LCIA METHODS

ILCD 2011 v1.0.10 method update in openLCA

Report: Version 1.1

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1 Overview

The current version of the ILCD 2011 v1.0.10 method from August 2016 in openLCA replaces the ILCD 2011 version 1.0.5 from February 2013. The characterization factors (CFs) of the updated openLCA impact assessment method "ILCD 2011 v1.0.10" are based on the list provided by the Joint Research Centre (JRC) of the European Commission at the URL: http://eplca.jrc.ec.europa.eu/uploads/CFs%20package%20August%202016.zip

The characterization factors of the openLCA ILCD 2011 method refer to elementary flows available in the reference data of openLCA. This data includes all the elementary flows in openLCA from the databases available in the Nexus site[2] and additional flows used in the methods. The assignment of characterization factors to the elementary flows of openLCA was done by mapping them to the list of ILCD elementary flows and characterization factors provided by JRC. The mapping was based on a comparison of the compartments, names, and CAS numbers included in both lists. If no match could be found, the documentation provided by JRC or by the original method developers was reviewed in order to find the correspondent factor, if relevant for the specific flow and impact category. This document provides supplementing information related to the updated ILCD 2011 method in openLCA and the assumptions considered when assigning the characterization factors to the elementary flows. It is recommended to consider the information here provided when using this ILCD 2011 method implementation for impact assessment and when comparing the calculated LCIA results with other ILCD method implementations.

Table 1 shows a summary of the ILCD recommended methods per impact category. Please refer to the technical note for further information related to the ILCD characterization factors provided by the Joint Research Centre (JRC) of the European Commission (JRC, 2012). Further information about the International Reference Life Cycle Data System (ILCD) can be found in http://eplca.jrc.ec.europa.eu/?page_id=86.

Please refer to the original publications of each methodology for a general description and the scientific background of the impact categories included in the ILCD 2011 method.

Table 1 Recommended methods of the ILCD 2011 Impact assessment method

Impact category	Recommended method	Impact indicator
Climate change midpoint	IPCC (2007)	Global Warming Protection (GWP 100) measured in CO_2 equivalents
Climate change endpoint, human health	ReCiPe 2008 v1.05[3] (De Schryver et al., 2009)	Disability Adjusted Life Years (DALY)
Climate change endpoint, ecosystems	ReCiPe 2008 v1.05[3] (De Schryver et al., 2009)	Potentially Disappeared Fraction of species (PDF)
Ozone depletion midpoint	World Meteorological Organization (WMO, 1999)	Ozone Depletion Potential (ODP 100) measured in chlorofluorocarbon-11 equivalents (CFC-11)

[2] URL: https://nexus.openLCA.org/ (accessed 25.11.2016)

[3] The method recommended refers to the Hierarchist perspective of ReCiPe 2008.

