Quantis
Sustainability counts

IMPACT 2002+: User Guide

Draft for version Q2.21 (version adapted by Quantis)

Prepared by:
Sébastien Humbert[1]*
An De Schryver[1]
Xavier Bengoa[1]
Manuele Margni[2]
Olivier Jolliet[3]

* Corresponding author (sebastien.humbert@quantis-intl.com, info@impactmodeling.org)

[1] Life Cycle Assessment Expert, Quantis, Lausanne, Switzerland
[2] CIRAIG, École Polytechnique de Montréal, Montréal QC, Canada
[3] Center for Risk Science and Communication, Department of Environmental Health Sciences, School of Public Health, University of Michigan, Ann Arbor MI, USA

IMPACT 2002+ is a methodology that was originally developed at the Swiss Federal Institute of Technology Lausanne (EPFL), Switzerland. It is now maintained and further developed by The IMPACT Modeling Team.

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Note:
The difference between the versions Q2.21 (November 2012) and 2.2 (March 2012) is an additional set of characterization factors improving the method's completeness. All changes are documented in the Annex 5.
The difference between the versions Q2.2 (updated by Quantis) and 2.1 are mainly that water turbined, water withdrawal and water consumption are added, and that aquatic acidification, aquatic eutrophication and water turbined are brought to the damage category ecosystem quality. Furthermore, climate change CFs are adapted with GWP for 100 year time horizon.
The differences between the versions v2.1 and v2.0 are minor. They concern mainly 1° adaptation reflecting the update of the DALY used per case of cancer and non-cancer (respectively 13 and 1.3 instead of 6.7 and 0.67) and 2° some format update (typos corrected, email addresses updated, font improved, references updated, etc.).

A user guide for the Life Cycle Impact Assessment Methodology
IMPACT 2002+ (Jolliet et al. 2003c)

The paper (Jolliet et al. 2003c) and characterization factors (IMPACT2002+_vQ2.2_CF_1a.xls) can be downloaded at http://www.quantis-intl.com

The supporting paper (Jolliet et al. 2003c) and (Pennington et al. 2005) can be obtained via the *International Journal of Life Cycle Assessment* (http://www.scientificjournals.com/sj/lca/Pdf/aId/6237 or http://dx.doi.org/10.1007/BF02978505) and the *Environmental Science and Technology* (http://pubs.acs.org/journals/esthag/) websites respectively.

- This *user guide* is intended for supporting users to apply and interpret the LCIA methodology IMPACT 2002+ version Q2.21.

Why a version adapted by Quantis and what has been adapted?

The original IMPACT 2002+ version 2.1 is not bringing all possible impact categories to an endpoint and neglects some impact categories which are increasingly demanded by industry. We see it necessary to create an adapted version Q2.2 for the following reasons:

1. There is a strong demand of companies for analyzing climate change using IPCC 100 year instead of 500 year time horizon
2. Issues relating to water withdrawal, consumption and turbine are increasingly demanded by companies and should be considered
3. Eutrophication and acidification should be brought to endpoint level to add capacity to interpret results of ecosystem quality at endpoint without neglecting these important categories

The following adaptations are made in vQ2.2 (March 2012) and vQ2.21 (November 2012):

1. Climate change CFs are adapted a 100 year time horizon
2. Water withdrawal, water consumption and water turbined are added
3. Aquatic acidification, aquatic eutrophication and water turbined are added at endpoint to the damage category ecosystem quality
4. Normalization factors are updated
5. (November 2012) New set of characterization factors (see Annex 5 for details)

CONTENT

Abstract

The life cycle impact assessment methodology IMPACT 2002+ vQ2.2 (version adapted by Quantis) proposes a feasible implementation of a combined midpoint/damage approach, linking all types of life cycle inventory results (elementary flows and other interventions) via several midpoint categories to several damage categories. For IMPACT 2002+ vQ2.2 new concepts and methods have been developed, especially for the comparative assessment of human toxicity and ecotoxicity as well as inclusion of impacts from turbined water and assessment of water withdrawal and consumption. IMPACT 2002+ vQ2.2 considers several midpoint categories, namely human toxicity carcinogenic effects, human toxicity non-carcinogenic effects (these two categories are sometimes grouped in one category: human toxicity), respiratory effects (due to inorganics), ionizing radiation, ozone layer depletion, photochemical oxidation, aquatic ecotoxicity, terrestrial ecotoxicity, aquatic acidification, aquatic eutrophication, terrestrial acidification/nutrification[1], land occupation, water turbined, global warming, non-renewable energy consumption, mineral extraction, water withdrawal and water consumption. All midpoint scores are expressed in units of a reference substance and related to the four damage categories human health, ecosystem quality, climate change, and resources. These four damage categories are expressed respectively in DALY, PDF·m^2·y, kg CO_2-eq, and MJ. Normalization can be performed either at midpoint or at damage level. The IMPACT 2002+ methodology presently provides midpoint characterization factors, damage factors, normalized midpoint characterization factors and normalized damage factors for almost 1500 different life cycle inventory results, which can be downloaded at http://www.impactmodeling.org (IMPACT 2002+ v2.1) or http://www.quantis-intl.com (IMPACT 2002+ vQ2.2, version adapted by Quantis, presented in the current document).

Keywords

IMPACT 2002+; life cycle assessment; life cycle impact assessment; midpoint/damage approach; characterization/damage/normalization factors; human toxicity; carcinogenic; non-carcinogenic; respiratory effects; ionizing radiation; ozone layer depletion; photochemical oxidation; aquatic ecotoxicity; terrestrial ecotoxicity; aquatic acidification; aquatic eutrophication; terrestrial acidification/nutrification; land occupation; water turbined; global warming; non-renewable energy consumption; mineral extraction; water withdrawal; water consumption; human health; ecosystem quality; climate change; resources.

[1] Note that some documents use the term “nitrification” instead of “nutrification”. Because the method Eco-indicator 99 uses the term “nutrification” we decided to use the same for simplification reasons.

0. Introduction

0.1. Structure of LCA

According to ISO 14044 life cycle assessment (LCA) is a method for assessing the environmental aspects and potential impacts associated with a good or a service delivered, by:

- compiling an inventory of relevant input and output of a product system [i.e., the life cycle inventory (LCI)],
- evaluating the potential environmental impacts associated with those inputs and outputs [i.e., the life cycle impact assessment (LCIA)] through the use of characterization factors (CFs), and
- interpreting the results of the inventory analysis and impacts assessment phases in relation to the objective of the study.

0.2. Principles of LCIA

According to ISO 14040 and ISO 14044, life cycle assessment (LCA) is a method for assessing the environmental aspects and potential impacts associated with a good or a service delivered by the following:

- identify product system improvement opportunities and assist the prioritization of them,
- characterize or benchmark a product system and its unit processes over time,
- make relative comparisons among product systems based on selected category indicators, or
- indicate environmental issues for which other techniques can provide complementary environmental data and information useful to decision-makers.

Thus LCIA methodologies aim to connect, as far as possible and desired, each LCI result (elementary flow or other intervention) to the corresponding environmental impacts by using CFs. According to ISO 14044, LCI results are classified into impact categories, each with a category indicator. The category indicator can be located at any point between the LCI results and the damage category (where the environmental effect occurs) in the cause-effect chain. Within this framework, two main schools of methodologies have evolved:

a) Classical impact assessment methodologies [e.g., CML (Guinée et al. 2002) and EDIP (Hauschild and Wenzel 1998)] restrict quantitative modeling to relatively early stages in the cause-effect chain and, classify and characterize LCI results in so-called midpoint categories by quantifying midpoint CFs. Themes are common mechanisms (e.g., climate change) or commonly accepted grouping (e.g., aquatic ecotoxicity).

b) Damage oriented methodologies such as ReCiPe (Goedkoop et al. 2008), Eco-indicator 99 (Goedkoop and Spriensma 2000) or EPS (Steen 1999) try to model the cause-effect chain up to the damage and quantify endpoint CFs.

The definition study of the UNEP-SETAC Life Cycle Initiative suggests utilizing the advantages of both approaches by grouping similar category endpoints into a structured set of damage categories. In addition, the concept also works with midpoint categories, each midpoint category relating to one or several damage categories. IMPACT 2002+ addresses this new challenge by presenting an implementation working both at midpoint and damage.

1. IMPACT 2002+: general concept

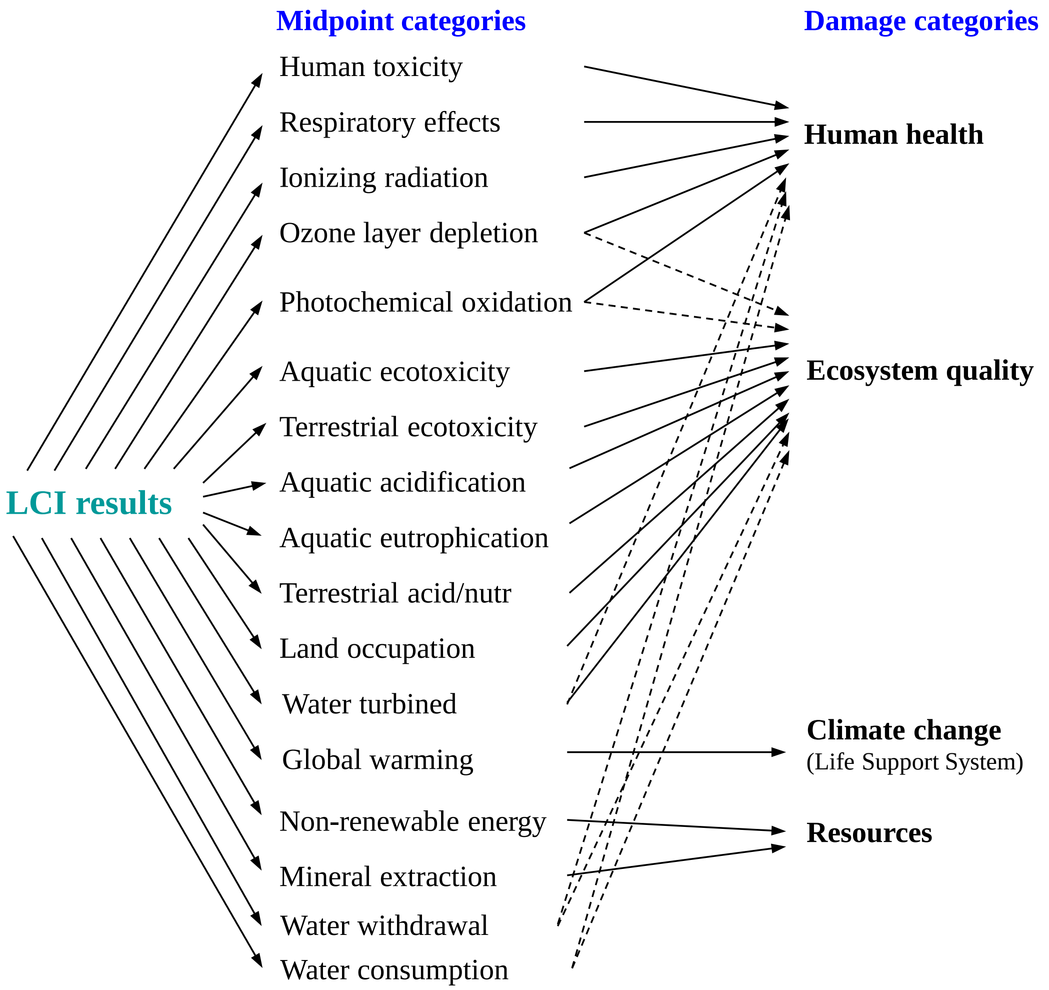

Figure 1-1: Overall scheme of the IMPACT 2002+ vQ2.2 framework[2], linking LCI results via the midpoint categories to damage categories, based on Jolliet et al. (2003a).

