IMPACT World+

version 2.0

CIRAIG

DTU

1 Harmonisation, corrections and updates of CF

1.1 Long term emissions and time dependent impact categories

In IW+, damage categories which generate long term impacts are split between two additive time frames: short- and long-term impacts. Impacts on Climate change (both human health and ecosystem quality), freshwater ecotoxicity, human toxicity (both cancer and non cancer) and marine acidification are therefore expressed over a short-term (0-100 years) and a long term period (over 100 years). Please note that the long-term impacts of climate change are calculated over the time period 100-500 years.

In the 2.0 version, we improved the consistency between inventory and impact assessment timeframes. LCI emissions reported in some LCA inventory databases are by default considered short term emissions (i.e. generated within the first 100 years), unless specifically defined being long-term emissions (i.e. occurring beyond a 100 year timeframe). Short term emissions (i.e., most emissions in LCA inventory databases) might generate short-term impacts (< 100 years after the emission) or both short plus long-term impacts (i.e occurring from time zero until a time horizon way beyond 100 years). Therefore long term emissions reported in some LCA inventory databases (for example the emissions identified in ecoinvent with a sub-compartment with "long-term" in its name, such as: "low-population density, long-term") are considered as generating 100% of their impact beyond the 100 year time horizon hence only have a long-term impact, characterized with the addition of short- and long-term CF. (Figure 1)

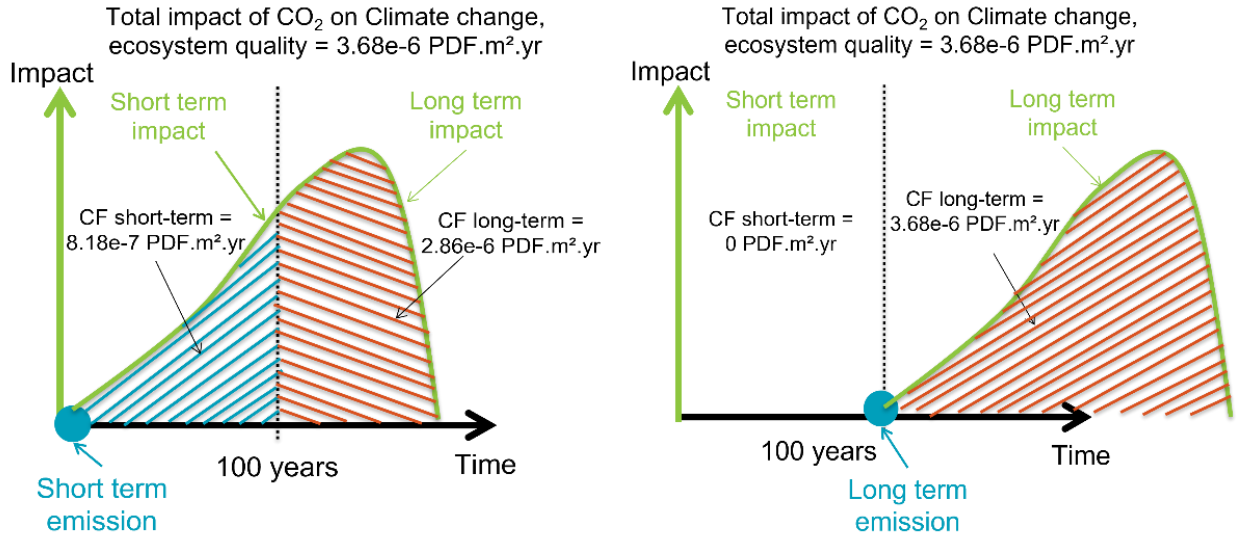

Figure 1: Long- and short-term impacts for long- and short term emissions in Impact World+ 2.0

1.2 Toxicity and ecotoxicity - Metal emissions in groundwater

We explicitly acknowledge that the impact of metal emissions in the groundwater compartment cannot presently be determined. It is a current limitation of the LCIA models: USEtox doesn't account for the fate of metals in groundwater and therefore for a potential transfer to surface water or other compartments (where ecosystems and humans are exposed). Therefore, IW+ assumes that CF of metal emissions emitted directly to the groundwater sub-compartments are equal to zero, meaning that it disregards the potential

(eco)toxicity impacts of metals that do end up in groundwater and may reach back to other compartments.

1.3 Marine eutrophication – air emissions

Some emissions to air, such as “ammonia as N” or “dinitrogen monoxide”, and all sub-compartment except for the “unspecified’ were missing in previous versions. They are now all characterized.

1.4 Land occupation and transformation update

CF values for land occupation and transformation elementary flows were updated (meaning that some discrepancies between the CF files and the article were corrected) for the following land use: annual crops, permanent crops and agriculture (mosaic).

1.5 Ionizing radiations

CF values for the midpoint indicator and the human health damage indicator have been updated (meaning that new flows were characterized using proxies and some discrepancies between the CF files and the article were corrected). New CF for the water compartment and the ocean sub-compartment were integrated. Also, new substances have been added: Americium-241, Strontium-90, Thorium-230.