Impact category	Recommended method	Impact indicator
Ozone depletion endpoint, human health	ReCiPe 2008 v1.05[3] (Goedkoop et al.,2008; Struijs et al. 2009a and 2010)	Disability Adjusted Life Years (DALY)
Human toxicity midpoint, cancer effects	USEtox v1.01 (Rosenbaum et al., 2008)	Comparative Toxic Unit for human health (CTUh)
Human toxicity midpoint, non-cancer effects	USEtox v1.01 (Rosenbaum et al., 2008)	Comparative Toxic Unit for human health (CTUh)
Human toxicity endpoint, cancer effects	DALY calculations adapted to USEtox v1.01 midpoint (Huijbregts et al., 2005).	Disability Adjusted Life Years (DALY)
Human toxicity endpoint, non-cancer effects	DALY calculations adapted to USEtox midpoint (Huijbregts et al., 2005)	Disability Adjusted Life Years (DALY)
Ecotoxicity freshwater midpoint	USEtox v1.01 (Rosenbaum et al., 2008)	Comparative Toxic Unit for ecosystems (CTUe)
Particulate matter/Respiratory inorganics midpoint	USEtox, Greco et al. (2007) and RiskPoll (Rabl and Spadaro, 2004), Humbert (2009)	Particulate matter, average diameter of 2.5E-06 µm(PM2.5)
Particulate matter/Respiratory inorganics endpoint	USEtox, Greco et al. (2007) and RiskPoll (Rabl and Spadaro, 2004). DALY (van Zelm et al., 2008), Kuenzli et al. (2000), Hofstetter (1998) and NEEDS (EC 2008)	Disability Adjusted Life Years (DALY)
Ionizing radiation midpoint, human health	Frischknecht et al., 2000	Ionizing Radiation Potentials (Uranium 235)
Ionizing radiation midpoint, ecosystems	Garnier- Laplace et al., 2009	Comparative Toxic Unit for ecosystems (CTUe)
Ionizing radiation endpoint, human health	WHO data used for DALY's. (Frischknecht et al., 2000)	Disability Adjusted Life Years (DALY)
Photochemical ozone formation midpoint, human health	ReCiPe2008 v1.05[4] (Van Zelm et al. (2008)	Photochemical ozone creation potential measured in Ethylen equivalents (C_2H_4)
Photochemical ozone formation endpoint, human health	ReCiPe 2008 v1.05[4] (Van Zelm et al., 2008)	Disability Adjusted Life Years (DALY)
Acidification midpoint	Seppälä et al. 2006, Posch et al., 2008	Mol Hydrogen equivalents (H+)
Acidification endpoint	ReCiPe 2008 v1.05[4] Van Zelm et al. 2007	Mol Hydrogen equivalents (H+)
Eutrophication terrestrial midpoint	Seppala et al., 2006, Posch et al., 2008	Mol Hydrogen equivalents (H+)
Eutrophication freshwater midpoint	ReCiPe 2008 v1.05[4] (EUTREND model Struijs et al., 2009b)	Phosphorus equivalents
Eutrophication marine midpoint	ReCiPe 2008 v1.054 (EUTREND model Struijs et al., 2009b)	Nitrogen equivalents
Eutrophication freshwater endpoint	ReCiPe 2008 v1.054 (Struijs et al., 2009b)	Potentially Disappeared Fraction of species (PDF)
Land use midpoint	Mila i Canals et al., 2007a	Soil Organic Matter (SOM), measured in (kg C/m2/a).
Land use endpoint	ReCiPe 2008 v1.055	Potentially Disappeared Fraction of species (PDF)
Resource depletion water, midpoint	Ecological Scarcity Method 2006 (Frischknecht et al., 2008)	Water consumption equivalent (m3)
Resource depletion, mineral, fossils and renewables, midpoint	CML 2002 (Guinée et al., 2002), Oers et al., 2002	Scarcity [Production/ (Ultimate Reserve)2] compared Antimony (Sb)
Resource depletion, mineral, fossils and renewables, endpoint	ReCiPe2008 v1.0.5[5] (Goedkoop and De Schryver 2009).	Surplus costs ($/kg) due to extraction/production (kg)

[4] The method recommended refers to the Hierarchist perspective of ReCiPe 2008.
[5] The method recommended refers to the Hierarchist perspective of ReCiPe 2008.

Impact category	Recommended method	Impact indicator
ReCiPe 1.05		
Resource depletion, mineral, fossils and renewables, endpoint ReCiPe 1.11	ReCiPe2008 v1.0.11[5] (Goedkoop and De Schryver 2013).	Surplus costs ($/kg) due to extraction/production (kg).

2 Update procedure: General mapping

As mentioned in the introduction, the assignment of characterization factors to the elementary flows included in the openLCA reference list was done by mapping them to the list of elementary flows and factors provided by ILCD. Elementary flows in openLCA and in ILCD are identified by a flow name, compartment information, flow property/unit and other additional descriptors (e.g. CAS numbers, formulas, synonyms, etc.). Mappings of both flow names (including also additional descriptors) and compartment information was applied. If a match by flow name and compartment could be found in the ILCD list, the correspondent CF was assigned to the openLCA elementary flow. Conversion factors were used in case the flow property information differed from one list to the other (e.g. "Lake water" (kg) <-> "Water, lake" (m3)). The general procedure and assumptions followed are described in the subsections below.