As shown in Figure 1-1, LCI results with similar impact pathways (e.g., all elementary flows influencing the stratospheric ozone concentration) are allocated to impact categories at midpoint level, also called midpoint categories. A midpoint indicator characterizes the elementary flows and other environmental interventions that contribute to the same impact. The term ‘midpoint’ expresses the fact that this point is located somewhere on an intermediate position between the LCI results and the damage on the impact pathway. In consequence, a further step may allocate these midpoint categories to one or more damage categories, the latter representing quality changes of the environment. A damage indicator result is the quantified representation of this quality change and calculated by multiplying the damage factor with the inventory data. The damage indicator result is often also named ‘damage impact score’ or simply ‘damage category’. More information on the general concept of such a methodological LCIA framework can be found in Jolliet et al. (2003a).

[2] Note that, water turbined, water withdrawal and water consumption are not proper midpoint categories, but rather inventory indicators that Quantis decided to use within the default midpoint profiles as a proxy until better models are available.

1.1. IMPACT 2002+: general characteristics

The LCIA methodology IMPACT 2002+ vQ2.2 proposes a feasible implementation of the aforementioned combined midpoint/damage-oriented approach. Figure 1-1 shows the overall scheme of the IMPACT 2002+ vQ2.2 framework, linking all types of LCI results via several midpoint categories [human toxicity carcinogenic effects, human toxicity non-carcinogenic effects (these both categories are sometimes grouped in one category: human toxicity), respiratory effects (due to inorganics), ionizing radiation, ozone layer depletion, photochemical oxidation, aquatic ecotoxicity, terrestrial ecotoxicity, aquatic acidification, aquatic eutrophication, terrestrial acidification/nutrification, land occupation, water turbined, global warming, non-renewable energy consumption, mineral extraction, water withdrawal, and water consumption] to four damage categories (human health, ecosystem quality, climate change, and resources). An arrow symbolizes that a relevant impact pathway is known and quantitatively modeled. Impact pathways between midpoint and damage levels that are assumed to exist, but that are not modeled quantitatively due to missing knowledge or that are in development or that are double counting are represented by dotted arrows.

New concepts and methods for the comparative assessment of human toxicity and ecotoxicity were developed for the IMPACT 2002+ methodology[3]. For other categories, methods have been transferred or adapted mainly from the Eco-indicator 99 (Goedkoop and Spriensma 2000), the CML 2002 (Guinée et al. 2002) methodology, the IPCC list (IPCC 2001), the USEPA ODP list (EPA), the ecoinvent database (Frischknecht et al. 2003), and Maendly and Humbert (2011) for water turbined. The following sections shortly describe the main assessment characteristics for midpoint and damage categories, as well as related normalization factors, and explain how to apply the methodology IMPACT 2002+ (version Q2.2). Table 1-1 shows a summary of IMPACT 2002+ (version Q2.2) characteristics.

Table 1-1: Main sources for characterization factors, reference substances, and damage units used in IMPACT 2002+ (version Q2.2).

<table>
<tr><th>[source]</th><th>Midpoint category</th><th>Midpoint reference substance[4]</th><th>Damage category</th><th>Damage unit</th><th>Normalized damage unit</th></tr>
<tr><td>[a]</td><td>Human toxicity (carcinogens + non-carcinogens)</td><td>kg Chloroethylene into air-eq</td><td>Human health</td><td rowspan="5">DALY</td><td rowspan="5">point</td></tr>
<tr><td>[b]</td><td>Respiratory (inorganics)</td><td>kg $PM_{2.5}$ into air-eq</td><td>Human health</td></tr>
<tr><td>[b]</td><td>Ionizing radiations</td><td>Bq Carbon-14 into air-eq</td><td>Human health</td></tr>
<tr><td>[USEPA and b]</td><td>Ozone layer depletion</td><td>kg CFC-11 into air-eq</td><td>Human health</td></tr>
<tr><td rowspan="2">[b]</td><td rowspan="2">Photochemical oxidation (= Respiratory (organics) for human health)</td><td rowspan="2">kg Ethylene into air-eq</td><td>Human health</td></tr>
<tr><td>Ecosystem quality</td><td>n/a</td><td>n/a</td></tr>
</table>

[3]Human Damage Factors are calculated for carcinogens and non-carcinogens, employing intake fractions, best estimates of dose-response slope factors, as well as severities. The transfer of contaminants into the human food is no more based on consumption surveys, but accounts for agricultural and livestock production levels. Indoor and outdoor air emissions can be compared and the intermittent character of rainfall is considered. Both human toxicity and ecotoxicity effect factors are based on mean responses rather than on conservative assumptions.

[4] The conditions to decide which substance will be used as a midpoint reference substance are the following: a clear example substance (with proven effects) for the considered category, substance with proven effects (e.g., CFC-11 for ozone layer depletion), a generally accepted reference substance (e.g., CO_2 for global warming) and a substance with relatively low uncertainties in the fate, exposure and effect modelisation (e.g., chloroethylene into air for human toxicity: this substance has a dominant intake pathway through inhalation and inhalation is the pathway where the lowest uncertainties occur).

[a]	Aquatic ecotoxicity	kg Triethylene glycol into water$_{-eq}$	Ecosystem quality	PDF·m^2·y	point
[a]	Terrestrial ecotoxicity	kg Triethylene glycol into soil$_{-eq}$	Ecosystem quality		
[b]	Terrestrial acidification/nutrification	kg SO_2 into air$_{-eq}$	Ecosystem quality		
[c]	Aquatic acidification	kg SO_2 into air$_{-eq}$	Ecosystem quality		
[c]	Aquatic eutrophication	kg PO_4^{3-} into water$_{-eq}$	Ecosystem quality		
[b]	Land occupation	m^2 Organic arable land$_{-eq}$ · y	Ecosystem quality		
	Water turbined	inventory in m^3	Ecosystem quality		
[IPCC]	Global warming	kg CO_2 into air$_{-eq}$	Climate change (life support system)	kg CO_2 into air$_{-eq}$	point
[d]	Non-renewable energy	MJ or kg Crude oil$_{-eq}$ (860 kg/m^3)	Resources	MJ	point
[b]	Mineral extraction	MJ or kg Iron$_{-eq}$ (in ore)	Resources		
	Water withdrawal	inventory in m^3	*n/a*	*n/a*	*n/a*
	Water consumption	inventory in m^3	Human health	(DALY)	(point)
			Ecosystem quality	(PDF·m^2·y)	(point)
			Resources	(MJ)	(point)

Note that the water impact score is currently under development. Sources: [a] IMPACT 2002 (Pennington et al. 2005, 2006), [b] Eco-indicator 99 (Goedkoop and Spriensma 2000), [c] CML 2002 (Guinée et al. 2002), [d] ecoinvent (Frischknecht et al. 2003), [IPCC] (IPCC 2001), and [USEPA] (EPA). DALY= Disability-Adjusted Life Years; PDF= Potentially Disappeared Fraction of species; -eq= equivalents; y= year.

The updated midpoint CFs for the substances indicated in Table 1-1 can be downloaded from the internet at http://www.quantis-intl.com.

1.2. Units

Different types of units are used in IMPACT 2002+.

At midpoint level:

- "kg substance s$_{-eq}$" ("kg equivalent of a reference substance *s*") expresses the amount of a reference substance *s* that equals the impact of the considered pollutant within the midpoint category studies (e.g., the Global Warming Potential on a 100-y scale of fossil based methane is 27.75 times higher than CO_2, thus its CF is 27.75 kg CO_{2-eq}).

At damage level:

- "DALY" ("Disability-Adjusted Life Years") characterizes the disease severity, accounting for both mortality (years of life lost due to premature death) and morbidity (the time of life with lower quality due to an illness, e.g., at hospital). Default DALY values of 13 and 1.3 [years/incidence] are adopted for most carcinogenic and non-carcinogenic effects, respectively (Keller 2005). Note that these values replace the values of 6.7 and 0.67 calculated by Crettaz et al. (2002) and used in the previous versions of IMPACT 2002+ (v1.0, v1.1 and v2.0). For example, a product having a human health score of 3 DALYs implies the loss of three years of life over the overall population[5].
- "PDF·m^2·y" ("Potentially Disappeared Fraction of species over a certain amount of m^2 during a certain amount of year") is the unit to "measure" the impacts on ecosystems. The PDF·m^2·y represents the

[5] 3 years of life lost distributed over the overall population and NOT per person!

fraction of species disappeared on 1 m^2 of earth surface during one year. For example, a product having an ecosystem quality score of 0.2 $PDF \cdot m^2 \cdot y$ implies the loss of 20% of species on 1 m^2 of earth surface during one year.

- MJ (“Mega Joules”) measures the amount of energy extracted or needed to extract the resource.

At normalized damage level:

- “points” are equal to “pers·y”. A “point” represents the average impact in a specific category *caused* by a person during one year in Europe[6]. In a first approximation[7], for human health, it also represents the average impact *on* a person during one year (i.e., an impact of 3 points in ecosystem quality represents the average annual impact of 3 Europeans. This last interpretation is also valid for climate change and resources.) It is calculated as the total yearly damage score due to emissions and extractions in Europe divided by the total European population.

[6] This average impact caused by a person per year in Europe is the total impact of the specific category divided by the total European population. The total impact is the sum of the product between all European emissions and the respective factors (see chapter 1.5 for details about normalization).

[7] Without taking into account intergenerational and transboundary impacts.

1.3. Midpoint categories

1.3.1. Human toxicity (carcinogenic and non-carcinogenic effects)

Human toxicity represents all effects on human health, except for respiratory effects caused by inorganics, ionizing radiation effects, ozone layer depletion effects and photochemical oxidation effects that are considered separately. This is mainly due because their evaluation is based on different approaches.

CFs for chronic toxicological effects on human health, termed 'human toxicity potentials' at midpoint- and 'human damage factors' at damage level, provide estimates of the cumulative toxicological risk and potential impacts associated with a specified mass (kg) of a chemical emitted into the environment. These are determined with the IMPACT 2002 model (IMPact Assessment of Chemical Toxics), which models risks and potential impacts per emission for several thousand chemicals (Pennington et al. 2005, 2006). 'IMPACT 2002' denotes the multimedia fate & multipathway exposure and effects model assessing toxic emission on human toxicity and ecotoxicity. The damage CFs are expressed in DALY/kg. For the midpoint CFs the reference substance is chloroethylene emitted into air and the CFs are expressed in kg chloroethylene into air$_{-eq}$/kg. Figure 1-2 represents the general scheme of impact pathway for human toxicity and ecotoxicity used in the tool IMPACT 2002.

