCIA practice (in collaboration with the LCI and LCM programmes).

B) General framework

Motivation

The framework provides a modular structure that provides a transparent basis for researchers with specific expertise to develop appropriate models that fit into the framework using the same inputs and outputs and to ensure good consistency. It builds up on ISO enabling in addition to link midpoint categories to damages in a consistent way.

Work description and programme

The general framework, consisting of the main elements of the impact pathway, has been mostly developed in the SETAC working Group and during the LCIA definition study of the Life Cycle Initiative. Here the task force has the responsibility to finalize this initial framework and to revise it if necessary, according to latest knowledge and eventual inputs of the other TFs. It will also develop selection criteria for recommended models and factors valid for all other Task Forces and ensure a consistent treatment of links between midpoint and damage categories.

According to this content, the following work programme is foreseen:

- Incorporation of results of the Hamburg workshop in the framework proposal of the LCIA definition study: writing of a scientific paper (ET&C or Int J. of LCA)
- Development of selection criteria for recommended indicators, models and practice
- Selection of common test cases to test LCIA

Deliverables

The following deliverables are foreseen:

- Scientific paper on the UNEP-SETAC LCIA framework
- Commented list of selection criteria recommended indicators, models and practice

In principle, results on Framework will feed into the information system and facilitate further methodology development in the different task forces

7.6 LCIA Task Forces 2 to 4 on recommended practice

General aims

According to the general LCIA aims and the guidance developed in the definition study, task forces 2 to 4 aim to enable a broader application of LCIA and more informed decisions through recommended practice. They aim in their respective domain:

a) to finalize the state of the art in the different areas based on the DS-study inputs and previous efforts

b) to stimulate inputs and challenges from outside experts to improve the different models or to propose better alternatives;

c) to evaluate and compare final proposals and to arrive at a proposal of recommended practice covering a broad range of LCI results. Midpoint and damage categories will be considered in parallel or successively according to opportunities and common priority setting. Where relevant, the need for spatial and temporal differentiation will be identified.

d) to present test cases and provide guidance documents

General work description and programme

Depending on the level of scientific achievement in each task force, work will include:

- Framing the field to define the functional components of the assessment
- The determination of initial base models as a starting point, to be improved further by open contributions: starting from a base model developed by a group of experts, other scientists can be invited to present alternative models or partial improvements of individual modules within a common framework. In short, the Life Cycle Initiative could stimulate the process of using a base model developed in ongoing projects opened up to other international teams providing inputs.
- The definition of recommended practice according to the deliverables identified below

The Work division is first organized according to midpoint categories (as defined in chapter 5 & background document III of the LCIA definition study), as each of these usually involves specific scientific expertise. However the link to damage categories will be considered from the start in framing the field and defining functional components of the assessment, ensuring consistent approaches between midpoint categories. According to the available level of scientific knowledge, these links to damages will be modelled quantitatively or described qualitatively. The specific work programmes are defined under each task force below.

Deliverables

The following deliverables are foreseen for each category and element considered:

- A finalized state of the art report and a proposal for framing the field and for the functional components of the assessment and base models (2003-2004).
- A recommended list of impact categories and category indicators, preferably consisting of sets at midpoint and at damage level, including new ones focusing on the concerns of resource extraction economies (2004).
- Recommended methodologies for the calculation of characterisation factors for the different impact categories identified, including links to damage categories (2005 according to category prioritarization made within the TF in accordance with programme management).
- Recommended characterisation factors for the different impact categories, to be included in the database on LCIA (2005 according to category prioritarization).
- Application to common test cases and the development of guide lines for users

7.7 LCIA Task Force 2: Natural resources and land use

Specific aims

This task force aims at establishing recommended practice and guidance for use for natural resources and land use categories, i.e.: water resources, minerals resources, energy carriers, soil resources and erosion, land use, salinisation and desiccation and biotic resources. It will address both midpoint categories and their relation to damage categories such as the biotic and abiotic natural environment.