2.1 Mapping of flow names between ILCD and openLCA

Two types of mappings were applied for the flow names: direct match and approximation by meaning.

1. Mapping of direct matches by name and CAS number: if both flows had identical name and, if relevant, identical CAS number in both nomenclature systems (i.e. ILCD and openLCA), they were mapped as a "direct match". CAS numbers were used only for those flows with CAS information in both databases, and when the flow could be identified uniquely by the CAS number (e.g. different water flows have equal CAS).

2. Approximation by meaning: if a direct match was not found or not applicable, a proxy by "meaning" has been searched (e.g. "Dinocap" in ILCD <-> "Fungicides, unspecified" in openLCA), looking at the flows by similar name, CAS number (if relevant and applicable), synonyms available, by category, or expert judgement.

2.1.1 Metals

Metals may be available in the openLCA and ILCD lists of elementary flows both as free elements or in their ionic form. As general approach, only flows with the same oxidation state in both lists have been mapped (e.g. Chromium VI in ILCD was assigned to Chromium VI in openLCA). In some cases, ILCD provided characterization factors only for the pure element (e.g. copper, lead, etc.). For those, the ionic/oxidized form from openLCA was mapped to the pure element, as shown in table 3.

Table 3 Mapping of metals between ILCD and openLCA

Elementary flows in ILCD	Elementary flows in openLCA
Arsenic[6]	Arsenic
	Arsenic compounds
Arsenic (+V)	Arsenic, ion
Antimony[7]	Antimony
	Antimony compounds
Barium	Barium
	Barium compounds
Beryllium	Beryllium
	Beryllium compounds
Cadmium	Cadmium
	Cadmium compounds
	Cadmium, ion
Chromium[8]	Chromium
	Chromium compounds
Chromium (III)	Chromium, ion[9]
Copper	Copper
	Copper compounds
	Copper, ion
	Copper, ions, unspecified
	Copper (+II)
Lead	Lead
	Lead compounds
	Lead (+II)
Mercury	Mercury
	Mercury compounds, unspecified
	Mercury (+II)
Nickel	Nickel
	Nickel compounds, unspecified
	Nickel, ion
	Nickel ion (+III)
Selenium	Selenium
	Selenium compounds
Silver	Silver
	Silver compounds
	Silver, ion
Thallium	Thallium
	Thallium compounds
Tin	Tin

[6] ILCD uses the same factor as for Arsenic (+V) for the pure element
[7] ILCD uses the same factor as for Antimony (+V) for the pure element
[8] ILCD uses the average of Cr(III) and Cr(VI) for calculating the characterisation factor of Chromium
[9] Chromium (III) is not relevant for the impact category Human Health, cancer effects, according to USEtox 1.01

Elementary flows in ILCD	Elementary flows in openLCA
	Organo-tin compounds
	Tin, ion
Vanadium	Vanadium
	Vanadium compounds
	Vanadium, ion
Zinc	Zinc
	Zinc compounds
	Zinc, fume or dust
	Zinc, ion

2.1.2 Other elementary flows

The characterization factors of nitrogen oxides from the ILCD list provided were mapped to the elementary flows nitrogen oxide in openLCA, as a general approach. In case of CFs for nitrogen oxides not provided in the ILCD list (i.e. Particulate matter), the CFs of nitrogen dioxide from the ILCD list provided were mapped to nitrogen oxides in openLCA.