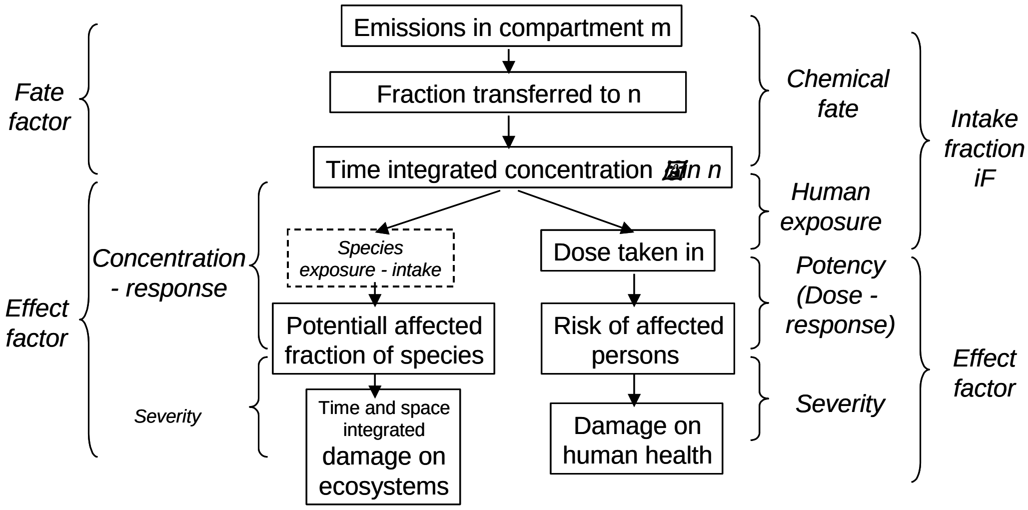

Figure 1-2: General scheme of the impact pathway for human toxicity and ecotoxicity (Jolliet et al. 2003b)

Basic characteristics for human toxicity are the following:

- Generic factors are calculated at a continental level for Western Europe nested in a World box.
- CFs are given for emissions into air, water, soil and agricultural soils ["soil (agr.)"].
- No CFs are yet available for *ocean*, *underground water* and *stratospheric* emissions.
  - For *stratospheric* emissions, the CFs for ozone depletion potential and climate change can be considered valid. However, CFs for other midpoint categories can be neglected because of the assumption that the pollutants will be degraded before reaching the ground and thus will not have other effects on human health and ecosystems.

- Human toxicity through emission into *agricultural soil* ["soil (agr.)"] is derived from an emission into average soil with some modifications.
    - The impact through food pathways is multiplied by a factor of 4.6. Because 22% (1/4.6) of the European soil is used as agricultural soil, the intake through food pathway - except for the one due to animal breathing - is 4.6 times higher than if the emissions would have been released on the entire European soil area.

Human toxicity CFs for *heavy metals* only apply for metals emitted in dissolved form (ions). Currently, the state of the art in human toxicity assessment enables a precision of about a factor of 100 (two orders of magnitude) compared to an overall variation of about 12 orders of magnitude (Rosenbaum et al. 2008). Thus all flows that have an impact over 1% of the total score should be considered as potentially important.

A new CF has been included in vQ2.2 for C10-C50 hydrocarbons (excluding benzene and PAH) emitted into water (Sanscartier et al. 2010): midpoint CF = 0.0015 chloroethylene into air$_{\text{-eq}}$/kg, damage CF = 4.21E-9 DALY/kg.

Additional CFs for human toxicity. A user interested in calculating human toxicity CFs for further pollutants can always use the model IMPACT 2002 downloadable at http://www.impactmodeling.org.

1.3.2. Respiratory effects (caused by inorganics)

This impact category refers to respiratory effects which are caused by inorganic substances. The CFs are given for emissions into air only (as it is not very likely that these pollutants will be emitted into soil or water). Damage CFs are expressed in DALY/kg and taken directly from Eco-indicator 99 (Goedkoop and Spriensma 2000). These are based on the work of Hofstetter (1998) using epidemiological studies to evaluate effect factors. The midpoint CFs are expressed in kg $PM_{2.5}$ into air$_{\text{-eq}}$/kg and obtained by dividing the damage factor of the considered substance by the damage factor of the reference substance ($PM_{2.5}$ into air).

Particulate matter (PM) can be classified based on their particle size. "$PM_{2.5}$" covers all particles < 2.5 ↘m, "PM_{10}" covers all particles < 10 ↘m and PM_{tot} covers all particles < 100 ↘m. Caution should be taken to avoid double counting. This is especially valid for PM_{10} and $PM_{2.5}$ (the latter is already counted in PM_{10}) and for NO_x and NO_2 (the latter is already counted in NO_x). Therefore, only one of the three CFs ($PM_{2.5}$, PM_{10} or PM_{tot}) should be applied to the inventory.

Carcinogenic effects of PM are directly included in epidemiologic studies. According to Dockery and Pope (1994) particles above 2.5 µm have no adverse effects, because they cannot enter the lung. Thus respiratory effects are only due to the fraction of particles <2.5 ↘m. However, as in many inventory studies data are given for PM_{10}, i.e., including all particulates < 10µm, the CF for "PM_{10}" is the factor for "$PM_{2.5}$" multiplied by a correction factor of 0.6, which according to Dockery and Pope (1994) represents the mass ratio of $PM_{2.5}/PM_{10}$ measured in the air. Similarly for PM_{tot} inventory flows, the CF for "PM_{tot}" is the CF for "$PM_{2.5}$" multiplied by a correction factor of 0.33, which according to Dockery and Pope (1994) represents the mass ratio of $PM_{2.5}/PM_{tot}$.

Note that an extensive review and recommendation of intake fractions and CFs for CO, primary PM_{10} and $PM_{2.5}$, and secondary PM from SO_2, NO_x and NH_3 has been conducted between 2008 and 2010 by some of the authors of IMPACT 2002+, resulting in updated intake factors and CFs for the category 'respiratory inorganics' (see Humbert 2009, Humbert et al. 2011b). However, for consistency reasons with earlier assessment using IMPACT 2002+, the version Q2.2 of IMPACT 2002+ keeps using the original version of the CF. Factors from Humbert (2009) and Humbert et al. (2011b) can be used in sensitivity analysis if needed and will be incorporated in the IMPACT World+ model.

1.3.3. Ionizing radiation

For the impact category ionizing radiation the CFs are given for emissions into air and water. No CFs are currently available for emissions into soil. Damage CFs are expressed in DALY/Bq and taken directly from Eco-indicator 99 (Goedkoop and Spriensma 2000). Midpoint CFs are expressed in Bq Carbon-14 into air_{-eq} / Bq and obtained by dividing the damage factor of the considered substance by the damage factor of the reference substance (Carbon-14 into air).

1.3.4. Ozone layer depletion

The CFs of ozone layer depletion are given for emissions into air only, as it is not very likely that the considered pollutants will be emitted into soil or water. The midpoint CFs are expressed in kg CFC-11 into air_{-eq} / kg and obtained from the US Environmental Protection Agency Ozone Depletion Potential List (EPA). Damage CFs are expressed in DALY/kg and for the midpoint reference substance (CFC-11= Trichlorofluoromethane) directly taken from Eco-indicator 99 (Goedkoop and Spriensma 2000). The damage CFs for other substances are obtained by multiplying the midpoints (in kg CFC-11 into air_{-eq} / kg) with the CFC-11 damage CF.

1.3.5. Photochemical oxidation

The CFs of photochemical oxidation are given for emissions into air only, as it is not very likely that the considered pollutants will be emitted into soil or water.

- ***Impact on human health:***

The Impact of photochemical oxidation on human health is sometimes named “Respiratory effects from organics”. Damage CFs are expressed in DALY/kg and taken directly from Eco-indicator 99 (Goedkoop and Spriensma 2000). The midpoint CFs are expressed in kg Ethylene into air_{-eq} / kg and are obtained by dividing the damage factor of the substance considered by the damage factor of the reference substance (Ethylene into air).

- ***Impact on ecosystem quality:***

Photochemical oxidation is known to have an impact on the growth of plants (a reduction of yield in Europe between 10% and 20%). However, currently no available studies support calculations of the damage on ecosystem quality due to photochemical oxidation. Note that “Ethylene” is also known as “Ethene”.

1.3.6. Aquatic ecotoxicity

The CFs of aquatic ecotoxicity” are given for emissions into air, water and soil and quantify the ecotoxicity effects on (surface) fresh water (referring to streams and lakes). No CFs are available for emissions into groundwater, stratosphere and oceans. The aquatic ecotoxicity CFs for *heavy metals* only apply for metals emitted in dissolved form (ions). The damage CFs are expressed in PDF·m^2·y/kg and determined with the IMPACT 2002 model (Pennington et al. 2005, 2006; see Figure 1-2). The midpoint CFs are expressed in kg

Triethylene glycol into $water_{-eq}$ / kg and obtained by dividing the damage CF of the substance considered by the damage CF of the reference substance (Triethylene glycol into water).

Currently, the state of the art in aquatic ecotoxicity assessment enables a precision of about a factor of 100 (two orders of magnitude) compared to an overall variation of about 12 orders of magnitude (Rosenbaum et al. 2008). Thus, all flows that have an impact over 1% of the total score should be considered as potentially important.

A new CF has been included in vQ2.2 for C10-C50 hydrocarbons (excluding benzene and PAH) emitted into water (Sanscartier et al. 2010): midpoint CF = 0.013 kg Triethylene glycol into $water_{-eq}$ / kg, damage CF = 6.53E-7 PDF·m^2·y/kg.

Additional CFs for aquatic ecotoxicity. A user interested in calculating aquatic ecotoxicity CFs for further pollutants can always use the fate, exposure and effects model IMPACT 2002 downloadable at http://www.impactmodeling.org.

1.3.7. Terrestrial ecotoxicity

Terrestrial ecotoxicity CFs are calculated in a similar way as aquatic ecotoxicity CFs for emissions into air, water and soil. CFs for *heavy metals* only applies for metals emitted in dissolved form (ions).It has been estimated that the substances have ecotoxic effects only by exposure through the aqueous phase in soil.

Damage CFs are expressed in PDF·m^2·y/kg and determined with the IMPACT 2002 model (Pennington et al. 2005, 2006) (see Figure 1-2). The midpoints CFs are expressed in kg Triethylene glycol into $soil_{-eq}$ / kg and obtained by dividing the damage CF of the considered substance by the damage CF of the reference substance (Triethylene glycol into soil).

A new CF has been included in vQ2.2 for C10-C50 hydrocarbons (excluding benzene and PAH) emitted into water (Sanscartier et al. 2010): midpoint CF = 0.11 kg Triethylene glycol into $soil_{-eq}$ / kg, damage CF = 8.7E-4 PDF·m^2·y/kg.

Currently, the state of the art in terrestrial ecotoxicity assessment enables a precision two orders of magnitude compared to an overall variation of about 12 orders of magnitude (Rosenbaum et al. 2008). Thus, all flows that have an impact over 1% of the total score should be considered as potentially important.

1.3.8. Aquatic acidification

The CFs for aquatic acidification are given for emissions into air, water and soil. Damage CFs are expressed in PDF·m^2·y/kg and calculated by multiplying the midpoint CFs by 8.82E-3 PDF·m^2·y/kg SO_2 into air_{-eq} (Tirado Seco, 2005)[8]. Note that this value is preliminary and a further study is going on to update this value. The midpoint CFs for aquatic acidification are expressed in kg SO_2 into air_{-eq} / kg and taken directly from CML (Guinée et al. 2002).

1.3.9. Aquatic eutrophication

The CFs for aquatic eutrophication are given for emissions into air, water and soil. Damage CFs are expressed in PDF·m^2·y/kg and calculated by multiplying the midpoint CFs by 11.4 PDF·m^2·y/ kg $PO_4{}^{3-}{}_{-eq}$

[8] The effect factor's model is created on the basis of a dose-effect curve. To calculate the dose-effect curve, changes in concentration of "acidifying" substances are linked to effects on European aquatic ecosystems. Effects are based on Tachet et al. (2000).

into water (Pablo Tirado, personal communication). Note that this value is preliminary and a further study is going on to update this value. The effect factor's model is created on the basis of a dose-effect curve. To calculate the dose-effect curve, changes in concentration of "eutrophying" substances are linked to effects on European aquatic ecosystems. Effects are based on Tachet et al. (2000). The midpoints CFs are expressed in kg PO_4^{3-} into water$_{-eq}$ / kg and taken directly from CML (Guinée et al. 2002).

