

# SimaPro 7

## Database Manual

Methods library



product ecology  
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# **SimaPro Database Manual**

**Methods library**

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Methods library

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# 1 Introduction

SimaPro contains a number of impact assessment methods, which are used to calculate impact assessment results. This manual describes how the various impact assessment methods are implemented in SimaPro. For specific details on the method see the literature references given or contact the authors of the method.

## *AN IMPORTANT NOTE ON CHANGING METHODS*

*If you want to change methods in SimaPro, it is strongly advised to copying the original method to your project. By copying you make sure you always have an original method in your database. Once changes are saved, there is no undo function!*

## 1.1 Structure of methods in SimaPro

The basic structure of impact assessment methods in SimaPro is:

1. Characterisation
2. Damage assessment
3. Normalisation
4. Weighting

The last three steps are optional according to the ISO standards. This means they are not always available in all methods. In SimaPro you can switch the optional steps on or off when you edit a method.

### Characterisation

The substances that contribute to an impact category are multiplied with a characterisation factor that expresses the relative contribution of the substance. For example, the characterisation factor for CO<sub>2</sub> in the impact category Climate change can be equal to 1, while the characterisation factor of methane can be 21. This means the release of 1 kg methane causes the same amount of climate change as 21 kg CO<sub>2</sub>. The total result is expressed as impact category indicators (formerly characterisation result).

### *Subcompartments*

In SimaPro, subcompartments can be specified for each substance. For example, you can define an emission to water having a subcompartment Ocean. This allows you to create detailed impact assessment methods, with specific characterisation factors for each subcompartment. Some impact assessment methods are not as detailed as the inventory in terms of specification of subcompartments. In this case SimaPro will choose the "unspecified" characterisation factor as the default factor for a substance that has a subcompartment specified in the inventory but has no specific characterisation factor in the chosen impact assessment method.

### Damage assessment

Damage assessment is a relatively new step in impact assessment. It is added to make use of 'endpoint methods', such as the Eco-indicator 99 and the EPS 2000 method. The purpose of damage assessment is to combine a number of impact category indicators into a damage category.

In the damage assessment step, impact category indicators that have a common unit can be added. For example, in the Eco-indicator 99 method, all impact categories that refer to Human health are expressed in DALY (disability adjusted life years). In this method it is allowed to add DALYs caused by carcinogenic substances to DALYs caused by climate change.

### Normalisation

Many methods allow the impact category indicator results to be compared by a reference (or Normal) value. This means the impact category is divided by the reference. A commonly used reference is the average yearly environmental load in a country or continent, divided by the number of inhabitants. However, the reference may be chosen freely. You could also choose the environmental load of lighting

a 60W bulb for one hour, 100 km of transport by car or 1 litre of milk. This can be useful to communicate the results to non LCA experts, as you benchmark your own LCA against something everybody can imagine. In SimaPro, there are often alternative normalisation sets available.

After normalisation the impact category indicators all get the same unit, which makes it easier to compare them. Normalisation can be applied on both characterisation and damage assessment results.

*PLEASE NOTE: SimaPro does not divide by the reference value (N), but multiplies. If you edit or add a normalisation value in a method, you must therefore enter the inverted value (1/N).*

### Weighting

Some methods allow weighting across impact categories. This means the impact (or damage) category indicator results are multiplied by a weighting factors, and are added to create a total or single score. Weighting can be applied on normalised or non normalised scores, as some methods like EPS do not have a normalisation step. In SimaPro, there are often alternative weighting sets available, always in combination with a normalisation set.

## 1.2 Checking impact assessment results

Although impact assessment methods become very extensive and include more and more substances, they still do not cover all substances that you can find in your inventory. This can be a methodological issue, as some methods for example do not include raw materials as impact category. It can be you added a new substance, which is not automatically included in the impact assessment method. Or you could have introduced synonyms by importing data from other parties.

SimaPro has a build in check to show you which substances are not included in the selected impact assessment method. For each result, the substances and their amounts not included in the method are shown under Checks in the result window.

Further, under Inventory results you can show the impact assessment results per substance. If a substance is not defined in the method, a pop-up hint will tell you this.

On a method level, you can run a check which will show you which of all substances available in the SimaPro database are included in the method on impact category level. To run this check, select a method and click the Check button in the right hand side of the methods window.

## 2 Method descriptions

### 2.1 CML 1992 v2.1

#### 2.1.1 Introduction

This classification method is based on the method published by CML of the University of Leiden in October 1992<sup>1</sup>. PRé has modified the method in a number of ways.

#### 2.1.2 Characterisation

Grouped substances or sum parameters have been defined in a number of classes. This has been done because the emissions are not always specified separately in the data sources for the processes concerned. Emissions are often specified under a collective name, e.g. aromatic hydrocarbons. Since the different substances within such a group can have considerable variation in their environmental impact, the resulting effect score may not be completely reliable.

The main classes are:

#### 1. Exhaustion of raw materials and energy

##### *Abiotic*

This term refers to energy sources and a number of scarce metals. In the CML 92 method, all the energy sources were grouped into a separate class called **Energy**.

The effect score for exhaustion is calculated on the following basis:

$$\text{Exhaustion} = (\text{amount consumed (kg)} \times \{1/\text{resources (kg)}\})^2$$

##### *Biotic*

This category is intended for rare animals and plants. This score is as yet very rudimentary and has therefore not been used.

#### 2. Pollution

##### *Greenhouse effect*

The Global Warming Potential (GWP) is the potential contribution of a substance to the greenhouse effect. This value has been calculated for a number of substances over periods of 20, 100 and 500 years because it is clear that certain substances gradually decompose and will become inactive in the long run. For the CML 92 method, we have taken the GWP over a 100-year period because this is the most common choice.

We have added values for CFC (hard) and for CFC(soft) to the CML (1992) method, since it is not always known which CFC is released. The GWP for this category of substances has been equated to that of CFCs frequently used in industrial mass and series production; for CFC (hard) this is the value for CFC-12, and for CFC (soft) it is the value for HCFC-22.

The effect score for the greenhouse effect is calculated per substance as follows:

$$\text{Greenhouse effect (kg)} = (\text{GWP 100} \times \text{airborne emission (kg)})^3$$

<sup>1</sup> R. Heijungs et al, *Environmental life cycle assessment of products, Guide, October 1992* CML, Leiden, The Netherlands, NOH report 9266.

<sup>2</sup> World Institute, *World Resources 1990-1991*, Oxford University Press, New York/Oxford.

<sup>3</sup> Houghton, Callender & Varney, *Climate Change 1992. The supplementary report to the IPCC scientific assessment*, Cambridge University Press, Cambridge, UK, 1992.

### Ozone layer depletion

Ozone Depletion Potential (ODP) values have been established mainly for hydrocarbons containing combined bromine, fluorine and chlorine, or CFCs. Here too, one of the substances (CFC-11) has been adopted as a reference. As for the greenhouse effect, we have added values for CFC (hard) and CFC (soft). The ODP equivalents for these groups are again those of CFC-12 and HCFC-22 respectively.

The effect score for ozone layer depletion is calculated as follows:

$$\text{Ozone layer depletion (kg)} = (\text{ODP} \times \text{airborne emission (kg)})^4$$

### Human toxicity

Criticism of the use of MAC values in the CML 1990 method led to the development of a fairly long list of substances that are poisonous to human beings. A notable feature is that human toxicity combines a score for emissions to air, water and soil. The following values have been established for most substances:

- Human-toxicological classification value for air (HCA)
- Human-toxicological classification value for water (HCW)
- Human-toxicological classification values for soil (HCS).

We have not included soil emissions in this because the program does not have an impact category for substances emitted to soil. The number of characterisation factors from soil is very limited. Moreover, it may be assumed that emissions that initially enter the soil will ultimately appear in the groundwater and hence can be dealt with as emissions to water.