2.1.3 Regionalized elementary flows

ILCD provides regionalized CFs for "Acidification midpoint", "Eutrophication terrestrial midpoint" and "Resource depletion water midpoint".

openLCA only contains regionalized water emission and resource flows for “Water” compounds, which are used by some LCI databases in openLCA Nexus, e.g. LC-Inventories, Agribalyse 1.3. For those existing elementary flows, regionalized CFs were added in the ILCD method of openLCA. However, it should be noted that the regionalized LCIA calculation approach in openLCA derives the location of the flow from the location of the process where the flow is used, instead of adding the location information to the flow name. This way, the addition of uncountable new flows to represent each of the different locations that might be relevant in a cradle-to-grave LCA is avoided. However, this approach is not feasible with aggregated data sets (i.e. system processes), that´s why the above mentioned LCI databases contain the regionalized water flows added to the reference list and for which specific regionalized CFs were included in the ILCD method.

For further information about the regionalized LCIA calculation of openLCA, please check the report "Regionalized LCIA in openLCA" or the video of the webinar about the topic in openLCA’s YouTube channel.

2.2 Mapping of compartments and subcompartments between ILCD and openLCA

Compartments describe an environmental context of the flow origin or destination (i.e. "to soil" or "to water" for example). The compartments are differentiated further in relevant subcategories within the compartment.

The compartments of the openLCA elementary flows were first assigned to the existing compartments in ILCD. Table 2a shows the compartments for which a direct match could be found (i.e. equal information in the compartment/subcompartment names or same effect of the described environmental context on the characterization factor calculation). Further assumptions were then necessary because not all compartments used in ILCD are provided in openLCA and vice versa. Table 2b shows the compartments for which a proxy mapping was applied. In this case, the compartments were mapped without loss of information or as a relationship one-to-many, i.e. mapping from less to more detailed compartments without loss of information (e.g. "Emissions to water, unspecified (long-term)" mapped to "Emission to fresh water, long-term"/ "ground water, long-term"/"river, long-term" in openLCA). Loss of information occurred due to mapping from more to less detailed compartments (e.g. "Non-renewable element resources from ground" mapped to "Resource/in unspecified"; in this case also the information in the flow name was relevant).

After assignment of compartments according to table 2a and 2b, the remaining openLCA elementary flows, for which the CF was not provided in the corresponding subcompartment of the ILCD list, were mapped to the "unspecified" subcompartment within the same compartment, if appropriate (e.g. given that an elementary flow was not available in the subcompartment "Emissions to agricultural soil" in ILCD "Emissions to soil, unspecified" was used instead for "Emission to soil/Agricultural" in openLCA). In case of the assignment of water compartments, the "Emissions to water, unspecified" in ILCD were only mapped to freshwater subcompartments, but not applied for "Ocean" in openLCA. In case of uncharacterized long-term emissions, the "unspecified" factors available within the compartment "air" and "water" from ILCD were mapped to the "long-term" subcompartments in openLCA (i.e. "Emissions to air, unspecified" mapped to " Low population density, long-term" in openLCA and "Emissions to water, unspecified" mapped to "Emission to fresh water, long-term"/ "ground water, long-term"/"river, long-term" in openLCA).

Table 2a Assignments of compartments and subcompartments between ILCD and openLCA, direct matches

Compartment in ILCD	Subcompartment in ILCD	Compartment in openLCA	Subcompartment in openLCA
Emissions to air	Emissions to air, unspecified	Emission to air	Unspecified
Emissions to air	Emissions to lower stratosphere and upper troposphere	Emission to air	Lower stratosphere + upper troposphere
Emissions to air	Emissions to non-urban air or from high stacks	Emission to air	Low population density
Emissions to air	Emissions to urban air close to ground	Emission to air	High population density
Emissions to soil	Emissions to soil, unspecified	Emission to soil	Unspecified
Emissions to soil	Emissions to agricultural soil	Emission to soil	Agricultural
Emissions to water	Emissions to water, unspecified	Emission to water	Unspecified
Emissions to water	Emissions to fresh water	Emission to water	Fresh water
Emissions to water	Emissions to sea water	Emission to water	Ocean
Land use	Land occupation	Resource	Land
Land use	Land transformation	Resource	Land
Resources from air	Renewable material resources from air	Resource	In air
Resources from ground	Non-renewable element resources from ground	Resource	In ground
Resources from ground	Non-renewable energy resources from ground	Resource	In ground
Resources from ground	Non-renewable material resources from ground	Resource	in ground
Resources from water	Non-renewable element resources from water	Resource	In water
Resources from water	Non-renewable material resources from water	Resource	In water

