SimaPro database manual

Methods library: Superseded methods

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About SimaPro

SimaPro was developed by PRé with the goal of making sustainability a fact-based endeavor. PRé has been a leading voice in sustainability metrics and life cycle thinking development for nearly 30 years, pioneering the field of environmental and social impact assessment. We develop tools that help you create value and drive sustainable change.

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1   Introduction

SimaPro contains a number of impact assessment methods, which are used to calculate impact assessment results. This document is an appendix of the SimaPro methods manual.

It includes Superseded methods which we no longer maintain in SimaPro because these have been updated or replaced by a newer version. We recommend therefore not using these but instead the methods included in the Methods Manual.

Methods	Name	Version	Project
European	BEES	4.02	Methods
Global	Boulay et al 2011 (Human Health)	1.02	Methods
North American	CML 1992	2.06	Methods
Others	CML 2 baseline 2000	2.05	Methods
Single issue	CML 2001 (all impact categories)	2.05	Methods
Superseded	Eco-indicator 95	2.06	Methods
Water footprint	Eco-indicator 99 (E)	2.10	Methods
	Eco-indicator 99 (H)	2.10	Methods
	Eco-indicator 99 (I)	2.10	Methods
	Ecological footprint	1.01	Methods
	Ecological Scarcity 2006	1.09	Methods

Figure 1: Screenshot of an excerpt of the list of Superseded methods included in SimaPro

2   Categorization of methods in SimaPro

Currently, in SimaPro we include six categories of methods:

- **European:** which include comprehensive LCIA methods that are focused on the European context and, therefore, mostly useful when doing LCA studies in Europe.

- **Global:** which include comprehensive LCIA methods with a global scope, i.e. ideal to apply in studies with a global value chain.

- **North American:** which include methods developed for the North American region.

- **Single issue:** which cover methods which focus on one single metric or environmental impact area, except for those focused on water. Water footprint methods are included in a separate category.

- **Water footprint:** which include methods to assess only water related impacts.

- **Superseded:** which include methods that are outdated and no longer supported by PRé. We strongly discourage users to select these. These are kept and continue to be distributed though because existing SimaPro users might use them.

3 Boulay et al 2011 (Human Health)

This method is based on the publication Boulay et al (2011).

3.1 Characterization

The method is an endpoint indicator expressed in DALY and is obtained by modelling each water user's loss of functionality. It addresses three different impact pathways:

1) malnutrition from water deprivation for agricultural users,

2) malnutrition from water deprivation for fisheries, and

3) water-related diseases associated with a lack of water for domestic use.

The cause-effect chain modelling is based on hydrological and socio-economic data. The water scarcity index is used at the midpoint level [Boulay et al 2011 (Water Scarcity)]. The level of economic development is considered through the adaptation capacity based on gross national income.

The method contains two different types of human health categories: distribution and marginal.

Distribution effects apply to all types of water consumption. Distribution refers to the impact assessment in which all users are competing and proportionally affected according to their distributional share of water use for off-stream users (here, agriculture, fisheries and domestic).

Marginal effects apply to agricultural water consumption. Marginal refers to a modelling choice in which any additional water use will deprive only one off-stream user (agricultural).

The "HH, marginal" category is comparable with the "HH, agricultural water scarcity" category in the Motoshita et al 2010 (Human Health) method and the "Human Health" category of the Pfister et al 2009 (Eco-indicator 99) and Pfister et al 2010 (ReCiPe) methods. Note that the "HH, distribution" category includes more effects and is NOT complementary to the "HH, marginal" category.

The regional factors are weighted averages based on the freshwater withdrawal by country data from the Pacific Institute (http://www.worldwater.org/data.html) [old data – 2014 – check for new data].

After calculating your results we recommend you view the 'Checks' tab to see if there are any significant flows omitted due to the incomplete list of characterization factors for some countries.

References

Boulay, A.M., Bulle, C., Bayart, J.B., Deschenes, L., Margni, M. (2011). Regional Characterization of Freshwater Use in LCA: Modeling Direct Impacts on Human Health. Environmental Science & Technology 45: 8948-8957.

3.2   CML 1992

This classification method is based on the method published by CML of the University of Leiden in October 1992[4].

PRé has modified the method: the depletion and energy classes were separated and the classes for smell and biotic exhaustion were excluded.

This v2 version is adapted for SimaPro 8. All characterization factors in this method are entered for the 'unspecified' sub-compartment of each compartment (Raw materials, air, water, soil) and thus applicable on all sub-compartments.

This method is NOT fully adapted for inventory data from the Ecoinvent library and the USA Input Output Database 98, and therefore omits emissions that could have been included in impact assessment.

3.2.1 Characterization

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, and 2. Pollution.

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:

Exhaustion = (amount consumed (kg) x {1/resources (kg)}) [5]

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,

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[4] R. Heijungs et al, *Environmental life cycle assessment of products, Guide, October 1992* CML, Leiden, The Netherlands, NOH report 9266.

[5] World Institute*, World Resources 1990-1991,* Oxford University Press, New York/Oxford.

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:

Greenhouse effect (kg) = (GWP 100 x airborne emission (kg)) [6]

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:

Ozone layer depletion (kg) = (ODP x airborne emission (kg)) [7]

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 characterization 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 6. 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.

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[6] Houghton, Callender & Varney, *Climate Change 1992. The supplementary report to the IPCC scientific assessment*, Cambridge University Press, Cambridge, UK, 1992.

[7] World Meteorological Organization, *Scientific assessment of ozone depletion 1991*, Global Ozone Research and Monitoring Project - Report no. 25, 1991.

Table 1: Substances from which HCA/HCW, ECA and POCP values for hydrocarbons are taken.

	equivalents			
Substances	human toxicity	human toxicity	ecotoxicity	smog
	air	water	water	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

The human toxicity effect score is calculated as follows:

Human toxicity (kg) = (HCA (kg.kg-1) x emission to air (kg) +

HCW (kg.kg-1) x emission to water (kg)) [8]

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 6. An equivalent has been selected for most other values that were not defined. The effect score for ecotoxicity is calculated as follows:

Ecotoxicity (m³) = (ECA (m³. kg-1) x waterborne emission (kg))[9]

[8] 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.

[9] Slooff, W., *Maximum tolerable concentrations, eco-toxicological effect assessment*, RIVM no. 719102018, Bilthoven, The Netherlands.

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 sum-parameters 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 6. NOx is omitted in the CML 92 methodThe effect score for smog is calculated as follows:

Smog (kg) = (POCP x airborne emission (kg))[10]

Acidification

The Acidification Potential (AP) is expressed relative to the acidifying effect of SO2. Other known acidifying substances are nitrogen oxides and ammonia. SOx has been added, with the same value as SO2.

Acidification effect scores are calculated as follows:

Acidification (kg) = (AP x airborne emission (kg))

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

Eutrophication

The Nutrification Potential (NP) is set at 1 for phosphate (PO4). Other emissions also influence eutrophication, notably nitrogen oxides and ammonium.

The eutrophication effect score is calculated as follows:

Eutrophication (kg) = (NP x airborne emission (kg))

Odor

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 localized environmental effect, and the degree of stench nuisance depends largely on local circumstances.

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[10] 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.

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.

Solids (kg) = (solid emission output (kg))

3.3   Normalization

The first and probably most widely used normalization 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 normalization 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 normalization 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.

3.4   Evaluation

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

4   Eco-indicator 95

Eco-indicator 95 is adapted for SimaPro 8. All characterization factors in this method are entered for the 'unspecified' sub-compartment of each compartment (Raw materials, air, water, soil) and thus applicable on all sub-compartments.

This method is NOT fully adapted for inventory data from the Ecoinvent library and the USA Input Output Database 98, and therefore omits emissions that could have been included in impact assessment.

Due to continual adjustments of the method and/or inventory data sets the Eco-indicator 95 in SimaPro 8 will not give the same result as the original printed version.

4.1   Characterization

The only difference between the characterizations 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 characterization 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 (Table 7).

Table 2: Air Quality Guidelines admissible air concentrations for annual exposure to humans

	Maximum concentration (µg/m³)	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

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. In table 8, a selection of substances that are persistent to a greater or lesser extent and that therefore accumulate in the environment.

Table 3: WHO based substances that are persistent

Substance	Norm (mg/liter)	Weighting factor	Effect
Antimony	0.005	2	Glucose and cholesterol content of blood
Arsenic	0.01	1	Probability of skin cancer $6*10^{-4}$
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

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.

*Heavy metal to air (kg lead eq.) = (AQG (lead)/AQG (substance) * emission)*

Heavy metal to water (kg lead eq.) = (GDWQ (lead)/GDWQ (substance) emission)*

Carcinogenic substances

The 'Air Quality Guidelines' do not specify acceptable levels, but calculate the probability of cancer at a level of 1 μg/m³. In Table 9 this probability is expressed as the number of people from a group of 1 million who will develop cancer with the stated exposure.

Table 4: Number of people from a group of 1 million who will develop cancer with the stated exposure.

	Probability of cancer at 1 μg/m³	Weighting factor for PAH equivalent	Type of cancer
Arsenic	0.004	0.044	General, also mutagenic effects
Benzene	0.000001	1.1 * 10-5	Leukemia
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

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 fibers 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.

Heavy metal to air (kg lead eq.) = (AQG (lead)/AQG (substance))

Winter smog

Only dust (SPM) and SO2 are factors in this problem. For both substances the 'Air Quality Guidelines' specify a level of 50 μg/m³. The weighting factors are thus both 1.

Winter smog (SO2 or SPM eq.) = SO2 emission + 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.

Pesticides (kg) = (active ingredients)

4.2   Normalization

The normalization 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.

4.3   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°C warmer, and in Southern Europe the summers will be 4°C 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[11].

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 fertilizers 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 fertilizer applied by farmers. In uncultivated

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[11] 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.

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.