1.6 Acidification and freshwater eutrophication midpoint categories

Midpoint values for these categories were not properly normalized in some previously generated versions of IW+, meaning the conversion to an equivalent substance unit here (like SO2 eq. for acidification and PO4 P-lim eq for freshwater eutrophication) was not done correctly. Now they have been properly recalculated by dividing all the CF by the CF of the reference flow so that, e.g., the CF for the emission of 1 kg SO_2, GLO is 1 kg SO_2 eq for acidification.

1.7 Water impact categories – new elementary flows

Characterization factors for many regionalized elementary flows for the categories: Water scarcity / Water availability, human health / Water availability, freshwater ecosystem / Water availability, terrestrial ecosystem, were added for new sub-regions covered in LCA databases such as CN-AH or IN-AP assuming their values were equal to country level CF values.

1.8 Precise report of changes

The precise reports of changes (flow by flow), for all software and database for which we provide an IW+ version, can be found here: https://github.com/CIRAIG/IWP_Reborn/tree/master/Report_changes.

Note that those reports depend on the database/software combination as software typically do not cover the same elementary flows and use different names.

2 IW+'s updated structure to assist its operationalisation.

The management of IW+ in previous versions did not allow for easy, consistent and transparent updates to the LCIA models, nor even for the integration of new indicators, such as plastic leakage impacts from the work of MariLCA. Hence, our efforts with the 2.0 version focused on completely refactoring the generation process of the characterization factors to ease the update process and also increase the transparency in the generation of CF from IW+. That means that the process of generating the files containing IW+'s CF values has been ***entirely automated***. A code was developed to automatically calculate CFs for the list of elementary flows of different database/software based on the original CFs from the published IW+ article[1] and applying explicit rules. This code is openly accessible on Github: https://github.com/CIRAIG/IWP_Reborn

The original CFs (from the published article) are contained in a Microsoft Access database. These original CFs are then read by the code and new ones are being extrapolated based on explicit rules such as stoichiometry (e.g., for acidification and eutrophication) or explicit link to new sub-compartments (e.g., from "unspecified" to "high. pop." for GHGs) or new geographies (e.g., creation of water flows "CN-AH").

Rules are then applied to the different elementary flows, such as forcing "groundwater" and "ocean" sub-compartment flows to zero in specific impact categories (e.g., freshwater ecotoxicity), or forcing the long-term emissions to zero for short-term impact categories.

Once all CFs are created, they are automatically mapped to the different classifications used by the different software/databases. As of now, versions of IW+ 2.0, in the right format (json, xlsx, csv…), can automatically be created for the following database/software:

- Many databases in SimaPro
    - ecoinvent
    - Agribalyse
    - Agrifootprint
    - ELCD
    - Industry2.0
    - US-ei2.2
    - USLCI
    - WFLDB
- ecoinvent in openLCA
- ecoinvent in brightway2
- "pure" ecoinvent (with the original names from the ecoinvent database)

[1] Bulle, C., Margni, M., Patouillard, L., Boulay, A., Bourgault, G., De Bruille, V., ... Jolliet, O. (2019). IMPACT World+: a globally regionalized life cycle impact assessment method. The International Journal of Life Cycle Assessment. https://doi.org/10.1007/s11367-019-01583-0

- the exiobase database (a Global Input-Output model)
- the openIO-Canada database (an internal Canadian Input-Output database developed at CIRAIG)

All these versions are available in open access on Zenodo (https://doi.org/10.5281/zenodo.7348580) and are directly importable in their respective software.