We have added a number of values for *groups* to this class: metallic ions and various groups of hydrocarbons. Metallic ions have been given a value equal to that of iron. The values of the hydrocarbons are given in Table 7. An equivalent has also been selected for most other values that were not defined; e.g. for chlorine, the equivalent value of bromine has been used.

Substances	Equivalents			
	human toxicity air	human toxicity Water	ecotoxicity water	smog air
CxHy	isopropanol	Isopropanol	crude oil	aliphatics average
CxHy aliphatic	isopropanol	Isopropanol	crude oil	aliphatics average
CxHy aromatic	benzene	Benzene	benzene	aromatics average
CxHy chloro	1,2, dichloroethane	1,2, dichloroethane	1,2, dichloroethane	average chlorinated org. compounds
PAH	benzo(a)pyrene	benzo(a)pyrene	benzo(a)pyrene	aromatics average

Table 4.2: substances from which HCA/HCW, ECA and POCP values for hydrocarbons are taken.

The human toxicity effect score is calculated as follows:

$$\text{Human toxicity (kg)} = (\text{HCA (kg.kg}^{-1}) \times \text{emission to air (kg)} + \text{HCW (kg.kg}^{-1}) \times \text{emission to water (kg)})^5$$

<sup>4</sup> World Meteorological Organisation, *Scientific assessment of ozone depletion 1991*, Global Ozone Research and Monitoring Project - Report no. 25, 1991.

<sup>5</sup> Vermeire, T.G et al., *Voorstel voor de humaan-toxicologische onderbouwing van C - (toetsings)waarden* [Proposal for the human-toxicological basis of test values], RIVM, Bilthoven, The Netherlands, 1991.

### Ecotoxicity.

Substances in this class are given values for toxicity to flora and fauna. The main substances are heavy metals, Values have been established for emissions to water and to soil, i.e.:

- Aquatic ecotoxicity (ECA)
- Terrestrial ecotoxicity (ECT).

Only the ECA values have been included in the CML 92 method because emissions to soil eventually appear in the groundwater and are thus already covered.

We have added a number of values for groups of hydrocarbons to this class. Values for the hydrocarbons are shown in Table 4. An equivalent has been selected for most other values that were not defined.

The effect score for ecotoxicity is calculated as follows:

$$\text{Ecotoxicity (m}^3\text{)} = \left( \text{ECA (m}^3 \cdot \text{kg}^{-1}\text{)} \times \text{waterborne emission (kg)} \right)^6$$

### Smog

The photochemical ozone creation potential (POCP) indicates the potential capacity of a volatile organic substance to produce ozone. Values have been published for a wide range of volatile organic substances. The value for ethene has been set at 1. The values for most other substances are less than this. The POCP of these sumparameters such as alcohols, ketones, aldehydes and various groups of hydrocarbons groups is the average of all the relevant substances in the CML (1992) list. The values for the hydrocarbon groups are given in Table 4. NO<sub>x</sub> is omitted in the CML 92 method.

The effect score for smog is calculated as follows:

$$\text{Smog (kg)} = \left( \text{POCP} \times \text{airborne emission (kg)} \right)^7$$

### Acidification.

The Acidification Potential (AP) is expressed relative to the acidifying effect of SO<sub>2</sub>. Other known acidifying substances are nitrogen oxides and ammonia. SO<sub>x</sub> has been added, with the same value as SO<sub>2</sub>.

Acidification effect scores are calculated as follows:

$$\text{Acidification (kg)} = \left( \text{AP} \times \text{airborne emission (kg)} \right)$$

Note that the results of the acidification classes from CML (1990) and CML (1992) are not calculated in the same way.

### Eutrophication

The Nutriphication Potential (NP) is set at 1 for phosphate (PO<sub>4</sub>). Other emissions also influence eutrophication, notably nitrogen oxides and ammonium.

The eutrophication effect score is calculated as follows:

$$\text{Eutrophication (kg)} = \left( \text{NP} \times \text{airborne emission (kg)} \right)$$

<sup>6</sup> Slooff, W., *Maximum tolerable concentrations, ecotoxicological effect assessment*, RIVM no. 719102018, Bilthoven, The Netherlands.

<sup>7</sup> Protocol to the convention on long-range transboundary air pollution concerning the control of emissions of volatile organic compounds or their transboundary fluxes, United Nations - Economic Commission for Europe (UNECE), Geneva, Switzerland, 1991.

### *Odour.*

Weighting factors for stench have been developed, although their use is unusual in LCAs. In these, ammonia is given the value 1.

This class is not included in the CML 92 method because it is a highly localised environmental effect, and the degree of stench nuisance depends largely on local circumstances.

### *Solids*

This class is not included in the original CML 1992 classification. We have added the solids class to the method because solid emissions form an important environmental problem in their own right. The weight of the waste emission is used for calculation, and no weighting factors are involved.

$$\text{Solids (kg)} = (\text{solid emission output (kg)})$$

### 2.1.3 Normalisation

The first and probably most widely used normalisation set was published in 1993 by Guinée from the CML. This set was compiled by extrapolating 1988 data from the Dutch Emission Registration. Most of the data was simply multiplied by a factor 100, to extrapolate them to the world level, as The Netherlands contribute about 1% to the Gross National Product figures in the World. An exception was made for greenhouse and ozone depleting emissions. These were taken directly from IPCC. The figures are supposed to reflect the world emissions. In order to make the figures more manageable, we have divided them by the world population of 6.000.000.000. A very recent project executed by IVAM-ER, NWS (University of Utrecht) and PRé, under commission from VROM and RIZA, in the Netherlands has resulted in three new sets of normalisation figures. They are for a large part based on the Emission registration (base year 1994), and several other sources. The results of this project have been peer reviewed by Guinée. The normalisation levels are:

- Dutch territory. All emissions registered emitted within the Netherlands and all raw materials consumed by the Dutch economy.
- Dutch consumer. The effect of imports have been added, the effects of exports have been subtracted. The calculation was performed using the Dutch input-output matrix.
- European territory (EC, Switzerland, Austria and Norway). Most data are from original European data. In some cases data was extrapolated from Dutch and Swiss data. The energy consumption within a region was taken as a basis for extrapolation.

### 2.1.4 Evaluation

Although several organisations have developed evaluation factors using panel methods, there is no generally recognised method to evaluate the results obtained with the CML method.

## 2.2 Eco-indicator 95 v2.1

### 2.2.1 Characterisation

The only difference between the characterisations in the SimaPro 2 CML and SimaPro 3 Eco-indicator 95 methods is in the ecotoxicity and human toxicity effect definition. Both toxicity scores have been replaced by:

- Summer smog (already available in the SimaPro 2 CML method)
- Winter smog
- Carcinogens
- Heavy metals to air and water
- Pesticides

The characterisation values are based on the following data:

#### *Effect score of persistent toxic substances in air and water*

This effect score relates in particular to heavy metals because long-term exposure at low levels brings clear health risks. The risks relate particularly to the nervous system and the liver and can be assessed for toxicity to both human beings and ecosystems. It is assumed in general (Globe, Air Quality Guidelines) that human toxicity is the most important limiting factor. The Air Quality Guidelines specify the following admissible air concentrations for annual exposure to humans:

	Maximum concentration (µg/m <sup>3</sup> )	Weighting factor	Main health effect
Cadmium	0.02	50	Kidneys
Lead	1	1	Blood biosynthesis, nervous system and blood pressure
Manganese	7	0.14	Lungs and nervous system (shortage cause skin complaints)
Mercury	1	1	Brain: sensory and co-ordination functions

*Table 4.3: Air Quality Guidelines admissible air concentrations for annual exposure to humans*

Chromium and nickel are regarded as carcinogens because the risk of cancer is greater than the toxicological effect.

Based on this concentration a weighting factor can be determined which is equal to the inverse of the admissible concentration. This agrees with the critical volume approximation that used to be applied with the MAC value. We have expressed the effect score as a lead equivalent.