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 NOx 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/m³. 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/m³.

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 anymore. 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 (fertilizer) 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 SO2 and SPM (suspended particle matter, or small dust and soot particles). NOx, 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 SO2 and SPM concentrations reached values of 5000 micrograms per cubic meter. In Southern Poland and Eastern Germany average readings of 200µg/m³ still occur repeatedly. The Air Quality Guidelines specify a limit of 50µg/m³ for long-term exposure to both SPM and SO2. Based on this, a reduction of 75% would be necessary.

Globe estimates that a reduction in SO2 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[12] 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 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/m³ for Northern European towns and cities. The Air Quality Guideline specifies a value of 1 ng/m³ in American cities without coke furnaces in the vicinity and 1 to 5 ng/m³ 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/m³. 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/m³.

The Air Quality Guideline specifies a threshold concentration of 0.01 ng/m³ 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[13]. 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/m³.

Based on a background concentration of 1 ng/m³ 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/liter). 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.

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[12] 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.

[13] Eurostat, estimate based on data for 6 EU member states

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-fiber (communications) and aluminum (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.

4.4   Summary of weighting factors

Table 10 summarizes 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.

Table 10 gives you an opportunity to calculate other weightings for yourself if you wish to use different criteria.

Table 5: Background weighting factors.

	Characterization	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

5   Eco-indicator 99

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 World bank 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.
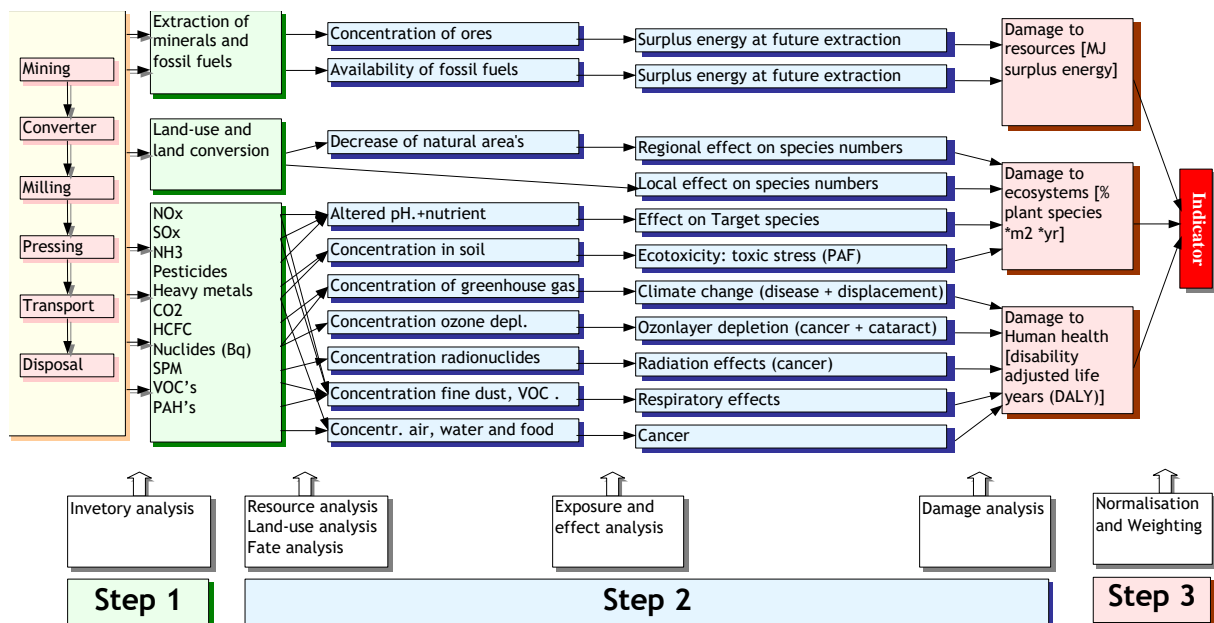

Figure 2: Detailed representation of the damage model

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.

5.1 Characterization

Emissions

Characterization is 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 affects 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)*m2*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)* m2*year/kg emission.

Land use

Land use (in manmade 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:

Damage as a result of either conversion of land or occupation of land. Damage is expressed in Potentially Disappeared Fraction (PDF)* m^2*year/ m^2 or m2a.

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.

5.2   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

Hierarchist 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.

5.3 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.

5.4 Normalization

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

5.5 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.

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

6 Ecological Footprint

The ecological footprint is defined as the biologically productive land and water a population requires to produce the resources it consumes and to absorb part of the waste generated by fossil and nuclear fuel consumption.

6.1 Characterization

In the context of LCA, the ecological footprint of a product is defined as the sum of time integrated direct and indirect land occupation, related to nuclear energy use and to CO2 emissions from fossil energy use:

$$EF = EF_{direct} + EF_{CO2} + EF_{nuclear}$$

6.2 Normalization and weighting

Normalization is not a part of the method. To get a footprint, each impact category is given the weighting factor 1.

References

Frischknecht, R.; Jungbluth, N.; Althaus. H.J.; Doka, G.; Dones, R.; Hischier, R.; Hellweg, S.; Humbert, S.; Margni, M.; Nemecek, T.; Spielmann, M. 2007. Implementation of Life Cycle Impact Assessment Methods: Data v2.0. ecoinvent report No. 3, Swiss centre for Life Cycle Inventories, Dübendorf, Switzerland.

Wackernagel, M. 1994. Ecological Footprint and Appropriated Carrying Capacity: A Tool for Planning Toward Sustainability (PhD thesis). Vancouver, Canada: School of Community and Regional Planning. The University of British Columbia.

7   Ecological scarcity 2013

The "ecological scarcity" method (also called Ecopoints or Umweltbelastungspunkte method) is a follow up of the Ecological scarcity 2006 (see section 6.9) and the Ecological scarcity 1997 method (see section 7.4) which was named Ecopoints 97 (CH) in the SimaPro method library.

The ecological scarcity method weights environmental impacts - pollutant emissions and resource consumption - by applying "eco-factors". The distance to target principle is applied in the Ecological scarcity method. The eco-factor of a substance is derived from environmental law or corresponding political targets. The more the current level of emissions or consumption of resources exceeds the environmental protection target set, the greater the eco-factor becomes, expressed in eco-points (EP = UBP). An eco-factor is essentially derived from three elements (in accordance with ISO Standard 14044): characterization, normalization and weighting.

The most important changes since last update are as follows:

- A reduction target of 80% has been set for CO2 and other greenhouse gases. This falls in the upper range of the Swiss reduction target and within the range of the reduction required to achieve the 2°C target.

- To assess energy, the federal government's long-term target (2,000 W per capita) is interpolated to the usual time frame set out in the legislation, which is 2035.

- With regard to air pollutants, additional eco-factors are provided for PAHs and radioactive isotopes.

- In this version, PAHs, dioxins and furans, and benzene are all assessed for their carcinogenic potential.

- As for water pollutants, additional eco-factors for oil emissions to the sea are provided based on an international agreement to protect the North Sea. Furthermore, eco-factors for the emissions of radioactive isotopes and persistent organic pollutants in watercourses are included for the first time.

- In some parts of the world, freshwater is a scarce resource. The regionalized ecofactors introduced in the last update are now indicated for all countries and as determined on the basis of scarcity in OECD and BRIC countries (Brazil, Russia, India and China).

- It is now recommended that the eco-factor for freshwater be applied to consumptive water use (and not water extraction).

- In Switzerland, resource efficiency has become a relevant area of environmental policy. For that reason, a new eco-factor for mineral primary resources (minerals and metals) was introduced. The ratio of annual production to available reserves is used as the basis for the characterization.

- New eco-factors were introduced for land use in various biomes. Characterization is based on the impacts of land uses upon plant and animal biodiversity.

- New eco-factors are provided for noise pollution caused by road, rail and air traffic.

7.1 Characterization, normalization and weighting

In the ecological scarcity method, a characterization may be applied if the corresponding environmental impact played a key role when the target was set. Accordingly, the current CO2 Act

stipulates that all greenhouse gases must be taken into account. Therefore, it is both possible and appropriate to use global warming potential values. Characterization is not, however, appropriate in every theoretically conceivable case. It should not be used in cases where the environmental impact of the characterization does not match the legislators' intention with regard to the way the reduction target (or the limit or target value) was set.

The ecoinvent implementation contains nineteen specific impact categories, with for each substance a final UBP (environmental loading points) score as characterization factor which compile the characterization, normalization and distance-to-target weighting. The impact categories considered by this method are not defined as an impact indicator but rather as type of emission or resource:

1. Water sources
2. Energy sources
3. Mineral sources
4. Land use
5. Global warming
6. Ozone layer depletion
7. Main air pollutants and PM
8. Carcinogenic substances into air
9. Heavy metals into air
10. Water pollutants
11. POP into water
12. Heavy metals into water
13. Pesticides into soil
14. Heavy metals into soil
15. Radioactive substances into air
16. Radioactive substances into water
17. Noise
18. Non radioactive waste to deposit
19. Radioactive waste to deposit
20. Deposited waste

Weighting is conducted on the basis of goals set by Swiss environmental policy. In specific cases, global, international or regional goals are used and converted to the Swiss level. The method can also be applied to other countries and regions. To do so, information about the current environmental situation and the official environmental targets is required.

References

Frischknecht Rolf, Büsser Knöpfel Sybille, 2013: Swiss Eco-Factors 2013 according to the
Ecological Scarcity Method. Methodological fundamentals and their application in
Switzerland. Environmental studies no. 1330. Federal Office for the Environment, Bern: 254
pp.Bern 2013. www.bafu.admin.ch/uw-1330-e

8 Ecological scarcity 2006

The "ecological scarcity" method (also called Ecopoints or Umweltbelastungspunkte method) is a
follow up of the Ecological scarcity 1997 method (see section 7.4), named Ecopoints 97 (CH) in the
SimaPro method library.