Motivation

Dissipation of resources and especially water resources is of significant importance in the development of sustainable industrial and consumption practices. The current inability of LCIA to account for water usage is a significant deficiency, which needs to be addressed in the short term. This resource impact category is especially crucial for developing countries, in which a large fraction of worldwide resource extraction takes place. Developing the assessment of related impact categories such as salinisation, dessication and erosion is essential to contribute to avoiding relevant impacts in these countries.

Specific work description and programme

A common framework needs to be first defined for a consistent assessment of resources, taking into account their functional value and their dissipation through use and/or disposal, addressing the proposals made in chapter 12 of the Background document III, in conjunction with previously existing methods. This work proposes a generalised framework for assessing the impacts of using resources, biotic and abiotic. This framework contains two constants which need to be quantified for each abiotic resource considered, at present referred to as the resource limit and back-up technologies.

The definite challenge for water resources lies in its regional and local specificity. It is necessary to identify sources of data for describing freshwater quality (and reserve availability) and future water technology scenarios, possibly differentiated per geographical region, and also to identify possible pathways towards intrinsic impact categories. The use of water from sensitive coastal or marine water systems, e.g. estuaries, must also be investigated further.

For land use, work will focus on the synergies between scientific knowledge on the impact of land use on e.g. biodiversity and specific LCA research carried out on land use and land transformation. It has first to frame the field, identifying which issues can be well covered by LCIA and which ones should be rather investigated with other tools. This initial step should lead to the definition of the functional components of the assessment.

The task force will determine whether two subgroups would make sense as land use involves specific questions and scientific expertise. The following work programme is foreseen:

- Workshop on LCA and natural resources (2004). This workshop and connected preparatory work aims to summarise the field and to define further work topics in this area. It will constitute a basis for future developments that focus on water and abiotic resources, checking and enhancing agreement on the proposed framework for resources as given in chapter 12A of the background document III of the LCIA definition study together with considering other

proposals. Venue possibilities would be at the end of one of the coming international meeting on minerals or linked to another symposium.
- Depending on workshop findings: Conduct a literature review to identify sources of data for the ultimate resource limits and to identify possible backup technologies for specific metallic and non-metallic minerals, including scenarios for future energy technologies.

- Conduct a literature study on water use in LCIA to identify sources of data for describing freshwater quality (and reserve availability) and water technology scenarios, possibly differentiated per geographical region. In the longer term workshops should be considered to facilitate and coordinate ongoing research.

- Workshop on Land use and biodiversity (2004). This workshop and connected preparatory work aims to reach some consensus about appropriate indicators and functional components at different levels of detail. There are a number of diversity indices that have been developed for use in aquatic ecosystems and deal with fish, plants and macroinvertebrates. But aquatic diversity indicators have not been extensively incorporated in LCIAs, and a great deal more effort needs to be put into this area of research. Indicators need to be tested against different definitions of biodiversity to assure that they are effective indicators of the impact category. Also discussion on links between land use indicators and final damage indicators for acidification, eutrophication and ecotoxicity.

In addition to pursuing work initiated in the workshop described above, other efforts for 2004 should focus on erosion and salinisation/dessication to frame the field (see chapter 5 of the definition study).

Specific deliverables
The following deliverables are foreseen:
- Proposed framework for abiotic resources with well identified functional components.
- Depending on workshop findings: initial identification of the ultimate resource limits together with possible backup technologies.
- Proposed indicators for land use impact on biodiversity, tested against different definitions of biodiversity. Develop a proposed approach for making use of common damage indicators for biotic natural resources.
- Application to common test case.

(also see deliverables above common to TF 2 to 4)

7.8 LCIA Task Force 3: Toxic impacts

Specific aims:

This task force aims at establishing recommended practice and guidance for use in ecotoxicity, human toxicity and related categories with direct effects on human health, i.e: ecotoxic substances, chemicals that are toxic to human, ionising radiation, accidents and noise. Photochemical smog and respiratory inorganics will be coordinated with task force 4. TF 3 will address midpoint categories and their relation to damage categories human health and biotic natural environment. Specific challenges for each impact category are defined in the LCIA definition study document.