Three different versions of the characterization factors exist: P-limited, N-limited and undefined. As default within IMPACT 2002+ the P-limited version is applied.

1.3.10. Terrestrial acidification & nutrification

The CFs are given for emissions into air only. No CFs are currently available for emissions into soil and water. Damage CFs are expressed in PDF·m^2·y/kg and taken directly from Eco-indicator 99 (Goedkoop and Spriensma 2000). The midpoint CFs are expressed in kg $SO_{2\text{-eq}}$ into air / kg and have been obtained from the damage CFs by dividing the damage CF of the substance considered by the damage CF of the reference substance (SO_2 into air).

1.3.11. Land occupation

Land occupation damage CFs are expressed in PDF·m^2·y/m^2·y and are taken directly from Eco-indicator 99 (Goedkoop and Spriensma 2000).

- Although Eco-indicator 99 (Goedkoop and Spriensma 2000) gives two "sub-categories" for land-use (land occupation and land conversion), in IMPACT 2002+ only land occupation is considered.

Midpoints CFs are expressed in m^2 Organic arable land$_{-eq}$· y / m^2 · y and obtained by dividing the damage CF of the considered flow (namely, type of land) by the damage CF of the reference flow (Organic arable land·y).

- Although this midpoint unit is given, land occupation is often directly expressed in damage units (PDF·m^2·y).

As specified in Eco-indicator 99 (Goedkoop and Spriensma 2000), the damage factors are based on empirical observations of the number of plant species per area type. In such observations all effects of the area type are included. This means that next to occupation effects, the effects of emissions (pesticides and fertilizers) are also included. To avoid double counting in these categories [(eco) toxicity of pesticides and acidification and eutrophication potential of fertilizers], only emissions that "leave" the field (through water, erosion and harvest) and emissions that are "above normal use" should be taken into account in the LCI.

1.3.12. Water turbined

The inventory of water used only by turbines (in hydropower dams) for energy (i.e., electricity) generation is expressed in m^3 of water. It is the sum of the total quantity of water turbined to generate the electricity necessary during the life cycle processes. The potential impacts of water turbined, e.g., on ecosystems quality, biodiversity or human health, vary depending on the location (whether the region is short of water or not) and the type of dam (run-of-river, non-alpine dams or alpine dams). The midpoints CFs are based on volumes of m^3 water turbined. Damage CFs for aquatic biodiversity are expressed in PDF·m2·y/m^3 of water turbined and based on Maendly and Humbert (2011) as follows:

- 0.004 PDF*m^2*y per m^3 of water turbined for run-of-river and non-alpine dams, and
- 0.001 PDF*m^2*y per m^3 of water turbined for alpine dams.
- When only the elementary flow "water turbined" exist without specifying whether it is from run-of-river, non-alpine dams or alpine dams, a weighted average value of 0.004 PDF*m^2*y per m^3 of water turbined can be used.

Although water turbined is also associated with some damage to human health, no CFs exist yet.

1.3.13. Global warming

Global warming CFs are given for emissions into air only. At the damage level the impact from global warming is presented in a separate damage category that is expressed in kg CO_{2-eq} into air / kg, identical to the midpoint category. The midpoint CFs for global warming are expressed in kg CO_{2-eq} into air / kg and taken from the IPCC list (IPCC 2001, and IPCC 2007 for CH_4, N_2O and CO). The Global Warming Potentials (GWPs) for a 100-year time horizon are used. The following CFs (for a 100-year time horizon) are applied:

- CO_2, in air = 0 kg CO_{2-eq}/kg
- CO_2, fossil = 1 kg CO_{2-eq}/kg
- CO_2, land transformation = 1 kg CO_{2-eq}/kg
- CO_2, biogenic = 0 kg CO_{2-eq}/kg
- CO, fossil = 1.9 kg CO_{2-eq}/kg (IPCC 2007; value used in IMPACT 2002+ v2.1 and previous was 1.57 simply based on the stoichiometric transformation of CO to CO2)
- CO, biogenic = 0 kg CO_{2-eq}/kg
- CH_4, fossil = 27.75 kg CO_{2-eq}/kg effect of CO_2 from methane degradation included, see explanation below
- CH_4, biogenic = 25 kg CO_{2-eq}/kg

Explanation on biogenic CO_2, CH_4 and CO:

- Closed biologic cycles are considered mass balanced over a time that is small compared to human life. Therefore both raw CO_2 and biogenic CO_2 have a CF of 0. In case the mass balance is not zero (e.g., non-degradable biomaterial in landfill or long term storage of biogenic carbon in materials) adaptation to the model can be done by calculating the mass balance of what is not released or considering dynamic LCA to evaluate the effects from long term storage.
- CO_2 from land transformation is assumed to come mostly from deforestation or of net reduction in the carbon content of agricultural soils because of oxidation and therefore not replaced by an equivalent amount of carbon in forest or soil OVER THE SAME LAND. It is therefore looked at as a « fossil » emission and therefore has a CF of 1. Note that if an inventory would classify a certain amount of CO_2 emitted from forest or soil as « transformation » whereas this same carbon is also considered as an uptake somewhere else

in the same inventory, then it should actually be classified as « biogenic » and therefore be attributed a CF of 0.

- CH_4, fossil is given a CF of 27.75. The GWP for 100y from IPCC2007 is adapted by including the effects from the CO_2 that will be created once the CH_4 degrades into CO_2.
- CH_4, biogenic is given a CF of 25, which reflects the GWP of the CH_4 before it becomes biogenic CO_2 (the later having a GWP of 0). 1 kg of CH_4 results in 2.75 kg of CO_2, meaning that in the value of 27.25 kg $CO_{2\text{-eq}}$/kg CH_4, actually 2.75 kg $CO_{2\text{-eq}}$/kg CH_4 come from the CO_2 that will be formed once the CH_4 degrade, and only 25 kg $CO_{2\text{-eq}}$/kg CH_4 comes from the CH_4 itself before it degrades into CO_2.

Note that the values published in IPCC 2007 for CH_4 only includes the direct effects from CH_4 and do not include the effects from the CO_2 that will be created once the CH_4 degrades into CO_2. Indeed, IPCC suggests doing so to avoid double counting the impacts from the CO_2 that forms when CH_4 degrades arguing that often national inventories already consider the CO_2 from CH_4 degradation in the CO_2 inventory. This is the same reason why CO is actually not reported in IPCC (2007). However, in LCA, inventory databases often make a carbon mass balance and discount the carbon emitted as CH_4 from the carbon emitted as CO_2. Therefore, in the case of LCA, there is no double counting if the effects of CO_2 from CH_4 degradation are included in the GWP from CH_4. Unspecified methane is assumed to be biogenic methane unless it can be shown that it is fossil based methane. For sensitivity or interpretation purpose, the damage of the impact of climate change on ecosystem quality and human health can be calculated using the CFs of De Schryver et al. (2009).

1.3.14. Non-renewable energy

CFs for non-renewable energy consumption, in terms of the total primary energy extracted, are calculated using upper heating values. Damage CFs are expressed in MJ total primary non-renewable energy / unit extracted (unit is kg or m3) and taken from ecoinvent (Frischknecht et al. 2003)[9]. The midpoint CFs are expressed MJ as well. The midpoint CFs can be expressed in kg Crude oil$_{\text{-eq}}$ (860 kg/m^3) / kg extracted, obtained by dividing the damage CF of the considered substance by the damage CF of the reference substance (crude oil=860 kg/m^3), however, this is not recommended for use.

Until v2.1 the value for wood was 16.9 MJ/kg. It was changed to 15 MJ/kg in vQ2.2. Note that this value represents renewable energy and therefore is not part of the non-renewable energy indicator but only given to be used as an indicator. There is one case in which wood can be taken into account: when counting the energy loss from deforestation (since standing wood in a steady state forest can be seen as an energy stock that is dissipated once for all once burnt).

1.3.15. Mineral extraction

Damage CFs for mineral extraction are expressed in MJ surplus energy / kg extracted and taken directly from Eco-indicator 99 (Goedkoop and Spriensma 2000). Surplus energy expresses the expected increase of extraction energy needed to extract 5 times the cumulative extracted amount since the beginning of extraction until 1990. For more details see Goedkoop and Spriensma (2000). The midpoint CFs are expressed in MJ as

[9] Former characterization factors for non-renewable energy given in versions 1.0 and 1.1 have been taken from BUWAL (1996, p.396).

well. The midpoint CFs can be expressed in kg $Iron_{-eq}$ (in $ore)_{-eq}$ / kg extracted, obtained by dividing the damage CF of the considered substance by the damage CF of the reference substance (iron, in ore), however, this is not recommended for use.

1.3.16. Water withdrawal

Due to the current incapacity of major software to perform a spatially differentiated assessment, the inventory indicator "water withdrawal" is used in the midpoint profile. The inventory "water withdrawal" includes the water use expressed in m^3 of water needed, whether it is evaporated, consumed or released again downstream, without water turbined (i.e., water flowing through hydropower dams). It considers drinking water, irrigation water and water for and in industrialized processes (including cooling water). It considers fresh water and sea water. The actual impacts of water withdrawal, e.g., on human health, ecosystems quality or resources, vary depending on the location (whether the region is short of water or not, sometimes referred to as "water stressed"). The midpoint CFs are based on volume of water withdrawal expressed in m3. No damage factors yet exist for water withdrawal as such though some work can assess part of the water withdrawal impacts [e.g., using the CF of Van Zelm et al. (2011) for shallow ground water extraction]. As a preliminary assessment, damage to ecosystem quality can be approximated by using 5% of the CFs of Pfister et al. (2009) for water consumption (first approximation).

Note that in the default studies, the impact assessment is not performed due to the complexity to evaluate the regionalization component of the study. Regionalized impact assessment has to be performed either by hand (for very simple studies) or using the Quantis water tool associated with the Quantis water database (contact: samuel.vionnet@quantis-intl.com or sebastien.humbert@quantis-intl.com) and should be part of a separate option in LCA studies.

1.3.17. Water consumption

Water consumption can be part of the water withdrawal. Note that water evaporated from dams is sometimes included in the water withdrawal values, and sometimes not. Due to the current incapacity of major software to perform a spatially differentiated assessment, the inventory indicator "water consumption" is used in the midpoint profile. Therefore, the midpoint CFs are simply based on volume of water consumed expressed in m3. A regionalized impact assessment can be done using the factors of different available impact assessment methods (see Quantis Water Database, contact: samuel.vionnet@quantis-intl.com or sebastien.humbert@quantis-intl.com).

Note that in the default studies, the damage assessment is not performed due to the complexity to evaluate the regionalization component of the study. Damage assessment has to be performed either by hand (for very simple studies) or using the Quantis water tool associated with the Quantis Water Database (contact: samuel.vionnet@quantis-intl.com or sebastien.humbert@quantis-intl.com).

1.4. Damage categories

As shown in Figure 1-1, all midpoint categories can be grouped into five damage categories.

1.4.1. Human health

The "human health" damage category is the sum of the midpoint categories "human toxicity", "respiratory effects", "ionizing radiation", "ozone layer depletion" and "photochemical oxidation". Human health impact is expressed in "DALYs" (see chapter 1.2 about units). The human health average damage is 0.0071 DALY/point (in version 2.1; see Table 1-2)[10] and is dominated by respiratory effects caused by inorganic substances emitted into air.

1.4.2. Ecosystem quality

The "ecosystem quality" damage category is the sum of the midpoint categories "aquatic ecotoxicity", "terrestrial ecotoxicity", "terrestrial acid/nutr", "land occupation", and, as of April 2011, "aquatic acidification", "aquatic eutrophication" and "Water turbined". Ecosystem quality impact is expressed in "PDF·m^2·y" (see chapter 1.2 about units).