The ecological scarcity method weights environmental impacts - pollutant emissions and
resource consumption - by applying "eco-factors". The eco-factor of a substance is derived from
environmental law or corresponding political targets. The more the current level of emissions or
consumption of resources exceeds the environmental protection target set, the greater the eco-
factor becomes, expressed in eco-points (EP). An eco-factor is essentially derived from three
elements (in accordance with ISO Standard 14044): characterization, normalization and
weighting.

8.1 Characterization, normalization and weighting

Characterization captures the relative harmfulness of a pollutant emission or resource extraction
vis-à-vis a reference substance within a given impact category (global warming potential,
acidification potential, radioactivity etc.). Normalization quantifies the contribution of a unit of
pollutant or resource use to the total current load/pressure in a region (in this case the whole of
Switzerland) per year. Weighting expresses the relationship between the current pollutant
emission or resource consumption (current flow) and the politically determined emission or
consumption target (critical flow).

The Ecoinvent implementation contains seven specific impact categories, with for each substance
a final UBP (environmental loading points) score as characterization factor which compile the
characterization, normalization and distance-to-target weighting. The impact categories
considered by this method are not defined as an impact indicator but rather as type of emission
or resource:

- Emissions into air
- Emissions into surface water
- Emissions into ground water
- Emissions into top soil
- Energy resources
- Natural resources
- Deposited waste

References

Frischknecht, R.; Steiner, R.; Jungbluth, N. 2008. Methode der ökologischen Knappheit - Ökofaktoren 2006. Öbu SR No. 28/2008, Bundesamt für Umwelt (BAFU), ÖBU Schweizerische Vereinigung für ökologisch bewusste Unternehmungsführung, Zürich und Bern.

Frischknecht, R.; Jungbluth, N.; Althaus, H.J.; Doka, G.; Dones, R.; Hischier, R.; Hellweg, S.; Humbert, S.; Margni, M.; Nemecek, T.; Spielmann, M. 2007. Implementation of Life Cycle Impact Assessment Methods: Data v2.0. ecoinvent report No. 3, Swiss centre for Life Cycle Inventories, Dübendorf, Switzerland.

Frischknecht, R.; Steiner, R.; Braunschweig, A.; Egli, N.; Hildesheimer, G. 2006. Swiss Ecological Scarcity Method: The New Version 2006. Available at http://www.esu-services.ch/fileadmin/download/Frischknecht-2006-EcologicalScarcity-Paper.pdf.

9 Ecological Scarcity 2006 (Water Scarcity)

This method is taken from http://www.esu-services.ch/projects/ubp06/ (23-May 2008), with adaptations by PRé as described below. The characterization factors have first been implemented by ESU-services Ltd. All files are provided without liability. Contact info: http://www.esu-services.ch/address/

Ecological Scarcity 2006 is a follow up of the Ecological scarcity 1997 method, which is called Ecopoints 97 (CH) in the SimaPro method library (superseded). The ecoinvent implementation contains seven specific impact categories, with for each substance a final UBP (environmental loading points) score as characterization factor. This method only contains the impact category Natural resources containing only water resources. The complete method can be found in the European methods category.

10 Ecopoints 97

The Swiss Ministry of the Environment (BUWAL) has developed the Ecopoint system, 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 (also called Swiss ecoscarcity) 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 normalization principle. It uses target values rather than current values.

3.   The Ecopoint system is based on Swiss policy levels instead of sustainability levels. Policy levels are usually a compromise between political and environmental considerations.

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

4.   quantified impacts of a product;

5.   total environmental load for each impact type in a particular geographical area;

6.   maximum acceptable environmental load for each impact type in that particular geographical area.

10.1 Normalization

In SimaPro you will find 3 normalization sets: Target; Actual; and Ecopoints.

1.   Normalization on Target Value or Critical Emission (N=Target)

The original formula is used to calculate the Ecopoints:

$$\text{Ecofactor} = \frac{1}{Fk} \times \frac{F}{Fk} \times Const$$

$\frac{1}{Fk}$ =normalization factor

$\frac{F}{Fk} \times Const$ =evaluation factor

2.   Normalization based on Actual Emission (N= Actual)

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

$$\text{Ecofactor} = \frac{1}{F} \times \frac{F}{Fk} \times \frac{F}{Fk} \times Const$$

$$\frac{1}{F} = \text{normalization factor}$$

$$\frac{F}{Fk} \times \frac{F}{Fk} Const = \text{evaluation factor}$$

F =Actual Swiss emission per year

Fk =Critical Swiss emission per year Const.=10^{12}/year

3. Ecopoints

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

10.2 Weighting

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

$$f = \frac{1}{Fk} \times \frac{F}{Fk} \times 10^{12} = \frac{F}{Fk^2} \times 10^{12}$$

f: ecofactor   F: actual total current load

Fk: target norm for total load 10^{12} constant

The first term (1/Fk) expresses the relative contribution of the load to the exceeding of the target norm. It is the normalization step. The second term (F/Fk) expresses the extent to which the target norm is already being exceeded.

Please note that not all sum parameters such as (heavy) metals, AOX contributants, are included in the method.

References

Braunschweig A. et al. 1998. Bewertung in Ökobilanzen mit der Methode der ökologischen Knappheit. Ökofaktoren, Methodik Für Oekobilanzen, Buwal Schriftenreihe Umwelt Nr 297.

11 Ecosystem Damage Potential

The Ecosystem Damage Potential (EDP) is a life cycle impact assessment methodology for the characterization of land occupation and transformation developed by the Swiss Federal Institute of Technology (ETH), Zürich. It is based on impact assessment of land use on species diversity.

11.1 Characterization

This method was created using empirical information on species diversity from Central Europe. With information about species diversity on 5581 sample plots, Characterization factors for 53 land use types and six intensity classes were calculated. The typology is based on the CORINE Plus classification.

Linear transformations of the relative species numbers are linearly transformed into ecosystem damage potentials. The damage potential calculated is endpoint oriented.

The impact factor for the unknown reference land use type (ref) before or after the land transformation is chosen as EDP(ref) = 0.80. This represents the maximum EDP, i.e. the land use type with the most negative impact.

The different impact categories implemented in SimaPro are:

- "land transformation" as a result of the addition of "transformation, from land use type I" and "transformation, to land use type I"

- "land occupation"

Normalization is not a part of this method.

Because the two impact categories are expressed in the same unit (points), PRé added a weighting step. Each impact category is given the weighting factor 1.

References

Koellner, T.; Scholz, R. 2007. Assessment of land use impact on the natural environment: Part 1: An Analytical Framework for Pure Land Occupation and Land Use Change. Int J LCA 12 (1): 16-23.

12 EDIP 2003

EDIP 2003 is a Danish LCA methodology that is presented as an update of the EDIP 97 methodology. The main innovation of EDIP2003 lies in the consistent attempt to include exposure in the characterization modelling of the main non-global impact categories. EDIP2003 can originally be used both with and without spatial differentiation. Only characterization factors for site-generic effects, which does not take spatial variation into account, are implemented in SimaPro 8.

12.1 Characterization

The EDIP 2003 methodology represents 19 different impact categories. Some of them are updated versions of EDIP 97, whereas others are modelled totally differently. Table 1 gives an overview of the EDIP 2003 impact categories. The choices made for implementing the methodology into SimaPro 8, are summed up for each impact category.

Table 6: Overview of the different impact categories in EDIP2003, and the changes made for implementation.

Impact categories	Implemented in original form	Choices made during implementation
Global warming		Time horizon of 100y is used (IPPC, 2007)
Ozone depletion	x	
Acidification	x	
Terrestrial eutrophication	x	
Aquatic eutrophication (N-eq)		Only emissions to inland waters only are included. Emissions to air included
Aquatic eutrophication (P-eq)		
Ozone formation (human)	x	Extended with extra factors from EI 2.0
Ozone formation (vegetation)	x	Extended with extra factors from EI 2.0
Human toxicity (exposure route via air)		Release height of 25m
Human toxicity (exposure route via water)	x	
Human toxicity (exposure route via soil)	x	
Ecotoxicity (water acute)	x	
Ecotoxicity (water chronic)	x	
Ecotoxicity (soil chronic)	x	
Hazardous waste	Directly taken from EDIP 97 (update 2004)	
Slags/ashes	Directly taken from EDIP 97(update 2004)	
Bulk waste	Directly taken from EDIP 97(update 2004)	
Radioactive waste	Directly taken from EDIP 97(update 2004)	
Resources	Directly taken from EDIP 97(update 2004)	

In the EDIP 2003 method, characterization factors for aquatic eutrophication are developed for two impact categories: aquatic eutrophication (N-eq) and aquatic eutrophication (P-eq). In each impact category, characterization factors for emissions effecting inland waters and emissions effecting marine waters are developed. This double set of characterization factors reflects the fact that, in general, eutrophication is limited by nitrate in fresh waters, and phosphate in marine waters.

In order to avoid double counting, that would occur if both emission types are implemented simultaneously, only the characterization factors for inland water are implemented in SimaPro. When characterization factors for marine water are needed, the following list can be used and implemented in the EDIP 2003 method:

Table 7: Characterization factors for emissions to marine water in aquatic eutrophication. Emission compartment soil corresponds with the source category waste water while water corresponds with the source category agriculture.

Substances	CAS no.	Impact category			
Emission to marine water		Aquatic eutrophication		Aquatic eutrophication	
Compartment		Soil	Water	Water	Soil
Nitric acid	7697-37-2	1,24E-01	1,61E-01	0,00E+00	0,00E+00
Nitrite	14797-65-0	1,62E-01	2,10E-01	0,00E+00	0,00E+00
Cyanide	57-12-5	2,92E-01	3,78E-01	0,00E+00	0,00E+00
Nitrogen, total		5,40E-01	7,00E-01	0,00E+00	0,00E+00
Phosphate	14265-44-2	0,00E+00	0,00E+00	3,30E-01	1,98E-02
Pyrophosphate	7722-88-5	0,00E+00	0,00E+00	3,50E-01	2,10E-02
Phosphorus, total		0,00E+00	0,00E+00	1,00E+00	6,00E-02

The emission to soil only takes into account the effects after plant uptake. For this impact category the topsoil is part of the technosphere. Emissions to air are also included in the model. The data needed for this compartment is not present in the guideline, but is received from Michael Hauschild.