The WHO 'Quality guidelines for drinking water' specify a number of values for persistent substances based on long-term, low-level exposure. These criteria have been drawn up to evaluate drinking water, based on established health effects. A selection is given below of substances that are persistent to a greater or lesser extent and that therefore accumulate in the environment.

Substance	Norm (mg/litre)	Weighting factor	Effect
Antimony	0.005	2	Glucose and cholesterol content of blood
Arsenic	0.01	1	Probability of skin cancer $6 \times 10^{-4}$
Barium	0.07	0.14	Blood pressure and blood vessels
Boron	0.3	0.03	Fertility
Cadmium	0.003	3	Kidneys
Chromium (all)	0.05	0.2	Heredity (carcinogenity only applicable in event of inhalation)
Copper	2	0.005	Generally no problems, sometimes liver abnormalities
Lead	0.01	1	Blood biosynthesis, nervous system and blood pressure
Manganese	0.5	0.02	Nervous system
Mercury	0.001	10	Kidneys, nervous system (methyl mercury)
Molybdenum	0.07	0.14	No clear description
Nickel	0.02	0.5	Weight loss, great uncertainty

Table 4.4: WHO based substances that are persistent

With this effect score the weighting factor is determined in order to be able to calculate the lead equivalent. SimaPro merges the scores for water and air. This is possible because they are both expressed as a lead equivalent and because the target reductions for air and water are the same.

We have combined the two scores for heavy metals. This was possible since they are both expressed as a lead equivalent and since the weighting factors are identical.

$$\text{Heavy metal to air (kg lead eq.)} = (\text{AQG (lead)}/\text{AQG (substance)}) * \text{emission}$$

$$\text{Heavy metal to water (kg lead eq.)} = (\text{GDWQ (lead)}/\text{GDWQ (substance)}) * \text{emission}$$

### Carcinogenic substances

The 'Air Quality Guidelines' do not specify acceptable levels, but calculate the probability of cancer at a level of  $1 \mu\text{g}/\text{m}^3$ . In the table below this probability is expressed as the number of people from a group of 1 million who will develop cancer with the stated exposure.

	Probability of cancer at $1 \mu\text{g}/\text{m}^3$	Weighting factor for PAH equivalent	Type of cancer
Arsenic	0.004	0.044	General, also mutagenic effects
Benzene	0.000001	$1.1 \times 10^{-5}$	Leukaemia
Nickel	0.04	0.44	Lung and larynx
Chromium (VI)	0.04	0.44	Lung, among others, and mutagenic effects
PAHs (benzo(a)pyrene)	0.09	1	Lung cancer but also other types of cancer

Table 4.5: Number of people from a group of 1 million who will develop cancer with the stated exposure.

It is worth considering whether to include asbestos in this list. The difficulty with this is that asbestos emissions cannot be expressed meaningfully in a unit of weight. The number and type of fibres is the determining factor.

It is not entirely clear whether these numbers can be used directly as a weighting factor in order to calculate, for example, a PAH equivalent. This is because it is not known exactly whether a linear correlation may be assumed between probability and exposure. At present we assume that this is so.

$$\text{Heavy metal to air (kg lead eq.)} = (\text{AQG (lead)}/\text{AQG (substance)})$$

### Winter smog

Only dust (SPM) and SO<sub>2</sub> are factors in this problem. For both substances the 'Air Quality Guidelines' specify a level of 50 µg/m<sup>3</sup>. The weighting factors are thus both 1.

$$\text{Winter smog (SO}_2 \text{ or SPM eq.)} = \text{SO}_2 \text{ emission} + \text{SPM emission}$$

### Pesticides

The Globe report describes pesticides as a problem for two reasons:

- Groundwater becomes too toxic for human consumption.
- Biological activity in the soil is impaired, as a result of which vegetation is damaged.

This means that account must be taken in the effect score weighting of both ecotoxicity (soil) and human toxicity (water). The target reduction is based on human toxicity. Globe distinguishes between

- disinfectants
- fungicides
- herbicides
- insecticides

Within these groups all the different sorts are listed, based on their active ingredient content. We propose also doing this for this effect score and shall also list the various mutual categories.

$$\text{Pesticides (kg)} = (\text{active ingredients})$$

### 2.2.2 Normalisation

The normalisation values are based on average European (excluding the former USSR) data from different sources. The reference year is 1990. In many cases we had to extrapolate data from one or more individual countries to the European level. As an extrapolation basis we used the energy consumption of the countries. In order to make the figures more manageable we divided the figures by the population of Europe: 497,000,000.

### 2.2.3 Evaluation

In the SimaPro 3 and the ecopoints methods the distance-to-target principle is used to calculate evaluation values. The basic assumption is that the seriousness of an impact can be judged by the difference between the current and a target level.

In the SimaPro 3 method the target is derived from real environmental data for Europe (excluding the former USSR), compiled by the RIVM. In the text below this report is referred to as Globe (The Environment in Europe: A Global Perspective).

The targets are set according to the following criteria:

- At target level the effect will cause 1 excess death per million per year
- At target level the effect will disrupt fewer than 5% of the ecosystems in Europe
- At target level the occurrence of smog periods is extremely unlikely

### Greenhouse effect

At present, temperatures are rising by 0.2% every ten years. Under the current policy this rate will increase to 0.3% every ten years. The consequence will be a large temperature change by 2050. In Northern and Eastern Europe the winters will be more than 5° warmer, and in Southern Europe the summers will be 4° warmer. Areas in particular that have no other systems in their vicinity that can

exist in such climatic conditions will suffer serious damage. This will affect approximately 20% of Europe.

The Globe report indicates that fewer than 5% of the ecosystems will be impaired if the greenhouse effect is reduced by a factor of 2.5.

### *Ozone layer depletion*

In accordance with the Montreal Protocol and its London amendment all CFC emissions must be reduced to zero. For the less persistent HCFCs it has been agreed that the contribution to the effect in 1989 may not exceed 2.6% of the total adverse effect of CFCs. After this, the use of these substances too is to be reduced gradually by 2015.

If that happens the annual total of fatalities per million inhabitants in Europe will first rise from approximately 1 to 2 and then fall to 1 death per year per million inhabitants. It does not yet seem directly necessary to reduce all HCFC emissions to zero because the norm (2 ppbv) is going to be achieved, even if after 2100. For these gases the target reduction is linked to the greenhouse effect<sup>8</sup>.

Based on this reduction for greenhouse gases, we therefore assume, for the moment, that the target reduction for HCFCs is of the order of 60%. Based on the premise that the HCFCs presently cause 2.6% of ozone layer depletion it can be estimated that this reduction will cause ozone layer depletion to fall to 1% of its present level. The reduction factor is thus 100. There is a great deal of uncertainty about this figure.

### *Acidification*

There is a great variety in Europe in the ability of ecosystems to withstand acidification. In Scandinavia, for example, problems can occur with deposits of 100 eq/ha.yr, while in some places in the Netherlands and Germany the soil can withstand a deposit of more than 2000 eq/ha.yr.

Actual deposition appears to reach its highest level in Central Europe, particularly as a result of the use of lignite.

If the deposition and ability to withstand acidification are combined with each other, it seems that major problems are occurring particularly in England, the Benelux countries, Germany, Poland, the Czech Republic and Slovakia.

A provisional estimate based on the RAINS computer model shows that the reduction must be of the order of a factor of 10 to 20 to keep damage to the ecosystem below 5%.

### *Eutrophication*

Eutrophication is seen in the Globe report particularly as the problem of excessive use of fertilisers by agriculture, as a result of which nitrates leach out and poison groundwater supplies. The problem is at its greatest in the Benelux countries, North-Rhine Westphalia (Germany) and Italy's Po valley plain (approx. 200 kg/ha).

In the CML classification Eutrophication refers mainly to air and water emissions. These rarely contribute more than 10% of the amount of fertiliser applied by farmers. In uncultivated biotopes, however, that are low in nutrients this eutrophication can have a serious adverse effect on biodiversity.