Motivation:

Impacts on human health and on ecosystems linked to the use and emissions of different toxic substances are of central importance to the development of sustainable innovative technology, e.g. in the fields of transportation, goods or housing. On the one hand, the Life Cycle Initiative can take profit of significant progresses carried out in LCIA of toxic substances. On the other hand, several crucial limitations of present methodologies need to be addressed to enable a proper interpretation of LCI results, e.g. for long term emissions of heavy metals or other present practice of LCIA. Interaction with e.g. REACH are of high interest on the application side.

Work description and programme:

According to this content, the following work programme is foreseen:

- State of the art review and determination of a modular framework for the estimation of toxicological human health and ecotox characterisation factors (functional components for the fate of chemicals, human exposure pathway models, toxicological (cancer + non-cancer) effects/ecotoxicological effects). This includes: a) A review on state-of-the-art of existing projects and actions, summarizing recent work from different projects and from the SETAC working group. b) Summarized results of method comparisons c) The determination of base criteria for evaluation of effect and fate and exposure models on work from SETAC WIA2, OMNIITOX and other sources.
- Expert seminar on the *review of toxicity base models* (Lausanne, December 2003). This expert seminar and connected preparatory work aims to make a proposal for base models and initiate a review process, while stimulating collaboration between OMNIITOX model development, TRACI development and scientists active.
- Expert workshop on *Metals essentiality and bioavailabilit*y in LCIA. This expert seminar and connected preparatory work aims to focus on the characterisation of metals (mineralogy and associated mobility, bio-availability, speciation, essentiality; background concentrations and natural releases of metals, choice of reference; and the choice of compartments for assessment) in RA and LCIA, starting a process of methodology development that is highly needed and desired by industry. The first activity in this field was the ICMM workshop in Montreal, in 2002. The present expert seminar will build on that. A subtask force must be established to bring experts with ERA expertise and LCIA expertise together, including experts from existing projects in this field. Additional resources should be sourced from the minerals industry and specifically the mined land rehabilitation research focus.
- *Reconvened ILSI panel* for review of proposals on human toxicity indicator in base model, regarding dose-effect response and severity.
- Invitation to specific domain experts, as well as open public invite, for specific proposals to suggest further improvements/additions.
- Data collection and supply for a wider range of chemicals, with the support of existing long term effort by different Environmental Protection Agency (e.g. US-EPA, EEA/JRC, etc.)

- Further investigation on the scope of the category regarding indoor emissions, worker health, accident statistics, ionizing and non ionizing radiations.
- Selection of recommended models and calculation of generic factors corresponding to typical emission situations (2005).

Specific deliverables
The following deliverables are foreseen:
- Human toxicity and ecotoxicity framework with well identified functional components
- Review reports for base model, including fate and ecotoxicity effects
- Review report and human toxicity effect indicator
- Report on workshop on metal essentialities
- Application to test cases and inputs to the REACH project/database
(Further work: see deliverables above common to TF 2 to 4 and the LCIA definition study documents)

7.9 LCIA Task Force 4: Transboundary impacts

Specific aims
This task force aims at establishing recommended practice and guidance for use in transboundary categories, i.e: climate change, ozone depletion, aquatic and terrestrial eutrophication and acidification. Photooxidant formation and respiratory inorganics (Primary and secondary particles) will be coordinated with Task Force 3. The task force will address midpoint categories and their relation to damage categories human health and biotic natural environment in a consistent way with Task Force 3

Specific challenges for each impact category are defined in the LCIA definition study document.

Motivation
These categories are of high importance for the establishment of an Integrated Product Policy at European level. A central point is the need for adapting knowledge from other scientific communities focusing on environmental modelling to the assessment of Life Cycle Impacts linked to functions and Products.

Specific work description and programme:

Collaborative framework: For these categories, it is of high importance to rely on the expertise and timely contribution of various experts from different fields. Input from external experts was indeed a major problem in the previous SETAC task forces in this area, as most of the specific expertise is outside the LCA community and as experts in these fields therefore usually do not attend SETAC-conferences. Therefore, as much as possible, meetings and workshops will be connected to meetings of experts in these impact categories.