The EDIP2003 characterization factors for human toxicity, exposure route via air, are enhanced. The new exposure factors are established for:

- Two different kinds of substances: short-living (hydrogen chloride) and long-living (benzene)
- Actual variation in regional and local population densities: added for each substance
- Different release heights: 1m, 25m and 100m.

The release height of 25m is presented as default in EDIP2003 and is used in SimaPro.

12.2 Normalization

There are normalization factors provided for Europe in the reference year 2004 (Laurent et al. 2011).

12.3 Weighting

Until the EDIP weighting factors have been updated to an EDIP2003 version, the weighting factors of EDIP97 (according to the update issued in 2004), are also used in EDIP2003. Because ecotoxicity has no normalization factors, also for weighting the value is set at zero. For resources, normalization and weighing are already included in the characterization factor and therefore set at zero.

References

Frischknecht, R.; Jungbluth, N.; Althaus, H.J.; Doka, G.; Dones, R.; Hischier, R.; Hellweg, S.; Humbert, S.; Margni, M.; Nemecek, T.; Spielmann, M. 2007. Implementation of Life Cycle Impact Assessment Methods: Data v2.0. ecoinvent report No. 3, Swiss centre for Life Cycle Inventories, Dübendorf, Switzerland.

Hauschild, M.; Potting, J. 2003. Spatial differentiation in Life Cycle impact assessment - The EDIP2003 methodology. Institute for Product Development Technical University of Denmark.

Laurent, A.; Lautier, A.; Rosenbaum, R.K.; Olsen, S.I.; Hauschild, M.Z. 2011. Normalization in EDIP97 and EDIP2003: updated European inventory for 2004 and guidance towards a consistent use in practice. Int J LCA 16 (8): 728-738.

13 EDIP/UMIP 97

The EDIP method (Environmental Design of Industrial Products, in Danish UMIP) was developed in 1996.

In 2004 the characterization factors for resources, the normalization and weighting factors for all impact categories were updated. Excluded in this version of the method in SimaPro are working environment and emissions to waste water treatment plants (WWTP).

The method is adapted for SimaPro. All characterization factors in this method are entered for the 'unspecified' sub-compartment of each compartment (raw, air, water, soil) and thus applicable on all sub-compartments, where no specific characterization value is specified.

13.1 Characterization

Global warming is based on the IPCC 1994 Status report. Is 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 NOx, in SimaPro we have chosen to use the POCPs for high background concentrations. Acidification is based on the number of hydrogen ions (H+) 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 bio-concentration. 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 bio-concentration. 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.

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 analyzing results, the characterization and normalization 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 normalization 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 normalization 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). Normalization 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 normalization data are known for an individual impact category, the normalization 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 normalization step.

13.2 Normalization

The normalization value is based on person equivalents for 1994 (according to the update issued in 2004). For resources, normalization and weighing are already included in the characterization factor and therefore set at zero.

13.3 Weighting

The weighting factors are set to the politically set target emissions per person in the year 2004 (according to the update issued in 2004), the weighted result are expressed except for resources which is based on the proven reserves per person in 1994. For resources, normalization and weighing are already included in the characterization factor and therefore set at zero.

Note:

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.

References

Hauschild, M.; Wenzel, H. 1998. Environmental Assessment of Products. Volume 2: Scientific background. Chapman and Hall. See http://www.wkap.nl/book.htm/0-412-80810-2.

Wenzel, H.; Hauschild, M.; Alting, L. 1997. Environmental Assessment of Products. Volume 1: Methodology, tools and case studies in product development. Chapman and Hall. See http://www.wkap.nl/book.htm/0-7923-7859-8.

14 EF Method (adapted)

EF method is the impact assessment method of Environmental Footprint (EF), initiative introduced by the European Commission. The EF method 2.0 was the one to be used in Product Environmental Footprint Category Rules (PEFCRs) and Organisation Footprint Sector Rules (OEFSRs) of the EF pilot phase. Its validity has ended in December 2021. The method included in the SimaPro Professional database includes a number of adaptations, which make the EF method compatible with the data libraries provided in SimaPro.

Since the method was modified, it is not suitable for conducting the EF-compliant studies but can be used for other assessments. The original version of the method will be distributed in the dedicated SimaPro EF database.

The implementation is based on EF method with the following modifications:

- It does not include any substances, which would be new to SimaPro, e.g. regionalized land use flows;

- Additional substances have been included as they are extensively used by the background databases and their synonyms are part of the original EF method:

    - Resource use, energy carriers - flows expressed in mass units (not only in net calorific value as in EF); characterization factor corresponds to the lower heating values of given fuel;

    - Resource use, mineral and metals - additional flows for already characterized mineral and metals;

    - Water use - flows representing geographies not covered in the original EF method; global factor was applied;

    - Climate change - carbon dioxide (emission to air) is added with factor of carbon dioxide, fossil; carbon dioxide, to soil or biomass stock is added with factor -1 (this flow is necessary for the correct modeling of land use in ecoinvent).

14.1.1 Characterization

Table 8: Characterization

Impact category	Recommended default LCIA method	Indicator
Climate change	Baseline model of the IPCC 2013, including the carbon feedbacks for different substances. *IPCC 2013 supplementary material chap. 8 tab 8SM15* https://www.ipcc.ch/pdf/assessment-report/ar5/wg1/supplementary/WG1AR5_Ch08SM_FINAL.pdf	Global Warming Potential 100 years
Ozone depletion	Steady-state ODPs *Scientific Assessment of Ozone Depletion: 1998. Global Ozone Research and Monitoring Project - Report No. 44,* ISBN 92-807-1722-7, Geneva. Undefined Report no. 4 by WMO (1999)	Ozone Depletion Potential (ODP) calculating the destructive effects on the stratospheric ozone layer over a time horizon of 100 years
Human toxicity, cancer	USEtox consensus model Rosenbaum, R.K., Bachmann, T.M., Gold, L.S., Huijbregts, A.J., Jolliet, O., Juraske, R., Koehler, A., Larsen, H.F., MacLeod, M., Margni, M., McKone, T.E., Payet, J., Schuhmacher, M., Van de Meent, D., Hauschild, M.Z., 2008, *USEtox™, the UNEP-SETAC toxicity model: recommended characterization factors for human toxicity and freshwater ecotoxicity in life cycle impact assessment.* Int J Life Cycle Assess 13 (7): 532-546	Comparative Toxic Unit for human (CTUh) expressing the estimated increase in morbidity in the total human population per unit mass of a chemical emitted (cases per kilogramme).
Human toxicity, non-cancer	USEtox consensus model Rosenbaum, R.K., Bachmann, T.M., Gold, L.S., Huijbregts, A.J., Jolliet, O., Juraske, R., Koehler, A., Larsen, H.F., MacLeod, M., Margni, M., McKone, T.E., Payet, J., Schuhmacher, M., Van de Meent, D., Hauschild, M.Z., 2008, *USEtox™, the UNEP-SETAC toxicity model: recommended characterization factors for human toxicity and freshwater ecotoxicity in life cycle impact assessment.* Int J Life Cycle Assess 13 (7): 532-546	Comparative Toxic Unit for human (CTUh) expressing the estimated increase in morbidity in the total human population per unit mass of a chemical emitted (cases per kilogram).
Respiratory inorganics	PM method recommendaed by UNEP Fantke, P., Evans, J., Hodas, N., Apte, J., Jantunen, M., Jolliet, O., McKone, T.E. (2016). *Health impacts of fine particulate matter. In: Frischknecht, R., Jolliet, O. (Eds.), Global Guidance for Life Cycle Impact Assessment Indicators: Volume 1.* UNEP/SETAC Life Cycle Initiative, Paris, pp. 76-99	Disease incidence due to kg of PM2.5 emitted
Ionising radiation, human health	Human health effect model as developed by Dreicer et al. 1995 Frischknecht, R., Braunschweig, A., Hofstetter P., Suter P. (2000), *Modelling human health effects of radioactive releases in Life Cycle Impact Assessment. Environmental Impact Assessment Review, Volume 20, Number 2, April 2000, pp. 159-189*	Ionizing Radiation Potentials: Quantification of the impact of ionizing radiation on the population, in comparison to Uranium 235
Photochemical ozone formation, human health	LOTOS-EUROS model Van Zelm, R., Huijbregts, M.A.J., Den Hollander, H.A., Van Jaarsveld, H.A., Sauter, F.J., Struijs, J., Van Wijnen, H.J., Van de Meent, D. (2008). *European characterization factors for human health damage of PM10 and ozone in life cycle impact assessment.* Atmospheric Environment 42, 441-453	Photochemical ozone creation potential (POCP): Expression of the potential contribution to photochemical ozone formation
Acidification	Accumulated Exceedance	Accumulated Exceedance (AE) characterizing the change in