The ecosystem quality damage is 13'800 PDF·m^2·y/point (in version Q2.2)[11] and is dominated by terrestrial ecotoxicity (9'500 PDF·m^2·y/point) and land occupation (3'770 PDF·m^2·y/point).

1.4.2.1. Transformation of units

To express the PDF·m^2·y in PAF·m^3·d (unit used in USEtox), the value in PDF·m^2·y needs to be multiplied by 2 PAF/PDF, by 17.8 m^3/m^2 (note: value to be discussed depending on which model one wants to be consistent with – e.g., a value of 2.5 m^3/m^2 is used in USEtox) and by 365 d/y (= 12'994 PAF·m^3·d/PDF·m^2·y). When the eutrophication result is given in kg $PO_4^{3-}{}_{-eq}$ (using IMPACT 2002+) into water, then to transform it into PAF·m^3·d (unit used in USEtox), the value in kg $PO_4^{3-}{}_{-eq}$ into water needs to be multiplied by 148'132 PAF·m^3·d/kg $PO_4^{3-}{}_{-eq}$ into water.

In ReCiPe, the endpoint factor for P emissions to freshwater is 21'685 PDF·m^3.day/kg P. This value represents 21'685*2 = 43'370 PAF.m^3.day/kg P, assuming 2 PAF/PDF (value used in IMPACT 2002+). If the midpoint CF is expressed in P_{-eq} emitted to freshwater, the conversion factor from midpoint to endpoint is equal to 21'685 PDF·m3.day/kg per P_{-eq} or 21'685/365 PDF.m3.year/kg per P_{-eq} If you want to convert to PDF.m2.day/kg, the conversion factor becomes 21'685/3 PDF.m2.day/kg (average river depth is set equal to 3 m). (M. Huijbregts, personal communication, May 23, 2011; based on Struijs et al 2011 IJLCA - CF for P and Struijs et al 2011 IEAM - CF for P) So if the results for eutrophication is expressed using kg P_{-eq} from the methodology ReCiPe, then, the conversion to PDF·m2·y and PAF·m3·d is done by multiplying the value in g P_{-eq} by respectively 19.8 PDF·m2·y/kg P_{-eq} (ReCiPe) and 43'370 PAF·m3·d/kg P_{-eq} (using 2 PAF/PDF).

In addition, 1 kg P_{-eq} = 3.1 kg PO_4^{3-}. Therefore, 43'370 PAF·m3·d/kg P_{-eq} = 43'370/3.1 = 14'000 PAF·m3·d/kg PO_4^{3-} (based on ReCiPe).

In the Water Footprint Network, the limit is set at 10 mgN/L. Using the characterization factor of 0.42 kg $PO_4^{3-}{}_{-eq}$ /kg N (IMPACT 2002+, based on CML), 1 L of water polluted by N at the limit of 10 mgN/L = 5.0E-5 PDF·m^2·y = 0.64 PAF·m^3·d. This can also be expressed as 20'000 L_{-eqN} and 1.6 L_{-eqN} polluted respectively for 1 PDF·m^2·y and 1 PAF·m^3·d. These damage values are based on IMPACT 2002+. Using the damage values of ReCiPe, 1 L of water polluted by N at the limit of 10 mgN/L = 2.7E-5 PDF·m^2·y = 0.06 PAF·m^3·d.

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[10] The Eco-indicator 99 HA v2 average human health damage is 0.0155 DALY/point (Goedkoop and Spriensma 2000).

[11] In versions 2.0 and 2.1 it was 13'700 PDF-m2-y and was not considering impacts from "aquatic acidification", "aquatic eutrophication" and "turbined water".

This can also be expressed as 37’000 L_{-eqN} and 17 L_{-eqN} polluted respectively for 1 PDF·m^2·y and 1 PAF·m^3·d calculated with ReCiPe.

The Swiss legal limits for RELEASE (OEaux 1998)[12] for phosphate are 0.8 mgP/L = 2.5 mgPO_4^{3-}/L. The impact per liter polluted with phosphate at the legal release limit of Switzerland is therefore = 0.035 PAF·m3·d.

1.4.3. Climate change

The damage category “Climate change” is the same category as the midpoint category “global warming”. Even if it is considered as a damage category, climate change impact is still expressed in “kg CO_{2-eq}”. The climate change damage factor of 9’950 kg CO_{2-eq}/point (see Table 1-2) is largely dominated by CO_2 emissions.

1.4.4. Resources

The damage category “Resources” is the sum of the midpoint categories “non-renewable energy consumption” and “mineral extraction”. This damage category is expressed in “MJ”. The resources damage factor of 152’000 MJ/point (see Table 1-2)[13] is largely dominated by non-renewable energy consumption.

1.5. Normalization

The idea of normalization is to analyze the respective share of each impact to the overall damage of the considered category. It facilitates interpretation of results by comparing the different categories on the same graph with the same units. It also enables a discussion of the implications of weighting. Indeed, it gives an estimation of the magnitude of the weighting factors required to discriminate between the different categories.

Example: If scenario A contributes to 0.01 points (pers·y) to human health impact (i.e. 1% of the human health impact caused by the European emissions and resource consumption per European person during one year), and 0.1 points to ecosystem quality (i.e. 10% of the ecosystem quality impact caused by the European emissions and resource consumption per European person during one year), then, to have both damages equivalent (in terms of impact), human health should be weighted 10 times more important than ecosystem quality. This analysis can be extended to other categories and to compare and discriminate different scenarios.

The normalization is performed by dividing the impact (at damage categories) by the respective normalization factors (see Table 1-2).

A normalization factor represents the total impact of the specific category divided by the total European population. The total impact of the specific category is the sum of the products between all European emissions + resource consumption and the respective damage factors. The normalized characterization factor is determined by the ratio of the impact per unit of emission divided by the total impact of all substances of the specific category (for which CFs exist) per person per year. The unit of all normalized characterization factors is therefore [point/$unit_{emission}$] = [pers·y/$unit_{emission}$] and can be expressed per kg, per Bq, or per

[12]The European directive 91/271CEE fixes limits for the release of phosphate compounds in receiving water bodies. In function of the size of the waste water treatment plant these limits for P_{tot} are of 2 mg/l (10 000 - 100 000 EH) or of 1 mg/l (> 100 000 EH).
[13] Note: The Eco-indicator 99 HA v2 (Goedkoop and Spriensma 2000) average resources damage is 8’410 MJ surplus energy/pers·y.

(m^2·y). In other words, it is the impact caused by a Unitarian emission that is equivalent to the impact generated by the given number of persons during 1 year.

Example: An average European has an annual global warming impact of 9'950 kg $CO_{2\text{-eq}}$ (through all activities in Europe). Thus if a substance A emitted into the air has a normalized CF of 2 point/kg, it means that the emission into air of 1 kg of that substance A will have the same impact (effect) on global warming as two Europeans during one year (2 · 9'950 kg $CO_{2\text{-eq}}$ = 19'900 kg $CO_{2\text{-eq}}$).

Normalized damage scores can be obtained by either of the following methods:

- by dividing by normalization factors (NF^d in DALY[14]/point) after having applied damage factors (DF^{dm} in DALY[15]/$unit_{emission}$) to emissions ($unit_{emission}$), or
- directly by applying normalized damage factors (DF^n in point/$unit_{emission}$) to emissions ($unit_{emission}$).

An overview of normalization factors for the four damage categories is given in Table 1-2. The main source used for European emissions is CML (Guinée et al. 2002). Table 1-3 shows the European population (EU_{pop}) used for modeling and normalization.

Table 1-2 : Normalization factors (NF^d) for the four damage categories for Western Europe, for versions 1.0, 1.1, 2.0 and 2.1.

Damage categories	Normalization factors for damage categories (NF^d)				Unit
	version 1.0 & 1.1	version 2.0	version 2.1	version Q2.2	
Human Health	0.0077	0.0068[16]	0.0071[17]	0.0071[18]	DALY/point
Ecosystem Quality	4'650	13'700[19]	13'700	13'800	PDF.m^2.y/point
Climate Change	9'950	9'950	9'950	11'600	kg CO_2 into air/point
Resources	152'000	152'000	152'000	152'000	MJ/point

Table 1-3: European population used for modeling and normalization in the different versions.

	EU_{pop}		
	version 1.0 & 1.1	version 2.0 & 2.1	version Q2.2
IMPACT 2002 human toxicity and ecotoxicity modeling	431'000'000 pers	431'000'000 pers	431'000'000 pers
IMPACT 2002+ normalization (except global warming and non-renewable energy consumption)	380'000'000 pers	431'000'000 pers	431'000'000 pers
IMPACT 2002+ normalization (global warming)	380'000'000 pers	380'000'000 pers	431'000'000 pers
IMPACT 2002+ normalization (non-renewable energy consumption, at midpoint)	380'000'000 pers	380'000'000 pers	380'000'000 pers
IMPACT 2002+ normalization (minerals, at midpoint)		431'000'000 pers	431'000'000 pers
IMPACT 2002+ normalization (resources, at damage)	380'000'000 pers	380'000'000 pers	380'000'000 pers

[14] or PDF·m^2·y, or kg $CO_{2\text{-eq}}$, or MJ.
[15] or PDF·m^2·y, or kg $CO_{2\text{-eq}}$, or MJ.
[16] Difference between version 2.0 and the previous versions is coming from the update of European population (431'000'000 instead of 380'000'000) and the update of several emissions.
[17] Difference between version 2.1 and version 2.0 is coming from the update of the DALY per case of cancer and non-cancer to 13 and 1.3 respectively instead of 6.7 and 0.67 in the previous versions.
[18] Difference between version 2.1 and version 2.0 is coming from the update of the DALY per case of cancer and non-cancer to 13 and 1.3 respectively instead of 6.7 and 0.67 in the previous versions.
[19] Difference between version 2.0 and the previous versions is coming from the addition of several "dominant" emissions (mainly heavy metals) for aquatic and terrestrial ecotoxicity.

2. Cautions, Limitations and interpretation

2.1. Link between Life Cycle inventory and Life Cycle Impact Assessment

2.1.1. Some relevant points to be aware of

Emission of metals. The user should be aware that current Life Cycle Impact Assessment (LCIA) methodologies have problems in modeling speciation, bioavailability and bioconcentration of metals, both for short term and long term emissions. Current Characterization Factors (CFs) of IMPACT 2002+ only apply for metals emitted in dissolved form (ions). Therefore, metal emissions have to be appropriately specified in the life cycle inventory analysis. For practical reasons, in the IMPACT 2002+ substance list, the factors have been associated to the CAS-number and names of the elementary form of the metals (not ions). However, as mentioned above, if CFs are not applied only to dissolved forms (ions) the final score results can be substantially overestimated.

Short term emissions and *long term emissions*. Considered as long term emissions are the emissions occurring after 100 years (up to a maximum of 60’000 years; e.g., for heavy metals leaching from a landfill). Emissions occurring before 100 years are considered as short term emissions. In the LCIA we are evaluating as a default long term emissions equal to present emissions (same CF), as there is little reason that a pollutant emission in 2000 years is less harmful than in the present. However, the developers of IMPACT 2002+ suggest that long and short term emissions should never be directly added up or only be used one by one, but both should be presented in the results and used for interpretation. This is particularly the case for persistent chemicals such as heavy metals. We therefore recommend users to check impacts of long term emissions – for which the same CFs as for short-term emissions are used – within a sensitivity study to verify if these pollutants could potentially represent a problem for future generations, being conscious that uncertainty on those estimations might be extremely important. In addition, it is not clear if these long term emissions+exposure are higher than the long term natural emissions + exposure, which could have occurred anyway without human intervention (as a substitution principle). If stabilization can be considered comparable to nature, in some respect there is no increase in emission levels.