Compartment in ILCD	Subcompartment in ILCD	Compartment in openLCA	Subcompartment in openLCA
Resources from water	Renewable material resources from water	Resource	In water

Table 2b Assignments of compartments and subcompartments between ILCD and openLCA, proxy matches

mapping from less to more detailed compartments without loss of information
mapping from more to less detailed compartments with loss of information

Compartment in ILCD	Subcompartment in ILCD	Compartment in openLCA	Subcompartment in openLCA
Emissions to air	Emissions to air, unspecified (long-term)	Emission to air	Low population density, long-term
Emissions to soil	Emissions to non-agricultural soil	Emission to soil	Forestry
Emissions to soil	Emissions to non-agricultural soil	Emission to soil	Industrial
Emissions to water	Emissions to fresh water	Emission to water	Lake
Emissions to water	Emissions to fresh water	Emission to water	Ground water
Emissions to water	Emissions to fresh water	Emission to water	River
Emissions to water	Emissions to fresh water	Emission to water	Fossil-
Emissions to water	Emissions to fresh water	Emission to water	Surface water
Emissions to water	Emissions to water, unspecified (long-term)	Emission to water	Fresh water, long-term
Emissions to water	Emissions to water, unspecified (long-term)	Emission to water	Ground water, long-term
Emissions to water	Emissions to water, unspecified (long-term)	Emission to water	River, long-term
Resources from air	Renewable material resources from air	Resource	Unspecified
Resources from ground	Non-renewable element resources from ground	Resource	Unspecified
Resources from ground	Non-renewable energy resources from ground	Resource	Unspecified
Resources from ground	Non-renewable material resources from ground	Resource	Unspecified
Resources from water	Non-renewable element resources from water	Resource	Unspecified
Resources from water	Non-renewable material resources from water	Resource	Unspecified
Resources from water	Renewable material resources from water	Resource	Unspecified

3 Update procedure: Impact categories

In the following, the approach for the implementation of the ILCD 2011 V1.0.10 method related to each impact category is described.

3.1 Climate change

The characterization factors (CFs) for climate change in the ILCD 2011 V1.0.10 method are based on the IPCC report (2007). According to IPCC (2007), carbon monoxide (CO) is qualified as indirect radiactive effect (i.e. the indirect effects of CO occur through reduced OH levels leading to enhanced concentrations of CH_4 and enhancement of ozone) and has a mean characterization factor of 1.9 for the GWP_{100}, but may vary depending on the location (IPCC, 2007). ILCD 2011 does not provide a CF for carbon monoxide for climate change in their list of factors, but there are implementations of the ILCD 2011 method in which CO is characterized. For instance, the ecoinvent ILCD 2011 method uses a CF of 1.57 kg CO_2 eq./kg CO calculated as the ratio of molecular weights, considering a full oxidation of CO to CO_2. The impact factor due to indirect impacts provided by IPCC is not used in the ecoinvent ILCD implementation though. However, the ecoinvent IPCC 2013 implementation contains a factor for “Carbon monoxide, fossil” which is the result of adding 1.57 to the factor for indirect impacts available in the AR5 report. Other LCIA methodologies, such as EDIP 2003 or Ecological Scarcity 2013, also have a characterization factor for carbon monoxide for the impact category of climate change. On the other hand, methods, such as ReCiPe, or the ILCD implementations of SimaPro or GaBi do not include an impact factor for carbon monoxide. In the ILCD 2011 v1.0.10 method of openLCA carbon monoxide is also not included in the impact category “Climate change” in order to be consistent with the list of CFs provided by JRC. Taking this into account, differences in results for processes inventorying CO and CO_2 separately may occur compared to other implementations of the ILCD 2011 method (i.e. ecoinvent).