	Seppälä, J., M. Posch, M. Johansson and J. P. Hettelingh (2006). *Country-dependent Characterisation Factors for Acidification and Terrestrial Eutrophication Based on Accumulated Exceedance as an Impact Category Indicator*. International Journal of Life Cycle Assessment 11(6): 403-416	critical load exceedance of the sensitive area in terrestrial and main freshwater ecosystems, to which acidifying substances deposit.
	Posch, M., J. Seppälä, J. P. Hettelingh, M. Johansson, M. Margni and O. Jolliet (2008). *The role of atmospheric dispersion models and ecosystem sensitivity in the determination of characterization factors for acidifying and eutrophying emissions in LCIA.* International Journal of Life Cycle Assessment 13(6): 477-486	
Terrestrial eutrophication	Accumulated Exceedance Seppälä, J., M. Posch, M. Johansson and J. P. Hettelingh (2006). *Country-dependent Characterisation Factors for Acidification and Terrestrial Eutrophication Based on Accumulated Exceedance as an Impact Category Indicator*. International Journal of Life Cycle Assessment 11(6): 403-416 Posch, M., J. Seppälä, J. P. Hettelingh, M. Johansson, M. Margni and O. Jolliet (2008). *The role of atmospheric dispersion models and ecosystem sensitivity in the determination of characterization factors for acidifying and eutrophying emissions in LCIA.* International Journal of Life Cycle Assessment 13(6): 477-486	Accumulated Exceedance (AE) characterizing the change in critical load exceedance of the sensitive area, to which eutrophying substances deposit
Freshwater eutrophication	EUTREND model Struijs, J., Beusen, A., van Jaarsveld, H. and Huijbregts, M.A.J. (2008b). Aquatic Eutrophication. Chapter 6 in: Goedkoop, M., Heijungs, R., Huijbregts, M.A.J., De Schryver, A., Struijs, J., Van Zelm, R. (2008). *ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Report I: Characterisation factors, first edition. Chapter in anthology Chapter on aquatic eutrophication in the ReCiPe report (report I: characterization factors, 2008).*	Phosphorus equivalents: Expression of the degree to which the emitted nutrients reaches the freshwater end compartment (phosphorus considered as limiting factor in freshwater).
Marine eutrophication	EUTREND model Struijs, J., Beusen, A., van Jaarsveld, H. and Huijbregts, M.A.J. (2008b). Aquatic Eutrophication. Chapter 6 in: Goedkoop, M., Heijungs, R., Huijbregts, M.A.J., De Schryver, A., Struijs, J., Van Zelm, R. (2008). *ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Report I: Characterisation factors, first edition. In press. Chapter in anthology Chapter on aquatic eutrophication in the ReCiPe report (report I: characterization factors, 2008)*	Nitrogen equivalents: Expression of the degree to which the emitted nutrients reaches the marine end compartment (nitrogen considered as limiting factor in marine water)
Land use	CFs set re-calculated by JRC starting from LANCA® v 2.2 as baseline model. Bos U., Horn R., Beck T., Lindner J.P., Fischer M. (2016). *LANCA® Characterization Factors for Life Cycle Impact Assessment. Version 2.* Franhofer Verlag, Stuttgart, DE. http://publica.fraunhofer.de/eprints/urn_nbn_de_0011-n-3793106.pdf	Soil quality index
Ecotoxicity freshwater	USEtox consensus model Rosenbaum, R.K., Bachmann, T.M., Gold, L.S., Huijbregts, A.J., Jolliet, O., Juraske, R., Koehler, A., Larsen, H.F., MacLeod, M., Margni, M., McKone, T.E., Payet, J., Schuhmacher, M., Van de Meent, D., Hauschild, M.Z., 2008, *USEtox™, the UNEP-SETAC toxicity model: recommended characterization factors for human toxicity and freshwater ecotoxicity in life cycle impact assessment*. Int J Life Cycle Assess 13 (7): 532-546	Comparative Toxic Unit for ecosystems (CTUe) expressing an estimate of the potentially affected fraction of species (PAF) integrated over time and volume per unit mass of a chemical emitted (PAF m3 year/kg)
Water scarcity	Available WAter REmaining (AWARE) as recommended by UNEP	m3 water eq. deprived

	Boulay A.M., Bare J., Benini L., Berger M., Lathuillière M.J., Manzardo A., Margni M., Motoshita M., Núñez M., Pastor A.V., Ridoutt B., Oki T., Worbe S., Pfister S. (2016). *The WULCA consensus characterization model for water scarcity footprints: Assessing impacts of water consumption based on available water remaining (AWARE)*	
Resource use, energy carriers	ADP for energy carriers, based on van Oers et al. 2002 as implemented in CML, v. 4.8 (2016). van Oers, L, Koning, A, Guinée, JB, Huppes, G (2002) *Abiotic resource depletion in LCA.* Road and Hydraulic Engineering Institute, Ministry of Transport and Water, Amsterdam http://www.leidenuniv.nl/cml/ssp/projects/lca2/report_abiotic_depletion_web.pdf	Abiotic resource depletion fossil fuels (ADP-fossil); based on lower heating value
Resource use, mineral and metals	ADP for mineral and metal resources, based on van Oers et al. 2002 as implemented in CML, v. 4.8 (2016). van Oers, L, Koning, A, Guinée, JB, Huppes, G (2002) *Abiotic resource depletion in LCA.* Road and Hydraulic Engineering Institute, Ministry of Transport and Water, Amsterdam http://www.leidenuniv.nl/cml/ssp/projects/lca2/report_abiotic_depletion_web.pdf	Abiotic resource depletion (ADP ultimate reserve)

14.1.2   Normalization and weighting

Global normalization set for a reference year 2010 is part of the EF method.

The EF 2.0 method includes two versions of the weighting factors – including and excluding three toxicity-related impact categories. Currently, those impact categories are "not seen as sufficiently robust to be included in external communications or in a weighted result". The EF 3.0 method only has a single weighting set, which includes toxicity.

After an evaluation of existing weighting methods, three weighting sets were developed: i) panel based approach - general public survey; ii) panel based approach - LCA experts' survey; iii) hybrid evidence-and judgement-based approach. Those three weighting sets were then aggregated by first averaging the sets based on panel based approach.

References

Fazio, S. Castellani, V. Sala, S., Schau, EM. Secchi, M. Zampori, L., *Supporting information to the characterization factors of recommended EF Life Cycle Impact Assessment methods*, EUR 28888 EN, European Commission, Ispra, 2018, ISBN 978-92-79-76742-5, doi:10.2760/671368, JRC109369.

Normalization and weighting factors: *Annex A of the Product Environmental Footprint Category Rules Guidance v6.3*, May 2018. http://ec.europa.eu/environment/eussd/smgp/pdf/PEFCR_guidance_v6.3.pdf.

Sala S., Cerutti A.K., Pant R., *Development of a weighting approach for the Environmental Footprint*, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-68042-7, EUR 28562, doi 10.2760/945290.

15 EPD (2008)

This method is to be used for the creation of Environmental Product Declarations or (EPDs), as published on the website Swedish Environmental Management Council (SEMC). The last update of this method is mainly based on the EPD document version 1.0 dated 2008-02-29.

15.1 Characterization

In the standard EPDs one only has to report on the following impact categories:

Original names	Names in SP
Gross Calorific Values (GVC) (referred to as "Higher Heating Values")	Non renewable, fossil
Greenhouse gases	Global warming (GWP100)
Ozone-depleting gases	Ozone layer depletion (ODP)
Acidifying compounds	Acidification
Gases creating ground-level ozone (Photochemical Ozone creation)	Photochemical oxidation
Eutrophying compounds	Eutrophication

Specific product category guidelines may require extra information.

15.2 Non renewable, fossil

The values as used for the calculation of the non renewable, fossil impact category are taken from the Cumulative energy demand LCIA method (v 1.05) as implemented in SimaPro. The values from IPPC (2007) are used as recommended on the EPD website. The characterization for biogenic methane has been corrected for the CO_2 sequestration.

15.3 Ozone layer depletion (ODP), Photochemical oxidation, Acidification and Eutrophication

The values as used by the EPD document are used.

15.4 Normalization and weighting

Normalization and weighting are not a part of this method.

References

"Revision of the EPD® system into an International EPD®": www.environdec.com/Documents/GPI/EPD_annexes_080229.pdf

We thank Leo Breedveld from 2B (www.to-be.it) for his advice and support.

16 EPD (2013)

This method is the successor of EPD (2008) and is to be used for the creation of Environmental Product Declarations (EPDs), as published on the website of the Swedish Environmental Management Council (SEMC). An EPD is always created according to a Product Category Rule. This method is especially important for everybody who is reporting a Product Category Rule (PCR) published by Environdec.

16.1 Characterization

In the standard EPDs one only has to report on the following impact categories:

Original names	Names in SimaPro
Acidification potential	acidification (fate not included)
Eutrophication potential	eutrophication
Global warming potential	global warming'
Photochemical oxidant creation potential	photochemical oxidation'

Additional indicators:

Original names	Names in SimaPro
Ozone-depleting gases (expressed as the sum of ozone-depleting potential in mass of CFC 11-equivalents, 20 years)	ozone layer depletion (ODP) (optional)
Abiotic resource depletion	Abiotic depletion (optional)
Abiotic depletion (fossil fuels)	Abiotic depletion, fossil fuels (opt.)

All impact categories are taken directly from the CML-IA baseline method (eutrophication, global warming and photochemical oxidation) and CML-IA non baseline method (acification). These two methods can be found in SimaPro as well.

16.2 Normalization and weighting

Normalization and weighting are not a part of this method.

References

General programme instructions for the international EPD® system, 2.01. 18 September 2013. Download at http://www.environdec.com/Documents/GPI/General_programme_instructions_2_01_2013 0918.pdf

17 EPS 2000

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 measurement. The indicator unit is ELU (Environmental Load Unit), which includes characterization, normalization and weighting.

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.

This V2 version is adapted for SimaPro. All characterization factors in this method are entered for the 'unspecified' sub-compartment of each compartment (Raw materials, air, water, soil) and thus applicable on all sub-compartments, where no specific characterization value is specified.

This method is NOT fully adapted for inventory data from the Ecoinvent library and the USA Input Output Database 98, and therefore omits emissions that could have been included in impact assessment.

17.1 Characterization

Emissions and resources are assigned to impact categories when actual effects are likely to occur in the environment, based on likely exposure. Empirical, equivalency and mechanistic models are used to calculate default characterization values.