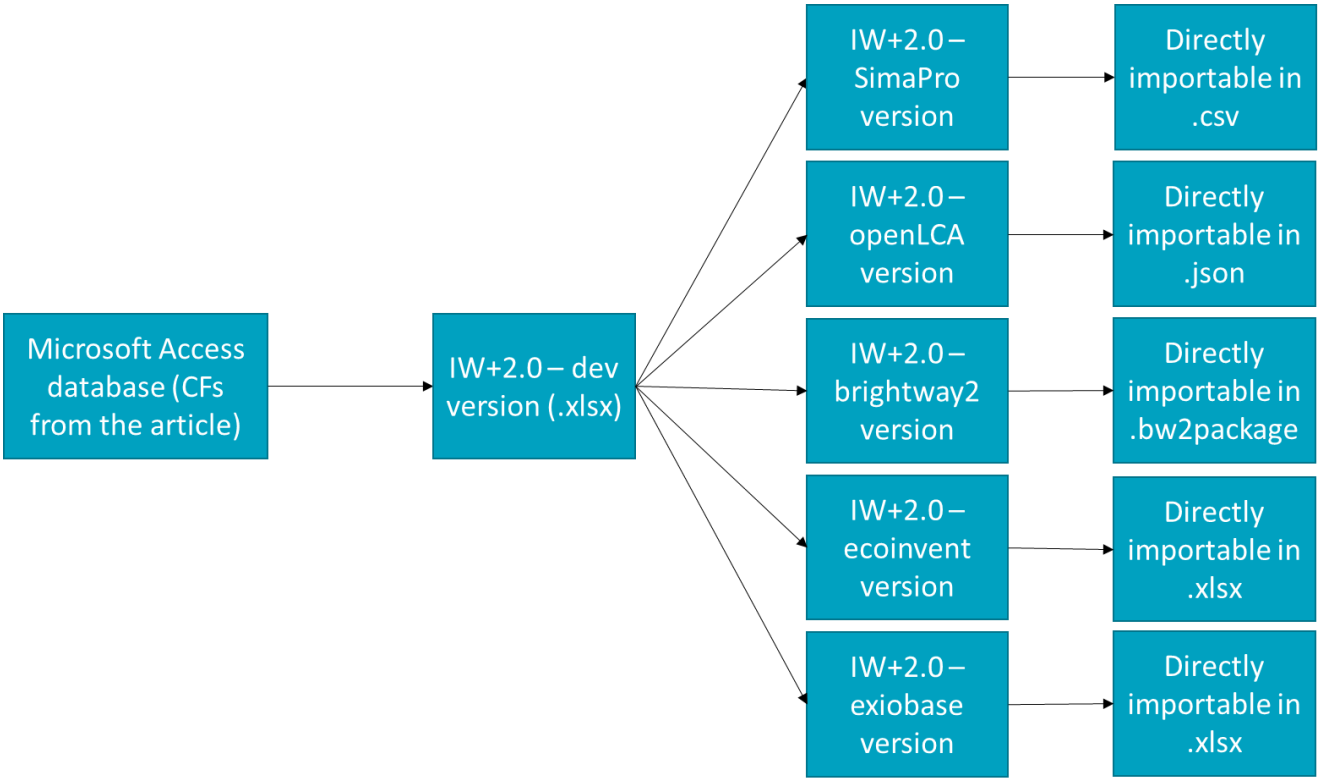

Figure 2: Organization of IW+ files

Appendix 1 Indicators of the AoP version

Table 1: Impact categories, indicators, and indicators' unit of the AoP version

Impact categories	Indicators displayed and units
Acidification	Midpoint: - Freshwater acidification (in kg SO_2 eq) - Terrestrial acidification (in SO_2 eq) Damage: - Marine acidification, long term (in PDF.m2.yr) - Marine acidification, short term (in PDF.m2.yr) - Freshwater acidification (in PDF.m2.yr) - Terrestrial acidification (in PDF.m2.yr)
Climate change	Midpoint: - Climate change, long term (in kg CO_2 eq (long)) - Climate change, short term (in kg CO_2 eq (short)) Damage: - Climate change, human health, long term (in DALY) - Climate change, human health, shot term (in DALY) - Climate change, ecosystem quality, long term (in PDF.m2.yr) - Climate change, ecosystem quality, short term (in PDF.m2.yr)
Ecotoxicity	Midpoint: - Freshwater ecotoxicity (in CTUe) Damage: - Freshwater ecotoxicity, long term (in PDF.m2.yr) - Freshwater ecotoxicity, short term (in PDF.m2.yr)
Eutrophication	Midpoint: - Freshwater eutrophication (in kg PO_4 P-lim eq) - Marine eutrophication (in kg N N-lim eq) Damage: - Freshwater eutrophication (in PDF.m2.yr) - Marine eutrophication (in PDF.m2.yr)

Human toxicity	Midpoint: - Human toxicity cancer (in CTUh) - Human toxicity non-cancer (in CTUh) Damage: - Human toxicity cancer, long term (in DALY) - Human toxicity cancer, short term (in DALY) - Human toxicity non-cancer, long term (in DALY) - Human toxicity non-cancer, short term (in DALY)
Ionizing radiations	Midpoint: - Ionizing radiations (in Bq C-14 eq) Damage: - Ionizing radiations, human health (in DALY) - Ionizing radiation, ecosystem quality (in PDF.m2.yr)
Land related issues	Midpoint: - Land occupation, biodiversity (in m^2 arable land eq.yr) - Land transformation, biodiversity (in m^2 arable land eq) Damage: - Land occupation, biodiversity (in PDF.m2.yr) - Land transformation, biodiversity (in PDF.m2.yr)
Ozone layer depletion	Midpoint: - Ozone layer depletion (in kg CFC-11 eq) Damage: - Ozone layer depletion (in PDF.m2.yr)
Particulate matter formation	Midpoint: - Particulate matter formation (in kg PM2.5 eq) Damage: - Particulate matter formation (in DALY)
Photochemical oxidant formation	Midpoint: - Photochemical oxidant formation (in kg NMVOC eq) Damage: - Photochemical oxidant formation (in DALY)

Resources	Midpoint: - Fossil and nuclear energy use (in MJ deprived) - Mineral resources use (in kg deprived)
Water related issues	Midpoint: - Water scarcity (in m^3 world-eq) Damage: - Thermally polluted water (in PDF.m2.yr) - Water availability, human health (in DALY) - Water availability, freshwater ecosystem (in PDF.m2.yr) - Water availability, terrestrial ecosystem (in PDF.m2.yr)