3.2 Ozone depletion

No comments related to the assignment of elementary flows of ILCD to the reference list of openLCA.

3.3 Human toxicity

No comments related to the assignment of elementary flows of ILCD to the reference list of openLCA.

3.4 Ecotoxicity

No comments related to the assignment of elementary flows of ILCD to the reference list of openLCA.

3.5 Particulate matter/Respiratory inorganics

The assessment in the original methods includes CFs for primary and secondary particulate matter (PM) (incl. creation of secondary PM due to sulphur oxides (SO_x), nitrogen oxides (NO_x) and ammonia (NH_3) emissions and carbon monoxide (CO)).

The human health effects of primary PM are considered differently between the original methods. According to Greco et al. (2007) and USEtox (Rosenbaum et al., 2008) only PM2.5 are considered as primary PM. However, in the RiskPoll model (Spadaro and Rabl, 2004), PM2.5, PM2.5-10 and PM 10 are included as primary PM, while according to Humbert (2009), the effect factor of PM 2.5-10 is assumed to be substantially lower compared to the one of PM2.5 and thus, should not be not considered as primary PM. This is also supported by Hofstetter (1998) and Van Zelm et al. (2008).

As the CFs for particulate matter provided by ILCD are based on all methods discussed above but complemented as in Humbert (2009), in the openLCA ILCD v1.0.10 method implementation PM2.5, and PM 10 are characterized, as recommended by Humbert (2009). Table 4 shows the assignment of all primary PM in ILCD to the respective elementary flows in openLCA. All mappings of primary PM in openLCA can be considered as approximation with same detail, but without information loss. Other ILCD methods implementations (i.e. ecoinvent, SimaPro for example) do not assign CFs for "Particulate matter < 2.5 µm" and thus, LCIA impact results for this impact category based on the ILCD v1.0.10 method in openLCA will eventually be higher than compared to other ILCD method implementations.

Table 4 Mapping of ILCD and openLCA flows for primary particulate matter

Elementary flow in ILCD	Elementary flow in openLCA
particles (PM2.5)	Particulates, < 2.5 µm
particles (PM10)	Particulates, < 10 µm
particles (PM10)	Particulates, unspecified
particles (PM10)	Particulates, diesel soot

3.6 Ionizing radiation

According to the original data from ILCD, CFs for freshwater and sea water were only mapped to the corresponding compartments: the CFs provided by ILCD for "Emissions to fresh water" were mapped only to water compartments with freshwater origin (i.e. river, lake, surface water, etc.) in openLCA. CFs for elementary flows considered by ILCD for "Emissions to sea water" were only mapped to "Emission to water/ocean" in openLCA. Thus, if a CF of an elementary flow was provided only for the subcompartment of freshwater origin and is missing for sea water, the elementary flow remains uncharacterized for "Emission to water/ocean" as in the original data of ILCD. Other ILCD method implementations (i.e. ecoinvent, SimaPro for example) made other assignments, i.e. considering the same CF provided in one subcompartment as for the other subcompartment. Taking this to account, differences in results compared to other ILCD method implementations (i.e. ecoinvent, SimaPro for example) may occur.

For radioactive elementary flows which are included in the reference list in openLCA, but not considered as elementary flows in ILCD, the CFs for the respective isotopes available in ILCD have been used as approximation as shown in table 5.