In describing the level of eutrophication in rivers and lakes it is estimated that the critical value for phosphates is 0.15 mg/l and for nitrates 2.2 mg/l. At these levels there are no problems with eutrophication. In the rivers Rhine, Schelde, Elbe, Mersey and Ebro, however, these figures have been exceeded more than 5 times. This means that the emissions must be reduced by a factor 5.

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<sup>8</sup> By contrast, the elimination of CFCs will also result in a significant reduction in the greenhouse effect. CFCs are responsible for 24% of this effect. Eliminating the CFCs will therefore yield a 24% reduction in the greenhouse effect.

### *Summer smog*

A hundred years ago the ozone concentration averaged over the whole year was approximately 10 ppb. At present it is 25 ppb. This is approximately the maximum acceptable level; above 30 ppb, for example, crop damage can occur.

The major problem is not determined by the average figures but by the summer peaks which can reach more than 300 ppb. To reduce this type of dangerous peak by 90% it is necessary to reduce VOCs and NO<sub>x</sub> by 60 to 70%.

### *Heavy metals*

In Central Europe lead concentrations are very high, particularly in the soil and water. The air concentration is also high in towns and cities, particularly because of the use of leaded petrol. For adults the Air Quality Guideline specifies a limit in the air of 0.5 to 1 µg/m<sup>3</sup>. According to Globe this value is often exceeded by a number of times. Globe notes in passing (and without backing it up) that average lead concentrations in Poland are 20 µg/m<sup>3</sup>.

Eating locally grown vegetables would result in a blood lead level that is ten times too high. Lead levels in children's blood of 150 to 400 µg/l have been found. Such readings also occurred in the West 30 years ago, but not any more. The figures are five to ten times lower now. There is thought not to be a no-effect-level for exposure for children. Above 100 µg/l clear reductions in learning ability can be measured.

Thus although it is plausible that this pollution has a clearly measurable effect on human health, it is not easy to calculate a general reduction percentage for lead. The best estimate is a reduction by a factor of 5 to 10. We have taken a figure of 5 for heavy metal emissions to air.

Agriculture (fertiliser) is the major source of cadmium deposition. The average deposition rate is 0.6 to 0.67 g/ha on grassland and 3.4 to 6.8 g/ha for arable land. The Southern Netherlands holds the record with a deposition rate of 7.5 to 8.5 g/ha. Furthermore, approximately 14% is distributed via the air (see winter smog).

This leaching is calculated in the Globe report for the Rhine. A detailed calculation makes a convincing case for the necessity to reduce cadmium emissions by 80 to 85%. In some other rivers such as the Elbe cadmium contamination is substantially greater, and the required target will perhaps have to be set even higher. For the moment we are continuing with a target reduction of a factor of 5 for heavy metals in water.

### *Winter smog*

The most important sources of this problem which occurs mainly in Eastern Europe are SO<sub>2</sub> and SPM (suspended particle matter, or small dust and soot particles). NO<sub>x</sub>, organic substances and CO are also involved to a lesser extent. The dust particles can also contain heavy metals.

This form of smog achieved notoriety in 1952 when it caused an estimated 4000 deaths in London. The SO<sub>2</sub> and SPM concentrations reached values of 5000 micrograms per cubic metre. In Southern Poland and Eastern Germany average readings of 200 µg/m<sup>3</sup> still occur repeatedly. The Air Quality Guidelines specify a limit of 50 µg/m<sup>3</sup> for long-term exposure to both SPM and SO<sub>2</sub>. Based on this, a reduction of 75% would be necessary.

Globe estimates that a reduction in SO<sub>2</sub> emissions of more than 80% is necessary to eliminate by and large the occurrence of occasional smog periods. No target is proposed for SPM because it is not well a defined or well measured<sup>9</sup> pollutant.

We are continuing to use a factor of 5 as a target.

### *Carcinogenic substances*

Globe also provides some data on the distribution of carcinogenic substances. The main substances involved are polyaromatic hydrocarbons (PAHs), of which benzo[a]pyrene in particular is an important

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<sup>9</sup> A major shortcoming of the CML classification system is the lack of a weighting factor for particulate matter in calculating human toxicity. According to the Globe report, SPM is one of the most injurious substances to health.

example. This occurs, among other places, in coke furnaces and in (diesel) motors. In fact, the problem is only relevant in urban areas.

Globe specifies a value of 0.8 to 5 ng/m<sup>3</sup> for Northern European towns and cities. The Air Quality Guideline specifies a value of 1 ng/m<sup>3</sup> in American cities without coke furnaces in the vicinity and 1 to 5 ng/m<sup>3</sup> in cities with coke furnaces. In European towns and cities in the 60s, when open coal fires were still very much in use, the average concentrations were in excess of 100 ng/m<sup>3</sup>. In Eastern Europe the values are still high because of the use of coal-fired heating systems. As a point of comparison, a room in which a lot of smoking takes place can contain 20 ng/m<sup>3</sup>.

The Air Quality Guideline specifies a threshold concentration of 0.01 ng/m<sup>3</sup> at which 1 cancer case per million inhabitants per year will still occur. This criterion cannot be compared straightforwardly with the criterion for ozone layer depletion because not all the cancer cases are terminal. In addition, only about 1/3 of the population of Europe lives in towns or cities<sup>10</sup>. If we assume that one in every three cancer cases is terminal and if we only take the urban population the risk of death is about ten times lower. Based on this, there would be one death per million inhabitants per year at a concentration of 0.1 ng/m<sup>3</sup>.

Based on a background concentration of 1 ng/m<sup>3</sup> in towns and cities without coke furnaces (West European towns and cities in particular) a reduction by a factor of 10 could be estimated.

### *Pesticides*

Leaching of pesticides threatens groundwater sources throughout the EU. The groundwater is contaminated in 65% of the EU above the EU norm (0.5 µg/litre). The norm is exceeded tenfold in 25% of the EU. This occurs in 20% of the land area of Eastern Europe. A reduction by a factor of 25 is necessary to ensure that the norm is exceeded in less than 10% of Europe.

### *Exhaustion of raw materials and solid waste*

We have not defined any percentage reductions for exhaust of raw materials. There are two reasons for this:

No people die and no ecosystems are impaired as a result of the depletion of raw materials. It mainly causes economic and social problems.

Exhaustion is difficult to quantify because there are alternatives for most materials. For example, copper has already been replaced on a very wide scale by glass-fibre (communications) and aluminium (electricity-conducting medium). There are also good prospects for substituting materials in energy generation if the market is prepared to pay more for energy. In fact, the problem with energy is not the depletion of fossil fuels but the environmental impacts of combustion. Explicit account is taken of these in the indicator. In other words, you need not think that all the oil reserves that are presently known have actually been used. That would be an environmental disaster.

We have not defined any percentage reduction for waste. A similar reason applies to waste as to energy. No people die and only very small sections of ecosystems are threatened by the use of space for waste (apart from litter or fly-tipped waste). Emissions from incineration, the decomposition of waste and the leaching of, for example, heavy metals are major problems. These emissions are properly specified in a good LCA. Waste is thus included in similar fashion, but it is assessed in terms of its emissions.

We do not have any score for ecotoxicity and human toxicity, as is usually the case. Instead we have a score for carcinogenic substances, heavy metals, winter smog and pesticides. The reason for this is that we could not find any reduction target for such a vague concept. We therefore opted to specify the term "toxicity" in individual problems.

As a result of these changes, the Eco-indicator can be viewed as an indicator for emissions, and raw materials exhaustion and the use of space for waste must be assessed individually for the moment. Despite this limitation we feel that the indicator is a powerful tool. Emissions will be our greatest concern if we wish to protect health and ecosystems.

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<sup>10</sup> Eurostat, estimate based on data for 6 EU member states

### Summary of weighting factors

The table below summarises the values and the criteria used in determining them. The choice of these criteria is very important because there is a direct correlation with the reduction factors. If 5% ecosystem damage is compared with ten deaths per year rather than one, then all reduction factors based on the number of deaths criterion will fall by a factor of ten, assuming there is a linear correlation between an effect and the number of deaths.