2.1.2. Implementation in different types of software

IMPACT 2002+ can be formatted to be used with the different types of LCIA software available on the market. Presently, this methodology is formatted for Quantis SUITE 2.0, SimaPro and GaBi. It can be downloaded from our website http://www.impactmodeling.org or obtained through the contact with the main authors of this user guide. Annex 3 presents the way IMPACT 2002+ is implemented into Quantis SUITE 2.0, SimaPro and GaBi and how it has to be used.

2.2. How to check and interpret results?

When calculating the environmental impact using IMPACT2002+, several things have to be considered while interpreting the results.

Climate change and resources consumption are in general correlated, except when a lot of nuclear power energy has been used, which will increase the impact of resource consumption compared to climate change. This is the case when comparing European and Swiss or French electricity mix. The Swiss or French mix show a smaller ratio $CO_2/MJ_{prim\ non\text{-}renewable}$, due to the fact that 40%-80% of the electricity is generated by the nuclear power plant. Some other particular cases exist where climate change will increase compared to resource consumption, like for instance for processes that emit a lot of methane (CH_4)[20] or sulfur hexafluoride (SF_6)[21].

When climate change and resource consumption are dominated by road transports, the ratio between CO_2 emitted and energy consumed should be approximately 60 gCO_2/MJ. This ratio is valid for most of the fossil fuels based energy use. For scenarios that are dominated by road transport or fossil fuels consumption (coal/oil electricity, heating, etc.), human health (in DALYs) is generally dominated by respiratory effects due to inorganics. Next to this, the ranking of respiratory effects due to inorganics are correlated to energy and especially climate change midpoint categories.

If toxicity is dominated by heavy metals, one should check if they are coming from short term or long term emissions and interpret the results appropriately (see 2.1). Currently, the state of the art in human toxicity and ecotoxicity assessment enable a precision about a factor 100 (two orders of magnitude) compared to an overall variation of about 12 orders of magnitude. Thus all flows that have an impact over 1% of the total score should be considered as potentially important.

- For a very initial discussion, any difference lower than 10% is not considered significant for the energy and global warming scores. The difference needs to be higher than 30% to be significant for respiratory inorganics or acidification and eutrophication. For the toxicity categories, an order of magnitude (factor 10) difference is typically required for a difference to be significant, especially if the dominant emissions are different between scenarios or are dominated by long-term emissions from landfill that can be highly uncertain. (based on Humbert et al. 2009 – LCA of baby jars and pots)

The following examples give a first indication of the orders of magnitude expected for some results. However, these are rough estimations and shouldn't be used as such for specific applications.

- A car has an average impact of 0.02 DALY for human health, 4'000 PDF·m^2·y for ecosystem quality, 50'000 kg $CO_{2\text{-}eq}$ for global warming and 700'000 MJ for resource consumption (Internal results of different studies by EPFL). These values include the manufacturing, use during 200'000 km and end-of-life.
- The use of 1 kWh of electricity (UCTE low voltage) has an average impact of 4E-7 DALY for human health, 0.2 PDF·m^2·y for ecosystem quality, 0.6 kg $CO_{2\text{-}eq}$ for global warming and 12 MJ for resource consumption (ecoinvent 2.2).
- The production of 1 m3 of concrete has an average impact of 8E-5 DALY for human health, 19 PDF·m^2·y for ecosystem quality, 260 kg $CO_{2\text{-}eq}$ for global warming and 1400 MJ for resource consumption (ecoinvent 2.2).

20 like with landfills or agriculture.
21 SF_6 can dominate the production of magnesium for instance.

2.3. Uncertainties

Uncertainties can occur in the inventory, in the fate, in the exposure or in the effect part of the impact assessment calculation. For instance, exposure can be the driving overall uncertainty source for chemicals mainly taken in via milk or meat. Generally speaking, uncertainties in global warming and resources are low compared to uncertainties in human health and ecosystem quality. Table 2-1 gives a rough approximation of the "type" of uncertainties (for the fate, exposure and effect parts) for the different midpoint and damage categories for IMPACT 2002+ version 2.0, 2.1 and Q2.2.

Currently, the state of the art in human toxicity and ecotoxicity assessments enables a precision of about two orders of magnitude compared to an overall variation of about 12 orders of magnitude. Thus, all flows that have an impact over 1% of the total score should be considered as potentially important.

Table 2-1: Type of uncertainties (for the fate and effect parts) for the different midpoint and damage categories for IMPACT 2002+ version 2.0 and 2.1 and Q2.2.

Midpoint category	uncertainties for fate, exposure and effect	Damage category	uncertainties for fate, exposure and effect	uncertainties for fate, exposure and effect
Human toxicity (carcinogens + non-carcinogens)	High (higher for non-carcinogens than for carcinogens)	Human health	High	Medium (since in general dominated by respiratory inorganics)
Respiratory (inorganics)	Low	Human health	Low	
Ionizing radiations	High	Human health	High	
Ozone layer depletion	Medium	Human health	Medium	
Photochemical oxidation (= Respiratory (organics) for human health)	Medium	Human health	Medium	
		Ecosystem quality	n/a	High
Aquatic ecotoxicity	High	Ecosystem quality	Medium	
Terrestrial ecotoxicity	Very high	Ecosystem quality	High	
Terrestrial acidification/nutrification	High	Ecosystem quality	Medium	
Aquatic acidification	Low	Ecosystem quality	Medium	
Aquatic eutrophication	Low	Ecosystem quality	Medium	
Land occupation	High	Ecosystem quality	Low	
Water turbined	Low	Ecosystem quality	Medium	
Global warming	Low	Climate change (life support system)	Low at midpoint High at damage	Low at midpoint High at damage
Non-renewable energy	Low	Resources	Low	Low
Mineral extraction	Medium	Resources	Medium	
Water withdrawal	Low	Human health	High	High
		Ecosystem quality	High	High
		Resources	n/a	n/a
Water consumption	Low	Human health	High	High
		Ecosystem quality	Medium	Medium
		Resources	Medium	Medium

3. Weighting

The authors suggest considering the four (or five if water impact score is used) damage oriented impact categories human health, ecosystem quality, climate change, and resources separately for the interpretation phase of Life Cycle Assessment (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.

Also, it is always possible to use the factors of De Schryver et al. (2009) to bring global warming to human health and ecosystem quality therefore reducing the number of damage categories to interpret.

An intelligent way of analyzing the different weightings possible can be done by applying *the mixing triangle*. This method is presented in Annex 2.

Finally, the authors would like to stress again that, according to ISO norms, weighting is not usable for comparative assertions disclosed to the public (ISO 14044).

4. Abbreviations and Numerical Hypothesis

4.1. Abbreviations and Glossary

AEEF	Aquatic Ecotoxicological Effect Factor [$PAF \cdot m^3/kg$]
BUWAL	Bundesamt für Umwelt, Wald und Landwirtschaft (Swiss Agency for the Environment, Forests and Landscape, SAEFL)
BW	Body Weight [kg/pers]
category endpoint	Attribute or aspect of natural environment, human health, or resources, identifying an environmental issue giving cause for concern (ISO 14044)
characterization factor	factor derived from a characterization model which is applied to convert an assigned life cycle inventory analysis result to the common unit of the category indicator (ISO 14044)
CF	Characterization Factor (in general)
CF^m	Midpoint Characterization Factor [kg $SubstanceX_{-eq}$/kg]
DALY	Disability-Adjusted Life Years [year]
DF^{dm}	Damage Factor for the considered midpoint categories ["damage"[22]/kg]
DF^{dm}_{refsub}	Damage Factor of the considered reference substance for the considered midpoint category ["damage"[23]/kg-reference_substance]
DF^n	Normalized Damage Factor [points[24]/kg]
EC50	Effect Concentration for 50%
ED10	Effect-Dose, 10%
EF	Effect Factor
elementary flow	material or energy entering the system being studied that has been drawn from the environment without previous human transformation, or material or energy leaving the system being studied that is released into the environment without subsequent human transformation (ISO 14044)
functional unit	Quantified performance of a product system for use as a reference unit (ISO 14040)
EPA	US Environmental Protection Agency
GWP	Global Warming Potential
HDF	Human Damage Factor
iF	intake Fraction [kg_{intake}/kg]
IMPACT 2002	IMPact Assessment of Chemical Toxics and denotes the multimedia fate & multipathway exposure and effects model assessing toxic emission on human toxicity

[22] in DALY, $PDF \cdot m2 \cdot y$, kg CO_{2-eq} or MJ
[23] in DALY, $PDF \cdot m2 \cdot y$, kg CO_{2-eq} or MJ
[24] point = $pers \cdot y$

	and ecotoxicity
IMPACT 2002+	the complete LCIA methodology, including all impact categories
impact category	class representing environmental issues of concern to which LCI results may be assigned (ISO 14044)
IPCC	Intergovernmental Panel on Climate Change
Kow	octanol-water partition coefficient, Kow = $[kg_{sub}/l_{octanol}] / [kg_{sub}/l_{water}] = [l_{water}/l_{octanol}]$
LCI	Life Cycle Inventory
LC(I)A	Life Cycle (Impact) Assessment Methodology
LO(A)EL	Low Observed (Adverse) Effect Level
LT_h	average Life Time of humans [years]
MJ	Mega Joules
NF^d	Normalization Factor for the considered damage category ["damage" /points] (see Table 1-2). Damage can be in DALY, $PDF \cdot m^2 \cdot y$, kg CO_{2-eq} or MJ
NO(A)EL	No Observed (Adverse) Effect Level
OBD	Oxygen Biological Demand
ODP	Ozone Depletion Potential
OFEFP	Office Fédéral de l'Environnement, des Forêts et du Paysage (Swiss Agency for the Environment, Forests and Landscape, SAEFL)
PAF	Potentially Affected Fraction of species
PDF	Potentially Disappeared Fraction of species
product	Product systems and service systems (in the International Standard (ISO 14044) the term "product" used alone includes not only product systems but can also include service systems).
TD	Tumor Dose
TEEF	Terrestrial Ecotoxicological Effect Factor $[PAF \cdot m^3/kg]$
UBP	Umweltbelastungspunkte = eco-point in German
YLL	Years of Life Lost

4.2. Numerical Hypothesis

BW = Average Body Weight = 70 kg/pers.

F_{oc} = soil's relative content of organic carbon by dry matter = 0.02 $kg_{org\ matter}/kg_{dry\ soil}$ (Hauschild and Wenzel. 1998. P.257)

LT_h = 70 years.

Octanol: $\triangle_{octanol}$ = Volumetric mass of octanol = 800 $kg_{octanol}/m^3_{octanol}$

Organic Matter: Redfield ratio: C:N:P = 106:16:1 (SETC-LCIA p.91). Average composition of algae: $C_{106}H_{263}O_{110}N_{16}P$ (CML92 "Backgrounds-October92" p.101).

Soil: Dry soil = 2'400 $kg_{dry\ soil}/m^3_{dry\ soil}$ (Mackay 2001)

Soil structure/composition (% volume) (MacKay 2001, p. 64) 20% air = ~ 0 kg_{air}/m^3_{bulk} 30% water = 300 kg_{water}/m^3_{bulk} 50% dry soil = 1'200 $kg_{dry\ soil}/m^3_{bulk}$ Total = bulk = 1'500 kg_{bulk}/m^3_{bulk}

Water = 1'000 kg_{water}/m^3_{water}

5. Acknowledgements

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6.2. Internet Links and downloadable files

The multimedia model IMPACT 2002 and the LCIA methodology IMPACT 2002+, including all the supporting information (summary, papers, model and characterization factors) is accessible for download at the following web page: http://www.impactmodeling.org or by contacting the corresponding authors (sebastien.humbert@quantis-intl.com). Table 6-1 gives an exhaustive list of the files mentioned in this document and available for download.