Human Health

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

- 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 characterization factors are defined as 0 (zero).

In SimaPro, characterization 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 Normalized 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.

17.2 Normalization/Weighting

In the EPS default method, normalization/weighting is made through valuation. Normalization/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).

References

Steen B. 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.

18 Greenhouse Gas Protocol

The Greenhouse Gas Protocol (GHG Protocol), developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD), is an accounting standard of greenhouse gas emissions. This method is based on the draft report on Product Life Cycle Accounting and Reporting Standard.

18.1 Characterization

To calculate carbon dioxide equivalents (CO2eq) of all non-CO2 gases (CH4, N2O, SF6, HFCs, CFCs) the company shall use and report the most recent 100-year IPCC global warming potentials (GWP). The 100–year GWP is a metric used to describe the time-integrated radiative characteristics of well mixed greenhouse gases over a 100-year time horizon.

The total GHG emissions for a product inventory shall be calculated as the sum of GHG emissions, in CO2eq, of all foreground processes and significant background processes within the system boundary. A distinction is made between:

- GHG emissions from fossil sources
- Biogenic carbon emissions
- Carbon storage
- Emissions from land transformation

According to the draft standard on product accounting, fossil and biogenic emissions must be reported independently. The reporting of the emissions from carbon storage and land transformation is optional.

18.2 Normalization and weighting

Normalization and weighting are not a part of this method.

References

WBCSD & WRI. 2009. Product Life Cycle Accounting and Reporting Standard. Review Draft for Stakeholder Advisory Group. The Greenhouse Gas Protocol Initiative. November 2009.

19 ILCD 2011 Midpoint+

This is the corrected and updated method of the ILCD 2011 Midpoint (without the +) which can still be found in the Superseded folder. For this new version, the normalization factors were added as provided in "Normalisation method and data for Environmental Footprints; 2014; Lorenzo Benini, et al.; Report EUR 26842 EN". The characterization factors in the Land use category are updated based on "ERRATA CORRIGE to ILCD - LCIA Characterization Factors" - Version06_02_2015(v. 1.0.6) - "List of changes to CFs for land use from v 1 0 5 to v 1 0 6_REVISED.xlsx".

Characterization factors for long term emissions are set to zero, because this was an implicit requirement from the European Commission. Weighting factors were added with equal weights for each of the recommended categories as indicated by the guidance document.

The full title of this method is: ILCD recommendations for LCIA in the European context. The European Commission (EC-JRC–IES, 2011) analyzed several methodologies for LCIA and made some effort towards harmonization. Starting from the first pre-selection of existing methods and the definition of criteria, a list of recommended methods for each impact category at both midpoint and endpoint was produced.

The endpoint methods, however, are not included here, because the list is far from complete. Recommendations are given for the impact categories of climate change, ozone depletion, human toxicity, particulate matter/respiratory inorganics, photochemical ozone formation, ionizing radiation impacts, acidification, eutrophication, ecotoxicity, land use and resource depletion (Table 3).

Research needs are identified for each impact category and differentiated according to their priority. No method development took place in the development of the ILCD recommendations. The intention was to identify and promote current best practice. These recommendations do not provide recommendations for weighting across impact categories, nor for normalization within a given category relative to impacts in a given region.

Table 9: Recommended methods and their classification at midpoint (ILCD 2011).

Impact category	Recommended default LCIA method	Indicator	Classification*
Climate change	Baseline model of 100 years of the IPCC	Radiative forcing as Global Warming Potential (GWP100)	I
Ozone depletion	Steady-state ODPs 1999 as in WMO assessment	Ozone Depletion Potential (ODP)	I
Human toxicity, cancer effects	USEtox model (Rosenbaum et al, 2008)	Comparative Toxic Unit for humans (CTUh)	II/III
Human toxicity, non- cancer effects	USEtox model (Rosenbaum et al, 2008)	Comparative Toxic Unit for humans (CTUh)	II/III
Particulate matter/Respiratory inorganics	RiskPoll model (Rabl and Spadaro, 2004) and Greco et al 2007	Intake fraction for fine particles (kg PM2.5-eq/kg)	I
Ionising radiation, human health	Human health effect model as developed by Dreicer et al. 1995 (Frischknecht et al, 2000)	Human exposure efficiency relative to U235	II
Ionising radiation, ecosystems	No methods recommended		

Photochemical ozone formation	LOTOS-EUROS (Van Zelm et al, 2008) as applied in ReCiPe	Tropospheric ozone concentration increase	II
Acidification	Accumulated Exceedance (Seppälä et al. 2006, Posch et al, 2008)	Accumulated Exceedance (AE)	II
Eutrophication, terrestrial	Accumulated Exceedance (Seppälä et al. 2006, Posch et al, 2008)	Accumulated Exceedance (AE)	II
Eutrophication, aquatic	EUTREND model (Struijs et al, 2009b) as implemented in ReCiPe	Fraction of nutrients reaching freshwater end compartment (P)/ marine end compartment (N)	II
Ecotoxicity (freshwater)	USEtox model, (Rosenbaum et al, 2008)	Comparative Toxic Unit for ecosystems (CTUe)	II/III
Ecotoxicity (terrestrial and marine)	No methods recommended		
Land use	Model based on Soil Organic Matter (SOM) (Milà i Canals et al, 2007b)	Soil Organic Matter	III
Resource depletion, water	Model for water consumption as in Swiss Ecoscarcity (Frischknecht et al, 2008)	Water use related to local scarcity of water	III
Resource depletion, mineral, fossil and renewable**	CML 2002 (Guinée et al., 2002)	Scarcity	II

* Levels: "I" (recommended and satisfactory), level "II" (recommended but in need of some improvements) or level "III" (recommended, but to be applied with caution); "interim" indicates that a method was considered the best among the analyzed methods for the impact category, but still immature to be recommended.

** Depletion of renewable resources is included in the analysis but none of the analyzed methods is mature for recommendation

References

European Commission - Joint Research Centre. 2011. *International Reference Life Cycle Data System (ILCD) Handbook- Recommendations for Life Cycle Impact Assessment in the European context.* First edition November 2011. EUR 24571 EN. Luxemburg. Publications Office of the European Union; 2011

LCIA characterization factors release in February 2012 with errata from March 2012 can be downloaded from http://lct.jrc.ec.europa.eu/assessment/projects.

20 Impact 2002+

IMPACT 2002+, acronym of IMPact Assessment of Chemical Toxics, is an impact assessment methodology originally developed at the Swiss Federal Institute of Technology - Lausanne (EPFL), with current developments carried out by the same team of researchers now under the name of Ecointesys-life cycle systems (Lausanne). The present methodology proposes a feasible implementation of a combined midpoint/damage approach, linking all types of life cycle inventory results (elementary flows and other interventions) via 14 midpoint categories to four damage categories (Figure 3).
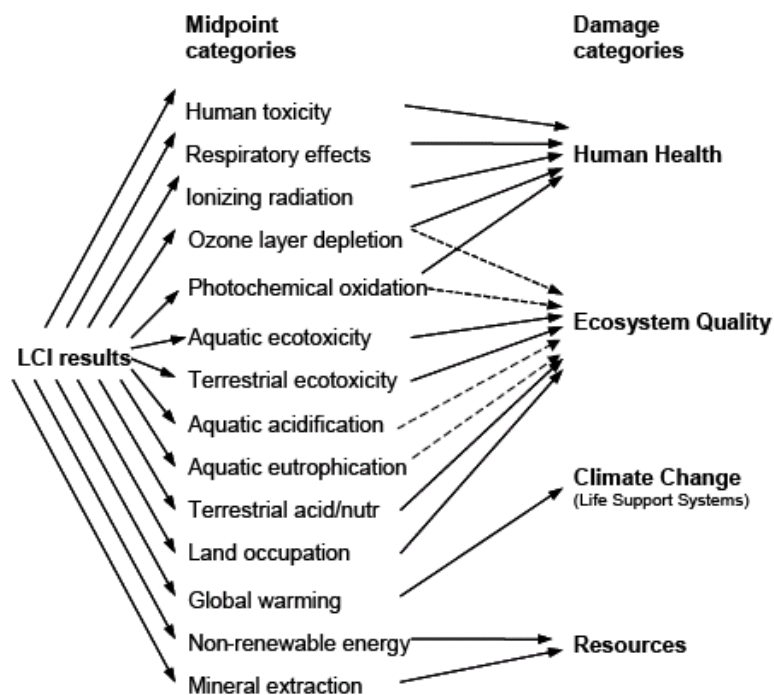

Figure 3: Overall scheme of the IMPACT 2002+ framework, linking LCI results via the midpoint categories to damage categories. Based on Jolliet et al. (2003a)

In SimaPro, only the characterization factors at endpoint level are provided.

20.1 Characterization

The characterization factors for human toxicity and aquatic and terrestrial ecotoxicity are taken from the methodology IMPACT 2002+. The characterization factors for other categories are adapted from existing characterizing methods, i.e. Eco-indicator 99, CML 2001, IPCC and the Cumulative Energy Demand.

The IMPACT 2002+ method (version 2.1) presently provides characterization factors for almost 1500 different LCI-results. In SimaPro, 15 different impact categories are presented, as human toxicity is split up in 'Carcinogens' and 'Non-carcinogens'.

20.2 Normalization

The damage factor reported in ecoinvent are normalized by dividing the impact per unit of emission by the total impact of all substances of the specific category for which characterization factors exist, per person per year (for Europe). The unit of all normalized midpoint/damage factors is therefore [pers*year/unitemission], i.e. the number of equivalent persons affected during one year per unit of emission.

20.3 Weighting

The authors of IMPACT2002+ suggest to analyze normalized scores at damage level considering the four-damage oriented impact categories human health, ecosystem quality, climate change, and resources or, alternatively, the 14 midpoint indicators separately for the interpretation phase of LCA. However, if aggregation is needed, one could use self-determined weighting factors or a default weighting factor of one, unless other social weighting values are available.