The table gives you an opportunity to calculate other weightings for yourself if you wish to use different criteria.

	Characterisation	Reduction factor	Criterion
Greenhouse	CML (IPCC)	2.5	0.1° per decade, 95th percentile?
Ozone layer	CML (IPCC)	100	Probability of 1 death per year per million inhabitants
Acidification	CML	10	95th percentile
Eutrophication	CML	5	Rivers and lakes damage to an unknown number of aquatic ecosystems? (95th percentile?)
Summer smog	CML	2.5	Prevent smog periods, health complaints, particularly amongst asthma patients and the elderly
Winter smog	Air Quality Guidelines	5	Prevent smog periods, health complaints, particularly amongst asthma patients and the elderly
Pesticide	Active ingredient	25	95th percentile ecosystems
Heavy metals in air	Air Quality Guidelines	5	Lead content in blood of children, limited life expectancy and learning performance in an unknown number of people
Heavy metals in water	Quality Guidelines for water	5	Cadmium content in rivers, ultimately also has an effect on people (see air)
Carcinogenic substances	Air Quality Guidelines	10	Probability of 1 death per year per million inhabitants

Table 4.6: Background weighting factors

## 2.3 Ecopoints 97 (CH) v2.1

### 2.3.1 Introduction

The Swiss Ministry of the Environment (BUWAL) has developed the Ecopoint system<sup>11</sup>, based on actual pollution and on critical targets that are derived from Swiss policy. It is one of the earliest systems for impact assessment with a single score. Like the Eco-indicator 95 method described above, it is based on the distance-to-target method. The Swiss Ecopoints 1997 (environmental scarcity) is an update of the 1990 method.

There are three important differences:

1. The Ecopoint system does not use a classification. It assesses impacts individually. Although this allows for a detailed and very substance-specific method it has the disadvantage that only a few impacts are assessed.
2. The Ecopoint system uses a different normalisation principle. It uses target values rather than current values.
3. The Ecopoint system is based on policy levels instead of sustainability levels. Policy levels are usually a compromise between political and environmental considerations.

Ecofactors (weighting factors) are calculated using the following formula:

$$f = 1/F_k \times F/F_k \times 10^{12} = F/F_k^2$$

*f*:      *ecofactor*

*F*:      *actual total current load*

*F<sub>k</sub>*:    *target norm for total load*

$10^{12}$     *constant*

The first term (1/*F<sub>k</sub>*) expresses the relative contribution of the load to the exceeding of the target norm. It is the Normalisation step. The second term (*F*/*F<sub>k</sub>*) expresses the extent to which the target norm is already being exceeded.

The following data are necessary in calculating a score in ecopoints for a given product:

- quantified impacts of a product;
- total environmental load for each impact type in a particular geographical area;
- maximum acceptable environmental load for each impact type in that particular geographical area.

In SimaPro you will find 3 versions of the method that give identical evaluation and indicator values. The difference is caused by the choice of normalisation factor.

#### 1) Normalisation on Target Value or Critical Emission (N=Target)

The original formula is used to calculate the Ecopoints:

$$\text{Ecofactor} = 1/F_k \times F/F_k \times \text{Const.}$$

*1/F<sub>k</sub>*=normalisation factor

*F/F<sub>k</sub>*\*Const.=evaluation factor

#### 2) Normalisation based on Actual Emission (N= Actual)

The adapted formula is used to calculate the Ecopoints so that normalisation based on actual emissions can be done:

$$\text{Ecofactor} = 1/F \times F/F_k \times F/F_k \times \text{Const.}$$

<sup>11</sup> *Methodik für Oekobilanzen auf der Basis oekologischer Optimierung*, Schriftenreihe Umwelt no. 133, BUWAL, Bern, Switzerland, October 1990.

*1/F=normalisation factor*

*F/Fk\*F/Fk\*Const.=evaluation factor*

*F=Actual Swiss emission per year*

*Fk=Critical Swiss emission per year Const.=1E12/year*

### 3) Ecopoints

Ecofactors given in the evaluation step, normalisation factors=1.

Please note that not all sum parameters such as (heavy) metals, AOX contributants, are included in the method. Source: A. Braunschweig et al. Bewertung in Ökobilanzen mit der Methode der ökologischen Knappheit. Ökofaktoren 1997, Methodik Für Oekobilanzen, Buwal Schriftenreihe Umwelt Nr 297, 1998.

A free, (German version only), can be ordered from:

BUWAL Dokumentationsdienst, CH-3003 Bern, Fax + 41 31 3240216, e-mail: docu@buwal.admin.ch Web site <http://www.buwal.ch/publikat/oekobila.htm>

## 2.4 Eco-indicator 99 v2.1

### 2.4.1 Introduction

Eco-indicator 99 is the successor of Eco-indicator 95. Both methods use the damage-oriented approach. The development of the Eco-indicator 99 methodology started with the design of the weighting procedure. Traditionally in LCA the emissions and resource extractions are expressed as 10 or more different impact categories, like acidification, ozone layer depletion, ecotoxicity and resource extraction. For a panel of experts or non-experts it is very difficult to give meaningful weighting factors for such a large number and rather abstract impact categories. It was concluded that the panel should not be asked to weight the impact categories but the different types of damage that are caused by these impact categories. The other improvement was to limit the number of items that are to be assessed. As a result the panel, consisting of 365 persons from a Swiss LCA interest group, was asked to assess the seriousness of three damage categories:

1. Damage to Human Health, expressed as the number of year life lost and the number of years lived disabled. These are combined as Disability Adjusted Life Years (DALYs), an index that is also used by the Worldbank and WHO.
2. Damage to Ecosystem Quality, express as the loss of species over an certain area, during a certain time
3. Damage to Resources, expressed as the surplus energy needed for future extractions of minerals and fossil fuels.

In order to be able to use the weights for the three damage categories a series of complex damage models had to be developed. In figure 2 these models are represented in a schematic way.

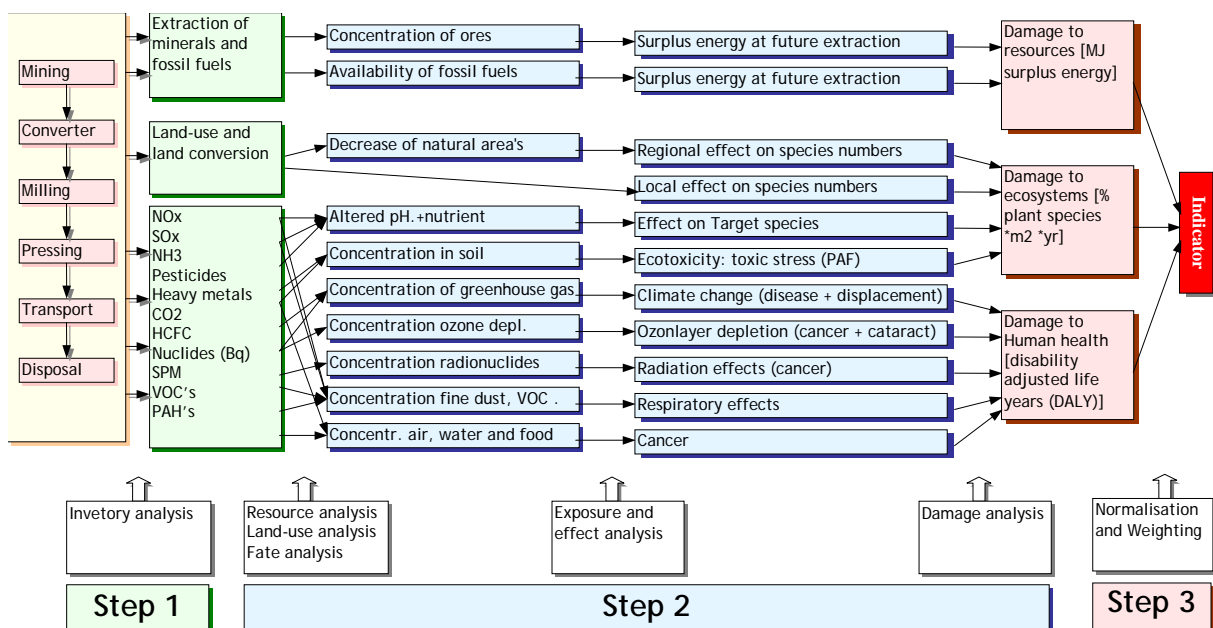


Figure 1: Detailed representation of the damage model

In general, the factors used in SimaPro do not deviate from the ones in the (updated) report. In case the report contained synonyms of substance names already available in the substance list of the SimaPro database, the existing names in the database are used. A distinction is made for emissions to agricultural soil and industrial soil, indicated with respectively (agr.) or (ind.) behind substance names emitted to soil.