Table 6-1: Main computer files mentioned in this document.

LCIA methodology IMPACT 2002+	
Subject	**Name of the file**
IMPACT 2002+ version Q2.2 (version adapted by Quantis) characterization factors. Excel spreadsheet including the complete list of characterization factors of all 17 midpoint and 4 damage categories.	IMPACT2002+_vQ2.2_CF_1a.xls
IMPACT 2002+ version 2.1 characterization factors. *Excel spreadsheet including the complete list of characterization factors of all 17 midpoint and 5*	*IMPACT2002+_v2.1_CF_2b.xls →* *CANCELED*

damage categories. → *CANCELED*	
IMPACT 2002+ version 2.1 characterization factors. Excel spreadsheet including the complete list of characterization factors of all 14 midpoint and 4 damage categories.	IMPACT2002+_v2.1_CF_1b.xls **IMPACT2002+_v2.1_CF_3a.xls**
IMPACT 2002+ version 2.0 characterization factors. Excel spreadsheet including the complete list of characterization factors of all 14 midpoint and 4 damage categories.	IMPACT2002+_v2.0_CF_2f.xls
IMPACT 2002+ version 2.1 characterization factors for SimaPro 6.0. ".cvs" file with characterization factors ready to be imported in SimaPro 6.0 software.	IMPACT2002+_v2.1_SimaPro6.0_1a.csv
IMPACT 2002+ version 2.0 characterization factors for SimaPro 6.0. ".cvs" file with characterization factors ready to be imported in SimaPro 6.0 software.	IMPACT2002+_v2.0_SimaPro6.0_2b.csv
IMPACT 2002+ version 2.0 characterization factors for SimaPro 5.1. ".cvs" file with characterization factors ready to be imported in SimaPro 5.1 software.	IMPACT2002+_v2.0_SimaPro5.1_1a.csv
IMPACT 2002+ version 2.1 characterization factors for Gabi 4. ".xls" file with characterization factors ready to be imported in GaBi software (upgraded version 4).	IMPACT2002+_v2.1_GaBi4_1a.xls
IMPACT 2002+ version 2.0 characterization factors for Gabi 4. ".xls" file with characterization factors ready to be imported in GaBi software (upgraded version 4).	IMPACT2002+_v2.0_GaBi4_1c.xls
IMPACT 2002+ version 2.1 User Guide. Practical guide supporting the user for a proper application of the LCIA methodology, explaining how to represent and interpret results with meaning and limitation about the characterization factors	IMPACT2002+ User Guide (for v2.1), Draft.pdf
IMPACT 2002+ version 2.1 Methodology Description. It gives the scientific background how the characterization factors are calculated.	IMPACT2002+ Methodology Description (for v2.1), Draft.pdf
Old versions/files available by contacting info@impactmodeling.org & sebastien.humbert@quantis-intl.com	
IMPACT 2002+ version 1.0 characterization factors	IMPACT2002+_v1.0_CF_1c.xls
IMPACT 2002+ version 1.1 characterization factors	IMPACT2002+_v1.1_CF_1f.xls

Multimedia fate & multipathways exposure and effect model IMPACT 2002

Subject	Name of the file
IMPACT 2002 model – Europe Single Zone. Model used in versions 1.0, 1.1, 2.0 and 2.1 of IMPACT 2002+.	IMPACT2002-EuropeSingleZone-public1.2.xls

7. Annexes

7.1. Annex 1: Normalization factors for the midpoint categories

In priority, the authors suggest to analyze normalized scores at damage level. Indeed, this will avoid doing an unconscious weighting of 1 between the different midpoint categories within the same damage category. Nevertheless, for those who would like to stop at midpoint level, appropriate normalized characterization factors are also available). An overview of normalization factors for the fourteen midpoint categories is given in Table 7-1.

Table 7-1: Normalization factors for the fourteen midpoint categories for Western Europe, for versions 1.0, 1.1, 2.0, 2.1 & Q2.2.

	Normalization factors			Unit
	version 1.0 & 1.1	**version 2.0[26] and 2.1**	**version Q2.2**	
Midpoint categories				
Human toxicity (carcinogens)	50.2	45.5	45.5	kg Chloroethylene into air $_{-eq}$
Human toxicity (non-carcinogens)	168	173	173	kg Chloroethylene into air $_{-eq}$
Human toxicity (carcinogens + non-carcinogens)	218	219	219	kg Chloroethylene into air $_{-eq}$
Respiratory (inorganics)	9.98	8.80	8.80	kg $PM_{2.5}$ into air $_{-eq}$
Ionizing radiations	6.04E+5	5.33E+5	5.33E+5	Bq Carbon-14 into air $_{-eq}$
Ozone layer depletion	0.225	0.204	0.204	kg CFC-11 into air $_{-eq}$
Photochemical oxidation (= Respiratory (organics) for human health)	14.1	12.4	12.4	kg Ethylene into air $_{-eq}$
Water withdrawal[27]			3.65E+5	kg Water withdrawal
Aquatic ecotoxicity	3.02E+4	1.36E+6[28]	1.36E+6	kg Triethylene glycol into water $_{-eq}$
Terrestrial ecotoxicity	7'160 kg Triethylene glycol$_{-eq}$ into water (v1.0)[29] 1.68E+4 (v1.1)	1.20E+6[30]	1.2E+6	kg Triethylene glycol into soil $_{-eq}$
Terrestrial acidification/nutrification	358	315	315	kg SO_2 into air $_{-eq}$
Aquatic acidification	75.1	66.2	66.2	kg SO_2 into air $_{-eq}$
Aquatic eutrophication	13.4	11.8	11.8	kg PO_4^{3-} into water $_{-eq}$
Land occupation	3'930	3'460	3460	m^2 Organic arable land$_{-eq}$ · y
Water turbined[31]			1.70E+4	m3 Water turbined
Global warming	9'950	9'950	11'600	kg CO_2 into air $_{-eq}$
Non-renewable energy	152'000	152'000	15'200	MJ
	1'770[32]	3'330	3'320[33]	kg Crude oil$_{-eq}$ (860 kg/m^3)

26 Little differences between version 1.1 and version 2.0 (the decrease of about 10%) is due to update of the European population and addition of some emissions.

27 1'000 l/pers.day = 365'000 kg/pers.y

28 The big difference between version 1.1 and 2.0 for aquatic ecotoxicity is due to the addition of emissions of several dominant pollutants (mainly heavy metals). The user should be aware that this normalization factor is subject to a lot of discussions (high uncertainties).

29 This number was a mistake in version 1.0.

30 The big difference between version 1.1 and 2.0 for terrestrial ecotoxicity is due to the addition of emissions of several dominant pollutants (mainly heavy metals). The user should be aware that this normalization factor is subject to a lot of discussions (high uncertainties).

31 ~4'000 kWh/pers.y * 4.34 m3/kWh UCTE (Low Voltage) = 17'000 m3/pers.y

32 This value is wrong. The correct values is the one specified for version 2.0 & 2.1 (3'330 kg Crude oil-eq (860 kg/m3)).

33 "=" 152'000 MJ/pers.y / 45.8 MJ/kg crude oil

Mineral extraction[34]	24.7	292	292	MJ
	485	5'730	5730	kg $Iron_{-eq}$ (in ore)

7.2. Annex 2: The mixing triangle

Since equal weighting is highly debatable, we propose to the user to apply the method of the mixing triangle (Hofstetter 1998. p.362), which is especially appropriated to discuss the trade-off between different impact categories. The mixing triangle can only be used to compare three categories. Thus if the user want to take into account all four damage categories two of them have to be summed (e.g. climate change and resources, because of high correlations in most situations).

As an example, in the following mixing triangle, relations between the normalized damage of three scenarios S1, S2 and S3 have been represented. This example is based without considering water use.

Table 7-2: Normalized damage [points/scenario (= pers·y/scenario)] used in the mixing triangle.

	S1	S2	S3
Human Health	1.35E+00	8.09E-01	9.88E-01
Ecosystem Quality	1.78E-01	1.41E-01	1.40E-01
Climate Change	3.98E+00	4.22E+00	4.12E+00
Resources	4.08E+00	4.32E+00	4.22E+00

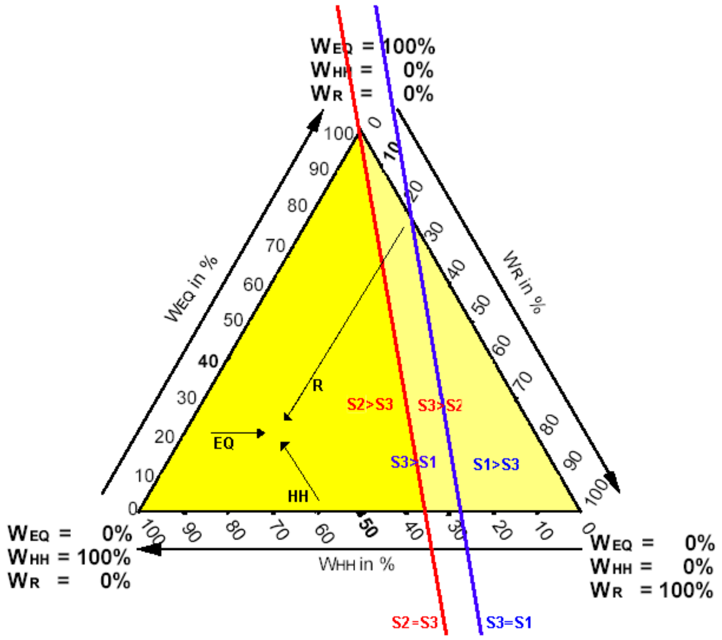

Figure 7-1: The mixing triangle for IMPACT 2002+, for comparison between three scenarios S1, S2 and S3.

- W_{EQ} = Weighting factor for the damage to ecosystem quality.
- W_{HH} = Weighting factor for the damage to human health.
- W_R = Weighting factor for the damage categories **Climate Change and Resources.**
- $W_{EG} + W_{HH} + W_R = 100\%$
- $\mathbf{W_R = W_{CC} + W_{Resource}}$
- Since in most situations Climate Change and Resources are highly correlated, as a matter of simplification, it is possible to represent their weight by the sum W_R.
- Arrows represent the direction in which the different weights should be read.

34 The difference between version 1.1 and 2.0 is coming mainly from the additions of "dominant" extractions in version 2.0 for the computation of normalization factor.

How to interpret this mixing triangle?

The red line represents the respective weights where scenario S2 is equal to scenario S3. At the left side (dark yellow), S2 is better than S3, and at the right side (light yellow), S3 is better than S2. This means that if Human Health is weighted more than 36% of the total, whatever the weight given to (Climate Change + Resources), the scenario S2 will always be better than S3. With a 50% weight given to Climate change and resources, the minimum weight for human health decreases to 28% making S2 better than S3.

The blue line represents the respective weights where scenario S3 is equal to scenario S1. The same explanation as above goes with this blue line. The two areas are not drawn with a color, but we see that if Human Health is weighted more than 28%, scenario S3 will always be better than S1, whatever the weight given to (Climate Change + Resources).

Between the two lines, S3 is the best scenario.

In a general overview, S2 is generally the best scenario, if a minimal weight is given to human health, a high weight has to be given to (Climate Change + Resources) to have another scenario becoming more interesting than S2.

7.3. Annex 3: How to use IMPACT 2002+ in different software?

With Quantis SUITE 2.0:

- The most up-to-date version of IMPACT 2002+ is implemented in Quantis SUITE 2.0
- For more information, contact info@quantis-intl.com or www.quantis-intl.com for more info.