PRé added an extra weighting step. Each damage category is given the weighting factor 1.

References

Frischknecht, R.; Jungbluth, N.; Althaus, H.J.; Doka, G.; Dones, R.; Hischier, R.; Hellweg, S.; Humbert, S.; Margni, M.; Nemecek, T.; Spielmann, M. 2007. *Implementation of Life Cycle Impact Assessment Methods: Data v2.0.* ecoinvent report No. 3, Swiss centre for Life Cycle Inventories, Dübendorf, Switzerland.

Jolliet, O.; Margni, M.; Charles, R.; Humbert, S.; Payet, J.; Rebitzer, G.; Rosenbaum, R. 2003. *IMPACT 2002+: A New Life Cycle Impact Assessment Methodology*. Int J LCA 8 (6): 324 – 330.

21 IPCC 2001 GWP

IPCC 2001 is a method developed by the International Panel on Climate Change.

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 characterization factors for emissions available in the SimaPro database.

21.1 Characterization

The IPCC characterization 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 NOx, water, sulphate, etc. in the lower stratosphere + upper troposphere.
- not considering the range of indirect effects given by IPCC.
- including CO2 formation from CO emissions.
- considering biogenic CO2 uptake as negative impact.

21.2 Normalization and weighting

Normalization and weighting are not a part of this method.

References

Intergovernmental Panel on Climate Change (IPCC). 2001. IPCC Third Assessment Report. The Scientific Basis. http://www.grida.no/climate/ipcc_tar/

22 IPCC 2007

IPCC 2007 is an update of the method IPCC 2001 developed by the International Panel on Climate Change. This method lists the climate change factors of IPCC with a timeframe of 20, 100 and 500 years.

22.1 Characterization

IPCC characterization factors for the direct (except CH4) 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 NOx, water, sulphate, etc. in the lower stratosphere + upper troposphere.
- not considering the range of indirect effects given by IPCC.
- not including CO2 formation from CO emissions.
- If only a minimum or maximum value of a substance is reported this minimum or maximum value is used.
- The substances that do not have a common name but only a formula are not included in the method.
- NOT considering biogenic CO2 uptake and emission, but only considering the biogenic methane release.

22.2 Normalization and weighting

Normalization and weighting are not a part of this method.

References

Intergovernmental Panel on Climate Change. 2007. IPCC Fourth Assessment Report. The Physical Science Basis. http://www.ipcc.ch/ipccreports/ar4-wg1.htm.

Intergovernmental Panel on Climate Change. 2007. IPCC Fourth Assessment Report. The Physical Science Basis. Errata. http://ipcc-wg1.ucar.edu/wg1/Report/AR4WG1_Errata_2008-08-05.pdf

23 IPCC 2013

IPCC 2013 is an update of the method IPCC 2007 developed by the International Panel on Climate Change. This method lists the climate change factors of IPCC with a timeframe of 20 and 100 years.

23.1 Characterization

IPCC characterization factors for the direct (except CH4) 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 NOx, water, sulphate, etc. in the lower stratosphere + upper troposphere.

- not considering the range of indirect effects given by IPCC.

- not including CO2 formation from CO emissions.

23.2 Normalization and weighting

Normalization and weighting are not a part of this method.

References

Intergovernmental Panel on Climate Change. 2013. IPCC Fifth Assessment Report. The Physical Science Basis. http://www.ipcc.ch/report/ar5/wg1/.

24 Motoshita et al 2011 (Human Health)

This method is based on the publication Motoshita et al (2011).

24.1 Characterization

The method is an endpoint indicator. It contains two different types of human health categories: one for infectious disease damage caused by domestic water scarcity and one for malnutrition damage caused by agricultural water scarcity.

For domestic water scarcity, the method assumes that water resource scarcity caused by water consumption will lead to a loss of access to safe water. The cause-effect chain modelling is based on hydrological and socio economic data. The water scarcity index used at the midpoint is Pfister et al 2009 (Water Scarcity). The level of economic development is considered through the parameter house connection to water supply.

The impacts of malnutrition caused by agricultural water deficit are modelled using the same data source for scarcity and distribution as above, multiplied by a socio-economic parameter describing the trade effect. This illustrates how food supply shortage in a country will spread to other countries through international food trade. Countries with low and middle incomes will be affected by the food shortage. This effect is quantified in DALY by using malnutrition-related DALYs in the importing countries (DALY/kcal malnutrition).

The "HH, agricultural water scarcity" category is comparable with the "HH, marginal" category of Boulay et al 2011 (Human Health) and the "Human Health" category of the Pfister et al 2009 (Eco-indicator 99) and Pfister et al 2010 (ReCiPe) methods. The "HH, domestic water scarcity" category is complementary to the "HH, agricultural water scarcity" category.

The method provides country-based characterization factors in the context of both domestic and agricultural water scarcity, expressed in DALY per m3 of water consumed.

The regional factors are weighted averages based on the freshwater withdrawal by country data from the Pacific Institute (http://www.worldwater.org/data.html) [old data – 2014 – check for new data].

After calculating your results we recommend you view the 'Checks' tab to see if there are any significant flows omitted due to the incomplete list of characterization factors for some countries.

References

Motoshita, M., Itsubo, N., Inaba, A. (2011). Development of impact factors on damage to health by infectious diseases caused by domestic water scarcity. Int J LCA 16, 65-73.

25 Pfister et al 2009 (Eco-indicator 99)

This method is based on the publication Pfister et al (2009). The method is based on the same endpoint categories as in the Eco-indicator 99 method.

Human health is obtained by modelling the cause-effect chain of water deprivation for agricultural users (lack of irrigation water) leading to malnutrition. It builds on the midpoint scarcity indicator [Pfister et al 2009 (Water Scarcity)] and models the cause-effect chain by multiplying it by:

- the agricultural users' share of water use from Vorosmarty,

- a socio-economic parameter defined as a human development factor for malnutrition, which relates the Human Development Index and

- two values independent of location combined in an effect factor that describes the DALY/m3 of water deprived for agriculture: the per-capita water requirements to prevent malnutrition (in m3/(yr•capita)) and the damage factor denoting the damage caused by malnutrition (DALY/(yr•capita)).

Ecosystem quality is obtained by modelling the cause-effect chain of freshwater consumption on terrestrial ecosystem quality and assessed following the Eco-indicator 99 method, with units of potentially disappeared fraction of species (PDF). The fraction of net primary productivity (NPP) which is limited by water availability represents the water-shortage vulnerability of an ecosystem, and is used as a proxy for PDF.

Resources is obtained by modelling the cause -effect chain of freshwater consumption on water resource depletion. The back-up technology concept is used following the Eco-indicator 99 method. The damage to resources resulting from water consumption is calculated by multiplying the energy demand for desalination by the fraction of water consumption contributing to freshwater depletion, which is dependent on the withdrawal to availability (WTA) ratio. The unit is expressed in surplus energy (MJ).

The "Human Health" category is comparable with the "HH, marginal" category in the Boulay et al 2011 (Human Health) method the "HH, agricultural water scarcity" category in the Motoshita et al 2010 (Human Health) method.

The regional factors are weighted averages based on the freshwater withdrawal by country data from the Pacific Institute (http://www.worldwater.org/data.html) [old data – 2014 – check for new data].

After calculating your results we recommend you view the 'Checks' tab to see if there are any significant flows omitted due to the incomplete list of characterization factors for some countries.

References

Pfister, S.; Koehler, A.; Hellweg, S. (2009). Assessing the environmental impacts of freshwater consumption in LCA. Environmental Science and Technology, 43(11), 4098–4104; DOI: 10.1021/es802423e (download: http://pubs.acs.org/doi/full/10.1021/es802423e)

26 Pfister et al 2009 (Water Scarcity)

This method is based on the publication Pfister et al (2009). This water scarcity indicator (WSI) is based on a withdrawal to availability (WTA) ratio and modelled using a logistic function (S-curve) in order to fit the resulting indicator to values between 0.01 and 1 m3 deprived/m3 consumed. The curve is tuned using OECD water stress thresholds, which define moderate and severe water stress as 20% and 40% of withdrawals, respectively. The indicator is applied to the consumed water volume and assesses consumptive water use only.

The regional factors are weighted averages based on the freshwater withdrawal by country data from the Pacific Institute (http://www.worldwater.org/data.html) [old data – 2014 – check for new data].

After calculating your results we recommend you view the 'Checks' tab to see if there are any significant flows omitted due to the incomplete list of characterization factors for some countries.

Please note that starting from SimaPro 9.2 Pfister Water Scarcity 2009 method will no longer be updated.

References

Pfister, S.; Koehler, A.; Hellweg, S. (2009). Assessing the environmental impacts of freshwater consumption in LCA. Environmental Science and Technology, 43(11), 4098–4104; DOI: 10.1021/es802423e (download: http://pubs.acs.org/doi/full/10.1021/es802423e)

27 Pfister et al 2010 (ReCiPe)

This method is based on the publication Pfister et al (2010). The method is based on the same endpoint categories as in the ReCiPe method.

Human health is expressed in DALY and is obtained by modelling the cause-effect chain of water deprivation for agricultural users (lack of irrigation water) leading to malnutrition. The cause-effect chain modelling is based on hydrological and socioeconomic data. The water scarcity index is used at the midpoint [Pfister et al 2009 (Water Scarcity)]. The level of economic development is considered though the parameter Human Development Index.

Ecosystem quality is obtained by modelling the cause-effect chain of freshwater consumption on terrestrial ecosystem quality and assessed following ReCiPe, with units of disappeared species per year.

Resources is obtained by modelling the cause-effect chain of freshwater consumption on water resource depletion following ReCiPe, with units of surplus cost to extract an additional cubic meter of water.