## 2.4.2 Characterisation

### *Emissions*

Characterisation factors are calculated at end-point level (damage). The damage model for emissions includes fate analysis, exposure, effects analysis and damage analysis.

This model is applied for the following impact categories:

- **Carcinogens**  
Carcinogenic effects due to emissions of carcinogenic substances to air, water and soil. Damage is expressed in Disability adjusted Life Years (DALY) / kg emission.
- **Respiratory organics**  
Respiratory effects resulting from summer smog, due to emissions of organic substances to air, causing respiratory effects. Damage is expressed in Disability adjusted Life Years (DALY) / kg emission.
- **Respiratory inorganics**  
Respiratory effects resulting from winter smog caused by emissions of dust, sulphur and nitrogen oxides to air. Damage is expressed in Disability adjusted Life Years (DALY) / kg emission.
- **Climate change**  
Damage, expressed in DALY/kg emission, resulting from an increase of diseases and death caused by climate change.
- **Radiation**  
Damage, expressed in DALY/kg emission, resulting from radioactive radiation
- **Ozone layer**  
Damage, expressed in DALY/kg emission, due to increased UV radiation as a result of emission of ozone depleting substances to air.
- **Ecotoxicity**  
Damage to ecosystem quality, as a result of emission of ecotoxic substances to air, water and soil. Damage is expressed in Potentially Affected Fraction (PAF)\*m<sup>2</sup>\*year/kg emission.
- **Acidification/ Eutrophication**  
Damage to ecosystem quality, as a result of emission of acidifying substances to air. Damage is expressed in Potentially Disappeared Fraction (PDF)\*m<sup>2</sup>\*year/kg emission.

### *Land use*

Land use (in man made systems) has impact on species diversity. Based on field observations, a scale is developed expressing species diversity per type of land use. Species diversity depends on the type of land use and the size of the area. Both regional effects and local effects are taken into account in the impact category:

- **Land use**  
Damage as a result of either conversion of land or occupation of land. Damage is expressed in Potentially Disappeared Fraction (PDF)\*m<sup>2</sup>\*year/m<sup>2</sup> or m<sup>2</sup>a.

### *Resource depletion*

Mankind will always extract the best resources first, leaving the lower quality resources for future extraction. The damage of resources will be experienced by future generations, as they will have to use more effort to extract remaining resources. This extra effort is expressed as "surplus energy".

- **Minerals**  
Surplus energy per kg mineral or ore, as a result of decreasing ore grades.

- **Fossil fuels**  
Surplus energy per extracted MJ, kg or m3 fossil fuel, as a result of lower quality resources.

### 2.4.3 Uncertainties

Of course it is very important to pay attention to the uncertainties in the methodology that is used to calculate the indicators. Two types are distinguished:

1. Uncertainties about the correctness of the models used
2. Data uncertainties

Data uncertainties are specified for most damage factors as squared geometric standard deviation in the original reports, but not in the method in SimaPro. It is not useful to express the uncertainties of the model as a distribution. Uncertainties about the model are related to subjective choices in the model. In order to deal with them we developed three different versions of the methodology, using the archetypes specified in Cultural Theory. The three versions of Eco-indicator 99 are:

1. the egalitarian perspective
2. the hierarchist perspective
3. the individualist perspective

#### *Hierchist perspective*

In the hierarchist perspective the chosen time perspective is long-term, substances are included if there is consensus regarding their effect. For instance all carcinogenic substances in IARC class 1, 2a and 2b are included, while class 3 has deliberately been excluded. In the hierarchist perspective damages are assumed to be avoidable by good management. For instance the danger people have to flee from rising water levels is not included. In the case of fossil fuels the assumption is made that fossil fuels cannot easily be substituted. Oil and gas are to be replaced by shale, while coal is replaced by brown coal. In the DALY calculations age weighting is not included.

#### *Egalitarian perspective*

In the egalitarian perspective the chosen time perspective is extremely long-term, Substances are included if there is just an indication regarding their effect. For instance all carcinogenic substances in IARC class 1, 2a, 2b and 3 are included, as far as information was available. In the egalitarian perspective, damages cannot be avoided and may lead to catastrophic events. In the case of fossil fuels the assumption is made that fossil fuels cannot be substituted. Oil, coal and gas are to be replaced by a future mix of brown coal and shale. In the DALY calculations age weighting is not included.

#### *Individualist perspective*

In the individualist perspective the chosen time perspective is short-term (100 years or less). Substances are included if there is complete proof regarding their effect. For instance only carcinogenic substances in IARC class 1 included, while class 2a, 2b and 3 have deliberately been excluded. In the individualist perspective damages are assumed to be recoverable by technological and economic development. In the case of fossil fuels the assumption is made that fossil fuels cannot really be depleted. Therefore they are left out. In the DALY calculations age weighting is included.

#### *Damage assessment*

Damages of the impact categories result in three types of damages:

1. Damage to **Human Health**, expressed as the number of year life lost and the number of years lived disabled. These are combined as Disability Adjusted Life Years (DALYs), an index that is also used by the World bank and the WHO.
2. Damage to **Ecosystem Quality**, express as the loss of species over an certain area, during a certain time
3. Damage to **Resources**, expressed as the surplus energy needed for future extractions of minerals and fossil fuels.

#### 2.4.4 Normalisation

Normalisation is performed on damage category level. Normalisation data is calculated on European level, mostly based on 1993 as base years, with some updates for the most important emissions.

#### 2.4.5 Weighting

In this method weighting is performed at damage category level (endpoint level in ISO). A panel performed weighting of the three damage categories. For each perspective, a specific weighting set is available. The average result of the panel assessment is available as weighting set.

#### 2.4.6 Default

The hierchist version of Eco-indicator 99 with average weighting is chosen default. In general value choices made in the hierachist version are scientifically and politically accepted.

## 2.5 CML 2 baseline 2000 v2.1

The method is an update from the method in the Dutch Guide to LCA, published in 1992 by the Centre of Environmental Science (CML). This method is also referred to as "CML 1992", the NOH method or Heijungs, 19992. The new CML 2 baseline method elaborates the problem-oriented (midpoint) approach. The method in SimaPro 5 is based on the spreadsheet (version 2.02) as published on the CML web site.

### 2.5.1 Characterisation

The CML Guide provides a list of impact assessment categories grouped into

- A: Obligatory impact categories (Category indicators used in most LCAs)
- B: Additional impact categories (operational indicators exist, but are not often included in LCA studies)
- C: Other impact categories (no operational indicators available, therefore impossible to include quantitatively in LCA)

In case several methods are available for obligatory impact categories, a baseline indicator is selected, based on the principle of best available practice. These baseline indicators are category indicators at "mid-point level" (problem oriented approach)". Baseline indicators are recommended for simplified studies. The guide provides guidelines for inclusion of other methods and impact category indicators in case of detailed studies and extended studies.