With SimaPro:

- Several versions of IMPACT 2002+ already exist for SimaPro (or are ready to be imported into the software). The version 2.1 has the following properties:
    1. 15 midpoint categories[35], in kg SubstanceX$_{-eq}$ (or Bq C^{14}_{-eq}, or m^2 Organic arable land$_{-eq}$·y, or MJ),
    2. 4 damage categories (aquatic acidification and aquatic eutrophication not taken into account), normalized at damage, in points[36],
    3. default weighting of 1, but not recommended to use by the authors.
- For more information, contact info@impactmodeling.org or sebastien.humbert@quantis-intl.com or www.pre.nl for more info.

[35] "carcinogenic" and "non-carcinogenic" are considered as two separated midpoint categories instead of only one commonly named "human toxicity".
[36] = pers·yr

With GaBi 4:

- The version 2.1 contains 14 midpoint categories. Human toxicity is considered as two separate categories (cancer and non-cancer), but the category non-renewable energy not considered (indeed, it is already present in GaBi 4).
- All categories are given at midpoint (in kg SubstanceX$_{-eq}$: Bq C^{14}$_{-eq}$, or m^2 Organic arable land$_{-eq}$·y, or MJ).
- Three sets of factors allow to go from:
    - Midpoint to Normalized Midpoint,
    - Midpoint to Damage,
    - Midpoint to Normalized Damage.
- For more information, contact info@impactmodeling.org or sebastien.humbert@quantis-intl.com or www.pe-international.com for more info.

7.4. Annex 4: Historical changes of IMPACT 2002+

- IMPACT 2002+ version Q2.21 (version adapted by Quantis): November 1, 2012
    - CFs added to land occupation
    - CFs added to non-renewable energy
    - CFs added to respiratory inorganics
    - CFs added to water withdrawal
    - New substance added for loss of biodiversity due to deforestation with 100-year horizon
- IMPACT 2002+ version Q2.2 (version adapted by Quantis): March 25, 2012
    - Climate change CFs are adapted with GWP for a 100 year time horizon
    - Addition of water withdrawal, water consumption and water turbined
    - Addition of aquatic acidification, aquatic eutrophication and water turbined to the damage category ecosystem quality
    - Updated normalization factors
- IMPACT 2002+ version 2.1: October 2005
    - Implemented into GaBi 4
    - DALY per case of cancer and non-cancer have been updated to 13 and 1.3 instead of 6.7 and 0.67 respectively
- IMPACT 2002+ version 2.0: March 2004
    - Implemented into ecoinvent 1.1
    - More substances for Ozone layer depletion and for Global warming
    - Human toxicity through emission into agricultural soil corrected
    - Non-renewable energy adapted to ecoinvent

- Normalization factors improved (mainly by addition of more emissions)
- IMPACT 2002+ version 1.1: January 2004
  - Main difference with version 1.0: terrestrial ecotoxicity corrected
- IMPACT 2002+ version 1.0: September 2003
  - Implemented into ecoinvent 1.0

7.5. Annex 5: IMPACT 2002+ vQ2.21 added substances

The method was updated by Quantis on 11/01/2012, to version Q2.21. Characterization factors were added for the elementary flows (substances) listed in the table below.

Table 7-5: Added characterization factors in version Q2.21

Impact category	Elementary flow	CF	Comment
Respiratory inorganics	Carbon monoxide, biogenic (unspecified)	0.001044286 kg PM2.5-eq / kg	Same as Carbon monoxide (unspecified)
Respiratory inorganics	Carbon monoxide, fossil (unspecified)	0.001044286 kg PM2.5-eq / kg	Same as Carbon monoxide (unspecified)
Respiratory inorganics	Particulates, > 2.5 um, and < 10um (unspecified)	0 kg PM2.5-eq / kg	Particles above 2.5 um assumed to have no impact
Land occupation	Occupation, forest, intensive, short-cycle	0.100917431 m2org.arable / m2a	Same as Occupation, forest, intensive
Land occupation	Occupation, permanent crops	1.055045872 m2org.arable / m2a	Same as Occupation, permanent crop, fruit, intensive
Land occupation	Occupation, permanent crops, irrigated	1.055045872 m2org.arable / m2a	Same as Occupation, permanent crop, fruit, intensive
Land occupation	Biodiversity loss due to deforestation, 100 years horizon	45.87 m2org.arable / m2	New substance added (see details below)
Non-renewable energy	Energy, from peat	1 MJ primary / MJ	Same as all other non-renewable resources
Non-renewable energy	Energy, gross calorific value, in biomass	0 MJ primary / MJ	Considered a renewable resource
Non-renewable energy	Energy, gross calorific value, in biomass, primary forest	1 MJ primary / MJ	Same as all other non-renewable resources
Non-renewable energy	Energy, gross calorific value, in peat	1 MJ primary / MJ	Same as all other non-renewable resources
Water withdrawal	Water, unspecified natural origin, AD	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, AE	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, AF	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, AFR	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, AG	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, AI	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, AL	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, AM	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, AN	1 m3 / m3	WSI not accounted for

Impact category	**Elementary flow**	**CF**	**Comment**
Water withdrawal	Water, unspecified natural origin, AO	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, AQ	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, AR	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, AS	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, AT	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, AU	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, AW	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, AX	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, AZ	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, BA	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, BB	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, BD	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, BE	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, BF	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, BG	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, BH	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, BI	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, BJ	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, BM	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, BN	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, BO	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, BR	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, BS	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, BT	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, BV	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, BW	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, BY	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, BZ	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, CA	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, Caribbean	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, CC	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, CD	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, CF	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, CG	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, CH	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, CI	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, CK	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, CL	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, CM	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, CN	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, CO	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, CPA	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, CR	1 m3 / m3	WSI not accounted for

Impact category	**Elementary flow**	**CF**	**Comment**
Water withdrawal	Water, unspecified natural origin, CU	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, CV	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, CX	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, CY	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, CZ	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, DE	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, DJ	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, DK	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, DM	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, DO	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, DZ	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, EC	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, EE	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, EG	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, EH	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, ER	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, ES	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, ET	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, extreme water stress	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, FI	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, FJ	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, FK	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, FM	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, FO	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, FR	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, GA	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, GB	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, GD	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, GE	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, GF	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, GH	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, GI	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, GL	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, GM	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, GN	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, GP	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, GQ	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, GR	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, GS	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, GT	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, GU	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, GW	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, GY	1 m3 / m3	WSI not accounted for

Impact category	Elementary flow	CF	Comment
Water withdrawal	Water, unspecified natural origin, GZ	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, high water stress	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, HK	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, HN	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, HR	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, HT	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, HU	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, ID	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, IE	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, IL	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, IM	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, IN	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, IQ	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, IR	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, IS	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, IT	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, JM	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, JO	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, JP	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, KE	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, KG	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, KH	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, KM	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, KN	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, KP	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, KR	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, KW	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, KZ	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, LA	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, LB	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, LC	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, LI	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, LK	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, low water stress	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, LR	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, LS	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, LT	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, LU	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, LV	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, LY	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, MA	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, MC	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, MD	1 m3 / m3	WSI not accounted for

Impact category	Elementary flow	CF	Comment
Water withdrawal	Water, unspecified natural origin, MEA	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, medium water stress	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, MG	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, MK	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, ML	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, MM	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, MN	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, MO	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, moderate water stress	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, MQ	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, MR	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, MT	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, MU	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, MW	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, MX	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, MY	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, MZ	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, NA	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, NC	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, NE	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, NG	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, NI	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, NL	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, NO	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, NP	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, NZ	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, OCE	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, OM	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, PA	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, PAO	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, PE	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, PG	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, PH	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, PK	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, PL	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, PR	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, PT	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, PY	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, QA	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, RE	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, RER	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, RLA	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, RNA	1 m3 / m3	WSI not accounted for

Impact category	Elementary flow	CF	Comment
Water withdrawal	Water, unspecified natural origin, RO	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, RU	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, RW	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, SA	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, SD	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, SE	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, SG	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, SI	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, SK	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, SL	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, SM	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, SN	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, SO	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, SR	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, ST	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, SV	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, SY	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, SZ	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, TD	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, TG	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, TH	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, TJ	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, TM	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, TN	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, TO	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, TR	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, TT	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, TW	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, TZ	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, UA	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, UG	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, US	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, UY	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, UZ	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, VC	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, VE	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, VN	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, VU	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, WO	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, YE	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, YU	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, ZA	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, ZM	1 m3 / m3	WSI not accounted for
Water withdrawal	Water, unspecified natural origin, ZR	1 m3 / m3	WSI not accounted for

Impact category	Elementary flow	CF	Comment
Water withdrawal	Water, unspecified natural origin, ZW	1 m3 / m3	WSI not accounted for

A new elementary flow "*Biodiversity loss due to deforestation, 100 years time horizon*" was created in the method update in order to account for loss of biodiversity when deforesting. It is classified in the land occupation impact category though it would in fact be more of a land transformation issue (but the latter category does not exist in IMPACT 2002+).

It is considered that all species disappear when deforestation occurs and an arbitrary remediation time of 100 years is applied for the recovery. As the restoration back to forest is not brutal but regular over time, the impact has to be divided by two as explained in Figure 7-2.

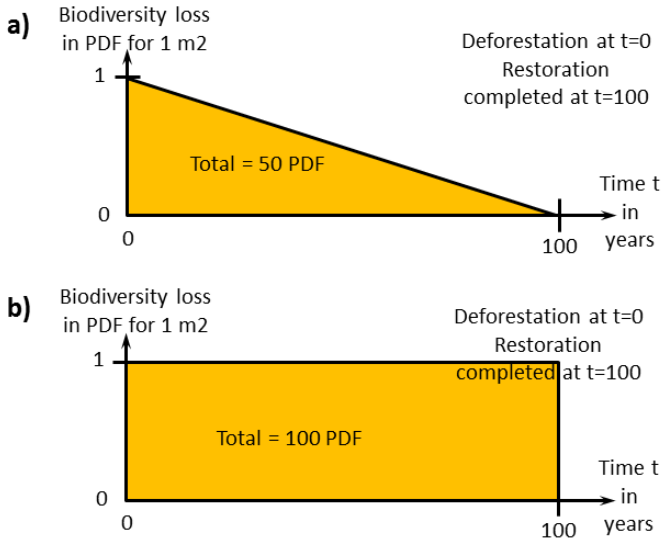

Figure 7-2: Restoration of biodiversity loss due to deforestation after 100 years. a) Progressive restoration, realistic scenario considered in here. b) Brutal restoration after 100 years, less realistic scenario.

Therefore for 1 m^2 deforested, the impact on biodiversity is of 50 PDF-m^2-year (100% species disappeared * 1 m^2 *100 years, divided by 2).

Therefore 1 m^2 of the elementary flow "*Biodiversity loss due to deforestation, 100 years time horizon*" is considered to correspond to an impact on biodiversity of 50 PDF-m^2-year. This latter value is part of the impact assessment methodology and is not part of the inventory process data. When expressing it at midpoint, it is divided by the characterization factor of "organic arable land" and provides the midpoint characterization factor of 45.87 m2org.arable / m2 of land deforested.

Note that it is NOT time-allocated according to PAS 2050 (the full impact is given).

The elementary flow, in m^2, quantifies the surface where biodiversity is lost due to deforestation.

This elementary flow was created by Quantis, on November 2012, for IMPACT 2002+ vQ.2.21, to assess biodiversity loss on the scale of PDF.m2.yr.

The user needs to enter the inventory flow (in m^2 deforested per functional unit) already allocated over the number of years over which the deforestation has to be allocated (20 years by default, to be consistent with PAS 2050).