It is the ambition of the task force to make contact with related scientific communities working on Integrated Assessment Models (IAM) and with experts of the scientific network under the UNECE convention on Long-Range Transboundary Air Pollution (CLRTAP; see footnote). The aim of this workshop will be to explore the interfaces between LC(I)A and Integrated models and to get external input for recommended practice on the impact categories covered by the transboundary impacts task force

Another need is to enable compatibility between transboundary categories and other categories related to human health and biotic natural environment: The link to damage categories will be considered from the start in framing the field and defining functional components of the assessment, ensuring consistent approaches between midpoint categories.

According to this content, the work programme is foreseen, in two phases:

It is aimed in the first year to frame the field and arrive to a set of recommended characterization factors at generic level for the midpoint categories. Further work will then be carried out to extend model and frame, possibly to site-dependency and latest models in development. Special attention should be paid to arrive at a regional balanced input, specifically also taking into account the perspective of developing regions.

The following activities are foreseen:
1) Preparation, possibly per impact category, of a state-of-the-art review, including the compatibility with other categories and the link to damages.
- Advice for a generic set of recommended characterization factors for the midpoint categories, with link to damages
2) Analysis of advanced recommended practice as input to further workshop
- Workshop about interfaces between Integrated Modelling and LCA, and about – site-dependent / generic – recommended practice on all impact categories.
- Proposal for new factors

Specific deliverables
The following specific deliverables are foreseen for each considered category

- A finalized state of the art and a proposal for framing the field and for the functional components of the assessment (2003-2004)
- A set of recommended generic characterization factors according to the adaptation of available models and factors (2004)
- Recommended methodologies for the calculation of compatible generic and site-dependent characterisation factors for different impact categories, including links to damage categories (2005 according to category prioritarization)

The Executive Body of the Convention on Long-range Transboundary Air Pollution decided in 1999 to include integrated assessment into the core activities of the Co-operative programme for Monitoring and Evaluation of the Long-range Transmission of Air Pollutants in Europe (EMEP). It was also decided to establish a Centre for Integrated Assessment Modelling (CIAM) building on past modelling work, in particular the RAINS model. The work at CIAM focuses on the analysis of scenarios for cost-effective reductions of – initially – acidification, – but now also – terrestrial eutrophication, tropospheric ozone (photooxidant formation in LCA) and related phenomena, especially fine particulate matter pollution. A workshop took place in spring 2003, bringing together experts on the traditional air pollutants and experts on greenhouse gasses, to explore the linkages and synergies between the traditional air pollutants and greenhouse gases. The workshop focused on impacts and their causal chain of environmental mechanisms, rather than on the societal drivers of production and consumption that are behind. A logic next step forward could be to have a workshop emphasising these societal drivers by exploring the interfaces between IAM and LCA.

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Appendix I: Proposed terminology for the LCIA programme of the Life Cycle Initiative and equivalency with other frameworks

Table I.1 summarises the proposed terminology and compares it with other frameworks. Further detailed definition are given for LCI results and for midpoint and damage categories or indicators

LCI results are substance and energy flows as well as other physical actions crossing the system boundary between an anthropogenic process and the environment. The Life-Cycle Inventory LCI does not contain all of these flows and actions, but only those whose total quantity is expected to influence the quality status of the environment in a relevant way (E.g. an emission of oxygen to the air is normally not tabled in the LCI). In certain cases (land use, noise, waste), the LCI results may also consist of auxiliary data which are converted into trans-boundary flows and actions only at the level of the LCIA methods.

Midpoint categories represent environmental issues of concern to which various flows or actions tabulated as LCI results contribute, involving common or similar processes (e.g. acidification, ionising radiation). These categories are termed “midpoint” because the selected category or tabulated data does not use the data to make the link to damage. In practice, the historical development of midpoint categories is the result of interaction between scientific discoveries and societal processes: The issue of acidification developed around 1960 when the increase of combustion gas induced substantial acidity changes of water bodies and soil, and the issue of stratospheric ozone depletion developed around 1970 when the decrease of stratospheric ozone was detected and explained, followed by a public debate of the problem. Midpoint categories may appear less significant if the corresponding problem is solved or if public concerns change.