Only baseline indicators are available in the CML method in SimaPro (Excel spreadsheet with characterisation and normalisation factors 24-01-2001). In general, these indicators do not deviate from the ones in the spreadsheet. In case the spreadsheet contained synonyms of substance names already available in the substance list of the SimaPro database, the existing names are used. A distinction is made for emissions to agricultural soil and industrial soil, indicated with respectively (agr.) or (ind.) behind substance names emitted to soil. Emissions to seawater are indicated with (sea), while emissions to fresh water have no addition behind their substance name (we assumed that all emissions to water in existing process sheets, are emissions to fresh water).

#### *Depletion of abiotic resources*

This impact category is concerned with protection of human welfare, human health and ecosystem health. This impact category indicator is related to extraction of minerals and fossil fuels due to inputs in the system. The Abiotic Depletion Factor (ADF) is determined for each extraction of minerals and fossil fuels (kg antimony equivalents/kg extraction) based on concentration reserves and rate of de-accumulation. The geographic scope of this indicator is at global scale.

#### *Climate change*

Climate change can result in adverse effects upon ecosystem health, human health and material welfare. Climate change is related to emissions of greenhouse gases to air. The characterisation model as developed by the Intergovernmental Panel on Climate Change (IPCC) is selected for development of characterisation factors. Factors are expressed as Global Warming Potential for time horizon 100 years (GWP100), in kg carbon dioxide/kg emission. The geographic scope of this indicator is at global scale.

#### *Stratospheric Ozone depletion*

Because of stratospheric ozone depletion, a larger fraction of UV-B radiation reaches the earth surface. This can have harmful effects upon human health, animal health, terrestrial and aquatic ecosystems, biochemical cycles and on materials. This category is output-related and at global scale. The characterisation model is developed by the World Meteorological Organisation (WMO) and defines ozone depletion potential of different gasses (kg CFC-11 equivalent/ kg emission). The geographic scope of this indicator is at global scale. The time span is infinity.

#### *Human toxicity*

This category concerns effects of toxic substances on the human environment. Health risks of exposure in the working environment are not included. Characterisation factors, Human Toxicity Potentials

(HTP), are calculated with USES-LCA, describing fate, exposure and effects of toxic substances for an infinite time horizon. For each toxic substance HTP's are expressed as 1,4-dichlorobenzene equivalents/ kg emission. The geographic scope of this indicator determines on the fate of a substance and can vary between local and global scale

#### *Fresh-water aquatic eco-toxicity*

This category indicator refers to the impact on fresh water ecosystems, as a result of emissions of toxic substances to air, water and soil. Eco-toxicity Potential (FAETP) are calculated with USES-LCA, describing fate, exposure and effects of toxic substances. The time horizon is infinite Characterisation factors are expressed as 1,4-dichlorobenzene equivalents/kg emission. The indicator applies at global/continental/ regional and local scale.

#### *Marine eco-toxicity*

Marine eco-toxicity refers to impacts of toxic substances on marine ecosystems (see description fresh water toxicity).

#### *Terrestrial ecotoxicity*

This category refers to impacts of toxic substances on terrestrial ecosystems (see description fresh water toxicity).

#### *Photo-oxidant formation*

Photo-oxidant formation is the formation of reactive substances (mainly ozone) which are injurious to human health and ecosystems and which also may damage crops. This problem is also indicated with "summer smog". Winter smog is outside the scope of this category. Photochemical Ozone Creation Potential (POCP) for emission of substances to air is calculated with the UNECE Trajectory model (including fate), and expressed in kg ethylene equivalents/kg emission. The time span is 5 days and the geographical scale varies between local and continental scale.

#### *Acidification*

Acidifying substances cause a wide range of impacts on soil, groundwater, surface water, organisms, ecosystems and materials (buildings). Acidification Potentials (AP) for emissions to air are calculated with the adapted RAINS 10 model, describing the fate and deposition of acidifying substances. AP is expressed as kg SO<sub>2</sub> equivalents/ kg emission. The time span is eternity and the geographical scale varies between local scale and continental scale.

#### *Eutrophication*

Eutrophication (also known as nutrification) includes all impacts due to excessive levels of macro-nutrients in the environment caused by emissions of nutrients to air, water and soil. Nutrification potential (NP) is based on the stoichiometric procedure of Heijungs (1992), and expressed as kg PO<sub>4</sub> equivalents/ kg emission. Fate and exposure is not included, time span is eternity, and the geographical scale varies between local and continental scale.

### 2.5.2 Normalisation

Normalisation is regarded as optional for simplified LCA, but mandatory for detailed LCA. For each baseline indicator, normalisation scores are calculated for the reference situations: the world in 1990, Europe in 1995 and the Netherlands in 1997. Normalisation data are described in the report: Huijbregts et al LCA normalisation data for the Netherlands (1997/1998), Western Europe (1995) and the World (1990 and 1995).

### 2.5.3 Grouping and weighting

Grouping and weighting are considered to be optional step. No baseline recommended rules or values are given for these steps. Therefore these steps are not available in SimaPro

## 2.6 EPS 2000 v2.1

### 2.6.1 Introduction

The EPS 2000 default methodology (Environmental Priority Strategies in product design) is a damage oriented method. In the EPS system willingness to pay to restore changes in the safe guard subjects is chosen as the monetary measure. The indicator unit is ELU (Environmental Load Unit). This method includes characterisation and weighting. Normalisation is not applied.

The top-down development of the EPS system has led to an outspoken hierarchy among its principles and rules. The general principles of its development are:

- The top-down principle (highest priority is given to the usefulness of the system);
- The index principle (ready made indices represent weighted and aggregated impacts)
- The default principle (an operative method as default is required)
- The uncertainty principle (uncertainty of input data has to be estimated)
- Choice of default data and models to determine them

The EPS system is mainly aimed to be a tool for a company's internal product development process. The system is developed to assist designers and product developers in finding which one of two product concepts has the least impact on the environment. The models and data in EPS are intended to improve environmental performance of products. The choice and design of the models and data are made from an anticipated utility perspective of a product developer. They are, for instance not intended to be used as a basis for environmental protection strategies for single substances, or as a sole basis for environmental product declarations. In most of those cases additional site-specific information and modelling is necessary.

The EPS 2000 default method is an update of the 1996 version. The impact categories are identified from five safe guard subjects: human health, ecosystem production capacity, abiotic stock resource, biodiversity and cultural and recreational values.

### 2.6.2 Classification

Emissions and resources are assigned to impact categories when actual effects are likely to occur in the environment, based on likely exposure.

### 2.6.3 Characterisation

Empirical, equivalency and mechanistic models are used to calculate default characterisation values.

#### *Human Health*

In EPS weighting factors for damage to human health are included for the following indicators:

- Life expectancy, expressed in Years of life lost (person year)
- Severe morbidity and suffering, in person year, including starvation
- Morbidity, in person year, like cold or flue
- Severe nuisance, in person year, which would normally cause a reaction to avoid the nuisance
- Nuisance, in person year, irritating, but not causing any direct action

#### *Ecosystem production capacity*

The default impact categories of production capacity of ecosystems are:

- Crop production capacity, in kg weight at harvest
- Wood production capacity, in kg dry weight
- Fish and meat production capacity, in kg full weight of animals
- Base cat-ion capacity, in H+ mole equivalents (used only when models including the other indicators are not available)
- Production capacity of (irrigation) water, in kg which is acceptable for irrigation, with respect to persistent toxic substances
- Production capacity of (drinking) water, in kg of water fulfilling WHO criteria on drinking water.

### *Abiotic stock resources*

Abiotic stock resource indicators are depletion of elemental or mineral reserves and depletion of fossil reserves. Some classification factors are defined 0 (zero).

In SimaPro characterisation values for abiotic depletion result from both the impact of depletion and impacts due to extraction of the element/mineral or resource.

### *Biodiversity*

Default impact category for biodiversity is extinction of species, expressed in Normalised Extinction of species (NEX).

### *Cultural and recreational values*

Changes in cultural and recreational values are difficult to describe by general indicators as they are highly specific and qualitative in nature. Indicators should be defined when needed, and thus are not included in the default methodology in SimaPro.