The "Human Health" category is comparable with the "HH, marginal" category in the Boulay et al 2011 (Human Health) method the "HH, agricultural water scarcity" category in the Motoshita et al 2010 (Human Health) method.

The regional factors are weighted averages based on the freshwater withdrawal by country data from the Pacific Institute (http://www.worldwater.org/data.html) [old data – 2014 – check for new data].

After calculating your results we recommend you view the 'Checks' tab to see if there are any significant flows omitted due to the incomplete list of characterization factors for some countries.

References

Pfister, Stephan; Saner, Dominik; Koehler, Annette (2010). The environmental relevance of freshwater consumption in global power production. The International Journal of Life Cycle Assessment 2011, 16, 580-591.

28 ReCiPe 2008

ReCiPe is the successor of the methods Eco-indicator 99 and CML-IA. The purpose at the start of the development was to integrate the 'problem oriented approach' of CML-IA and the 'damage oriented approach' of Eco-indicator 99. The 'problem oriented approach' defines the impact categories at a midpoint level. The uncertainty of the results at this point is relatively low. The drawback of this solution is that it leads to many different impact categories which makes the drawing of conclusions with the obtained results complex. The damage oriented approach of Eco-indicator 99 results in only three impact categories, which makes the interpretation of the results easier. However, the uncertainty in the results is higher. ReCiPe implements both strategies and has both midpoint (problem oriented) and endpoint (damage oriented) impact categories. The midpoint characterization factors are multiplied by damage factors, to obtain the endpoint characterization values.

ReCiPe comprises two sets of impact categories with associated sets of characterization factors. At the midpoint level, 18 impact categories are addressed:

1. Ozone depletion
2. Human toxicity
3. Ionizing radiation
4. Photochemical oxidant formation
5. Particulate matter formation
6. Terrestrial acidification
7. Climate change
8. Terrestrial ecotoxicity
9. Agricultural land occupation
10. Urban land occupation
11. Natural land transformation
12. Marine ecotoxicity
13. Marine eutrophication
14. Fresh water eutrophication
15. Fresh water ecotoxicity
16. Fossil fuel depletion
17. Minerals depletion
18. Fresh water depletion

At the endpoint level, most of these midpoint impact categories are multiplied by damage factors and aggregated into three endpoint categories:

- Human health
- Ecosystems
- Resource surplus costs

The three endpoint categories are normalized, weighted, and aggregated into a single score. Figure 4 sketches the relations between lifecycle inventory (LCI) parameters (left side), the 18 midpoint categories (middle), and the 3 endpoint categories, including the single score (right side).
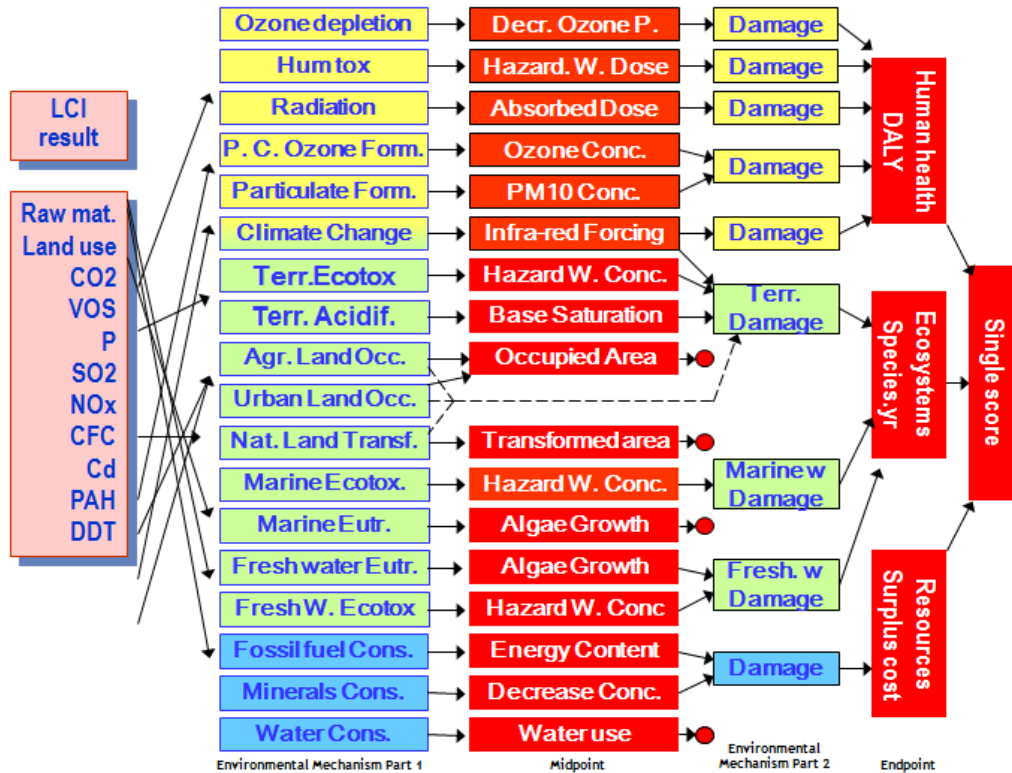

Figure 4: Representation of the relations between the inventory and the midpoint categories (environmental mechanisms) and the endpoint categories, including the single score (damage model).

28.1 Value choices

It is obvious that the environmental mechanisms and damage models are sources of uncertainty: the relationships modelled reflect state of the art knowledge of the environmental mechanisms that has a certain level of incompleteness and uncertainty. In ReCiPe, like in Eco-indicator 99, it was decided to group different sources of uncertainty and different (value) choices into a limited number of perspectives or scenarios, according to the "Cultural Theory" by Thompson 1990.

Three perspectives are discerned: individualist (I), hierarchist (H), and egalitarian (E). These perspectives do not claim to represent archetypes of human behaviour, but they are merely used to group similar types of assumptions and choices. For instance:

4. Perspective I is based on the short-term interest, impact types that are undisputed, technological optimism as regards human adaptation.

5. Perspective H is based on the most common policy principles with regards to time-frame and other issues.

6. Perspective E is the most precautionary perspective, taking into account the longest time-frame, impact types that are not yet fully established but for which some indication is available.

28.2 Characterization at midpoint level

Ozone depletion

The characterization factor for ozone layer depletion accounts for the destruction of the stratospheric ozone layer by anthropogenic emissions of ozone depleting substances (ODS). The unit is yr/kg CFC-11 equivalents.

Human toxicity and ecotoxicity

The characterization factor of human toxicity and ecotoxicity accounts for the environmental persistence (fate) and accumulation in the human food chain (exposure), and toxicity (effect) of a chemical. The unit is yr/kg 1,4-dichlorobenzeen (14DCB).

Radiation

The characterization factor of ionizing radiation accounts for the level of exposure. The unit is yr/kg Uranium 235 equivalents.

Photochemical oxidant formation

The characterization factor of photochemical oxidant formation is defined as the marginal change in the 24h-average European concentration of ozone (dCO3 in kg·m−3) due to a marginal change in emission of substance x (dMx in kg·year−1). The unit is yr/kg NMVOC.

Particulate matter formation

The characterization factor of particulate matter formation is the intake fraction of PM_{10}. The unit is yr/kg PM_{10} equivalents.

Climate change

The characterization factor of climate change is the global warming potential. The unit is yr/kg CO_2 equivalents.

Agricultural and urban land occupation

The amount of either agricultural land or urban land occupied for a certain time. The unit is m^2*yr.

Natural land transformation

The amount of natural land transformed and occupied for a certain time. The unit is $m^2 \cdot yr$.

Marine eutrophication

The characterization factor of marine eutrophication accounts for the environmental persistence (fate) of the emission of N containing nutrients. The unit is yr/kg N to freshwater equivalents.

Freshwater eutrophication

The characterization factor of freshwater eutrophication accounts for the environmental persistence (fate) of the emission of P containing nutrients. The unit is yr/kg P to freshwater equivalents.

Fossil fuel and minerals depletion

The characterization factor of fossil depletion is the amount of extracted fossil fuel extracted, based on the lower heating value. The unit is kg oil equivalent (1 kg of oil equivalent has a lower heating value of 42 MJ).

Minerals depletion

The characterization factor for minerals depletion is the decrease in grade. The unit is kg Iron (Fe) equivalents.

Freshwater depletion

The factor for the freshwater depletion is the amount of fresh water consumption. The unit is m^3.

28.3 Damage assessment

The endpoint characterization factors used in ReCiPe can be described as follows:

4.   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 WHO. The unit is years.

5.   Ecosystems, expressed as the loss of species over a certain area, during a certain time. The unit is years.

6.   Resources surplus costs, expressed as the surplus costs of future resource production over an infinitive timeframe (assuming constant annual production), considering a 3% discount rate. The unit is 2000US$.

28.4 Normalization

The normalization is based on the report of Sleeswijk et al. (2007). The normalization figures used in SimaPro are recalculated per citizen. The used population of EU25+3 is 464,036,294 citizens and the world has 6,055,000,000 citizens. Mineral use and the natural land transformation were not part of this project. Mineral use is based on data from USGS (2000). The source of the land transformation was FAO using the changes between 2000 and 2005.

28.5 Weighting

In this method, weighting is performed at damage category level (endpoint level in ISO terms). 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.

The hierarchist version of ReCiPe with average weighting is chosen as default. In general, value choices made in the hierarchist version are scientifically and politically accepted.

References

Goedkoop, M.J.; Heijungs, R.; Huijbregts, M.A.J.; De Schryver, A.M.; Struijs, J.; Van Zelm, R. 2009. ReCiPe 2008: A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level; First edition Report I: Characterisation. 6 January 2009, http://www.lcia-recipe.net.

Sleeswijk, A.W.; van Oers, L.F.; Guinée, J.B.; Huijbregts, M.A.J. 2007. Normalization in product life cycle assessment: An LCA of the global and European economic systems in the year 2000. Sci Total Environ 390 (1):227-240.