A midpoint indicator is the quantified representation of the corresponding midpoint category. The indicator may represent the quality status of an object or an important process in nature, but it may also be limited to an index that is useful for the successive determination of a quality status. The currently used midpoint indicators are of two different types:
Either (type 1) they are based on common impact processes and bundle the substance flows or physical changes from the LCI results up to a certain intermediate point, from where links to various damage categories are in principle possible (examples of this type 1 are the midpoint indicators for ozone depletion and Climate change), or (type 2) they bundle substance flows or physical changes from the LCI results with non-similar impact processes, but which address explicitly one damage category (example for this type 2 is the indicator for human toxicity which bundles various substance flows that are known to cause diseases and premature deaths of humans: fate, exposure and effect of these substance flows can be treated similarly, but environmental processes and types of diseases generally differ from one chemical to the other).

Damage categories classify damages to various parts of the environment that are of concern to society. The currently prevailing opinion is that these ‘parts of the environment’ consist of the biotic environment (living organisms in nature), the abiotic environment (non-living elements of nature) and the human population (being a special case of a living organism that is believed to merit particular considerations). As an extension, the man-made environment, mainly consisting of buildings and animal or vegetal cultures, may also be considered as a part of the environment giving rise to the nomination of damage categories. In contrast to the midpoint categories, the damage categories are intended to represent quality changes of 'ultimate' concern: Whilst acidification of water bodies or soil is a matter of concern because of the *consequences* of such acidification, the loss of human life years, the extinction of a plant species or the destruction of a crystal cave is considered as a damage in itself, or an environmental quality change of 'ultimate' concern. However, practice has not been fully consistent with respect to this distinction, for example the depletion of fossil energies has traditionally been considered as a damage category, although the prevailing concern regarding this depletion is not an 'ultimate' concern, but rather a functional concern in view of the future well-being of humans.

A damage indicator is the quantified representation of the quality status of a part of the environment that is addressed by a damage category. The quality status of the human population can e.g. be expressed by the number of life years lost (mortality) and/or the number and duration of various disease cases (morbidity), whilst the quality status of non-human organisms can be expressed by the geographical extension and the population density (occurrence) of a species. It is obvious that in practice, a damage indicator is always a simplified model of a very complex reality, giving only a coarse approximation to the quality status of the item.

The damage categories can be grouped with respect to Areas of Protection (AoP), such as human health, natural environment, natural resources, man-made environment (see figure 4.1); they can also be classified according to intrinsic and functional values (see table 4.2).

Appendix 1 Table 1: retained definitions

Proposed term LC Initiative LCIA	**Definition**	**ISO *&SETAC terms***	**DPSIR term**	**Common term & alternatives**	**Comment**
LCI results	Outcome of a life cycle inventory analysis that includes the flows crossing the system boundary and provide the starting point for life cycle impact assessment (ISO 14042). LCI results are **pressures** of the three following types: emissions, resource extraction & uses and physical changes	LCI results *Environmental interventions*	Pressure	Exchanges, Stressors, Emissions and resource uses	Stick to ISO, no other short, crisp and well accepted term; little risk of confusion
Midpoint Impact category (Midpoint category)	*Class representing environmental issues of concern to which LCI results may be assigned (ISO 14042), involving common or similar processes*	*No term*			
Midpoint Indicator	*Quantifiable representation of a midpoint impact category (ISO 14042)*	*Impact category indicator*	*State indicator*		*Closer to ISO*
Damage Impact category (Damage category)	Class representing damages on an ultimate Areas of Protection to which state/midpoint categories may be assigned (ISO 14042). A benefit is defined as a negative damage	More and less Endpoints, but was not defined as a category		Category with endpoint indicator	
Damage indicator	Quantifiable representation of a damage category	Endpoint	Impact indicator	Endpoint indicator	Endpoint has different meaning in Risk Assessment and LCA ISO 14042. Impact indicator cannot be used as such from the pressure-state-impact framework
Impact pathways	System of processes, linking the LCI results to state/midpoint indicators and to damage indicators (adapted from ISO 14042)	Environmental mechanism		Impact pathways	Test if more suited than the ISO term (it better describes some links, which, e.g. for noise, are not strictly mechanisms). If no advantage come back to ISO
Areas of Protection	Operational group of items of direct value to human society.	No ISO term, *Area of Protection*		Safeguard subjects	