## 2.6.4 Weighting

In the EPS default method, weighting is made through valuation. Weighting factors represent the willingness to pay to avoid changes. The environmental reference is the present state of the environment. The indicator unit is ELU (Environmental Load Unit).

## 2.6.5 References:

Bengt Steen (1999) A systematic approach to environmental strategies in product development (EPS). Version 2000 - General system characteristics. Centre for Environmental Assessment of Products and Material Systems. Chalmers University of Technology, Technical Environmental Planning. CPM report 1999:4.

Download as PDF file (246 kb) from <http://www.cpm.chalmers.se/cpm/publications/EPS2000.PDF>

Bengt Steen (1999) A systematic approach to environmental strategies in product development (EPS). Version 2000 - Models and data of the default methods. Centre for Environmental Assessment of Products and Material Systems. Chalmers University of Technology, Technical Environmental Planning. CPM report 1999:5.

Download as zipped PDF file (1140 kb) from [http://www.cpm.chalmers.se/cpm/publications/EPS1999\\_5.zip](http://www.cpm.chalmers.se/cpm/publications/EPS1999_5.zip)

## 2.7 EDIP v2.1

### 2.7.1 Introduction

The EDIP method (Environmental Design of Industrial Products, in Danish UMIP) was developed in 1996. Excluded in this version of the method in SimaPro are working environment and emissions to waste water treatment plants (WWTP). An update of the method is expected by the beginning of 2002.

### 2.7.2 Characterisation

Global warming is based on the IPCC 1994 Status report. In SimaPro GWP 100 is used. Stratospheric ozone depletion potentials are based on the status reports (1992/1995) of the Global Ozone Research Project (infinite time period used in SimaPro). Photochemical ozone creation potentials (POCP) were taken from UNECE reports (1990/1992). POCP values depend on the background concentration of NO<sub>x</sub>, in SimaPro we have chosen to use the POCPs for high background concentrations. Acidification is based on the number of hydrogen ions (H<sup>+</sup>) that can be released. Eutrophication potential is based on N and P content in organisms. Waste streams are divided in 4 categories, bulk waste (not hazardous), hazardous waste, radioactive waste and slags and ashes. All wastes are reported on a mass basis.

Ecotoxicity is based on a chemical hazard screening method, which looks at toxicity, persistency and bioconcentration. Fate or the distribution of substances into various environmental compartments is also taken account. Ecotoxicity potentials are calculated for acute and chronic ecotoxicity to water and chronic ecotoxicity for soil. As fate is included, an emission to water may lead not only to chronic and acute ecotoxicity for water, but also to soil. Similarly an emission to air gives ecotoxicity for water and soil. This is the reason you will find emissions to various compartments in each ecotoxicity category.

Human toxicity is based on a chemical hazard screening method, which looks at toxicity, persistency and bioconcentration. Fate or the distribution of substances into various environmental compartments is also taken account. Human toxicity potentials are calculated for exposure via air, soil, and surface water. As fate is included, an emission to water may lead not only to toxicity via water, but also via soil. Similarly an emission to air gives human toxicity via water and soil. This is the reason you will find emissions to various compartments in each human toxicity category.

#### *Resources*

As resources use a different method of weighting, it cannot be compared with the other impact categories, for which reason the weighting factor is set at zero. Resources should be handled with great care when analysing results, the characterisation and normalisation results cannot be compared with the other impact categories.

To give the user some information in a useful way all resources have been added into one impact category. As equivalency factor the result of the individual normalisation and weighting scores have been used, i.e. the resulting score per kg if they would have been calculated individually.

For detailed information on resources, including normalisation and weighting, choose the "EDIP/UMIP resources only" method.

#### **EDIP v2.0 resources only**

In the "EDIP/UMIP resources only" method only resources are reported. Opposite to the default EDIP/UMIP method, resources are given in individual impact categories, on a mass basis of the pure resource (i.e. 100% metal in ore, rather than ore). Normalisation is based on global production per world citizen, derived from World Resources 1992. Weighting of non-renewables is based on the supply-horizon (World Reserves Life Index), which specifies the period for which known reserves will last at current rates of consumption. If no normalisation data are known for an individual impact category, the normalisation value is set at one and the calculation of the weighting factor is adjusted so that the final result is still consistent. However this may give strange looking graphs in the normalisation step.

### 2.7.3 Normalisation

The normalisation value is based on person equivalents for 1990. For resources, normalisation and weighing are already included in the characterisation factor and therefore set at zero.

### 2.7.4 Weighting

The weighting factors are set to the politically set target emissions per person in the year 2000, the weighted result are expressed except for resources which is based on the proven reserves per person in 1990. For resources, normalisation and weighing are already included in the characterisation factor and therefore set at zero.

A note on weighting:

Presenting the EDIP method as a single score (addition) is allowed, however it is not recommended by the authors. Note that due to a different weighting method for resources (based on reserves rather than political targets), resources may never be included in a single score. This is the reason that the weighting factor for resources is set at zero.

### 2.7.5 References:

For background information, and information on how to calculate additional factors, please read:

#### **Environmental Assessment of Products.**

Volume 1 (methodology, tools and case studies in product development)

Henrik Wenzel, Michael Hauschild and Leo Alting

Chapman and Hall, 1997, ISBN 0 412 80800 5

See <http://www.wkap.nl/book.htm/0-7923-7859-8>

#### **Environmental Assessment of Products.**

Volume 2 (scientific background)

Michael Hauschild and Henrik Wenzel

Chapman and Hall, 1998, ISBN 0 412 80810 2

See <http://www.wkap.nl/book.htm/0-412-80810-2>

## 2.8 IPCC 2001 GWP V1.1

### 2.8.1 Introduction

This method lists the climate change factors of IPCC with a timeframe of 20, 100 and 500 years. The method from the ecoinvent 1.01 database was expanded with other characterisation factors for emissions available in the SimaPro database.

### 2.8.2 Characterisation

The IPCC characterisation factors for the direct global warming potential of air emissions. They are:

- not including indirect formation of dinitrogen monoxide from nitrogen emissions.
- not accounting for radiative forcing due to emissions of NO<sub>x</sub>, water, sulphate, etc. in the lower stratosphere + upper troposphere.
- not considering the range of indirect effects given by IPCC.
- including CO<sub>2</sub> formation from CO emissions.
- considering biogenic CO<sub>2</sub> uptake as negative impact.

### 2.8.3 Normalisation and weighting

Normalisation and weighting are not a part of this method.

### 2.8.4 References

Frischknecht R., Jungbluth N., et.al. (2003). Implementation of Life Cycle Impact Assessment Methods. Final report ecoinvent 2000  
Swiss Centre for LCI. Duebendorf, CH <http://www.ecoinvent.ch/>

Climate Change 2001. IPCC Third Assessment Report. The Scientific Basis.  
[http://www.grida.no/climate/ipcc\\_tar/](http://www.grida.no/climate/ipcc_tar/)

Intergovernmental Panel on Climate Change (IPCC)  
<http://www.ipcc.ch/>

## 2.9 Cumulative Energy Demand V1.1

### 2.9.1 Introduction

The method to calculate Cumulative Energy Demand (CED) is based on the method published by ecoinvent version 1.01 and expanded by PRé Consultants for energy resources available in the SimaPro database.

### 2.9.2 Characterisation

Characterisation factors are given for the energy resources divided in 5 impact categories:

1. Non renewable, fossil
2. Non renewable, nuclear
3. Renewable, biomass
4. Renewable, wind, solar, geothermal
5. Renewable, water

### 2.9.3 Normalisation

Normalisation is not a part of this method.

### 2.9.4 Weighting

In order to get a total ("cumulative") energy demand, each impact category is given the weighting factor 1.

### 2.9.5 References

Frischknecht R., Jungbluth N., et.al. (2003). Implementation of Life Cycle Impact Assessment Methods. Final report ecoinvent 2000, Swiss Centre for LCI. Duebendorf, CH, [www.ecoinvent.ch](http://www.ecoinvent.ch)



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