Table 5 Mapping of ILCD and openLCA flows for radioactive substances as approximation

Elementary flow in ILCD	Elementary flow in openLCA
cesium-137	Cesium-136
cobalt-58	Cobalt-57
iodine-133	iodine-135
krypton-85	krypton-85m
krypton-85	Krypton-87
krypton-85	Krypton-88
plutonium-238	Plutonium-241

Elementary flow in ILCD	Elementary flow in openLCA
radium-226	Radium-224
radium-226	Radium-228
thorium-230	Thorium-228
thorium-230	Thorium-232
thorium-230	Thorium-234
xenon-133	Xenon-131m
xenon-133	Xenon-133m
xenon-133	Xenon-135m
xenon-133	Xenon-137
xenon-133	Xenon-138

3.7 Photochemical ozone formation

No comments related to the assignment of elementary flows of ILCD to the reference list of openLCA.

3.8 Acidification

No comments related to the assignment of elementary flows of ILCD to the reference list of openLCA.

3.9 Eutrophication

According to ReCiPe 2008, CFs for freshwater eutrophication are only provided for freshwater compartments in openLCA, while CFs for marine eutrophication are available for seawater and freshwater compartments in openLCA. Given that freshwater bodies will reach the coastal waters, nitrogen enrichment of freshwater and sea water is considered for marine eutrophication, but phosphor enrichment is only accounted for freshwater according to the EUTREND model (ReCiPe 2008).

In other ILCD method implementations, CFs for freshwater compartments are also considered for "ocean" in freshwater eutrophication (i.e. ecoinvent, SimaPro for example). Taking this into account, differences in results compared to other ILCD method implementations may occur for freshwater eutrophication (i.e. ecoinvent, SimaPro for example).

3.10 Land use

Changes in the ILCD 2011 method in version 1.0.6 by JRC include logical modifications for elementary flows related to transformation (i.e. negative values for all "from" flows as contrary to all "to" flows). Additionally, new elementary flows were added and characterization factors were changed in the list provided by ILCD in version 1.0.6 and 1.0.8 for this impact category. Thus, great differences in results between impact assessment methods based on ILCD 2011 v1.0.10 in openLCA compared to other ILCD implementations can be observed for this impact category. Please see also the documentation of changes provided by JRC (2016a) for further information[10].

[10] URL: eplca.jrc.ec.europa.eu/uploads/CFs%20package%20August%202016.zip (accessed 25.11.2016)

3.11 Resource depletion water

In the current ILCD 2011 v1.0.10 method implementation in openLCA, many water flows relevant for resource water depletion, which were not mapped in ILCD 2011 v1.0.5 in openLCA, are now characterized (Figure 2). Thus, a considerable increase in the LCIA results is to be expected for this impact category.

Impact assessment method: ILCD 2011, midpoint

Impact factors

Impact category: Resource depletion - water

Flow	Category	Flow property	Unit	Factor	Uncertainty
Water, ground	resource/in water	Mass	m3/kg	1.62E-4	none
Water, lake	resource/in water	Volume	m3/m3	0.162	none
Water, river	resource/in water	Volume	m3/m3	0.162	none

Figure 1 Elementary flows characterized in ILCD 2011 v1.0.5 in openLCA

Impact assessment method: ILCD 2011, midpoint (1.0.10 betaversion)

Impact factors

Impact category: Resource depletion - water

Flow	Category	Flow property	Unit	Factor	Uncertainty
Waste water	water/fresh water	Mass	m3/kg	1.62E-4	none
Waste water/m3	water/ground water	Volume	m3/m3	-0.162	none
Waste water/m3	water/river	Volume	m3/m3	-0.162	none
Waste water/m3	water/unspecified	Volume	m3/m3	-0.162	none
Water	resource/in water	Mass	m3/kg	1.62E-4	none
Water	water/ground water	Mass	m3/kg	1.62E-4	none
Water	water/ground water, long-term	Mass	m3/kg	1.62E-4	none
Water	water/river	Mass	m3/kg	1.62E-4	none
Water	water/surface water	Mass	m3/kg	1.62E-4	none
Water	water/unspecified	Volume	m3/m3	-0.162	none
Water	water/unspecified	Mass	m3/kg	1.62E-4	none
Water (fresh water)	resource/in water	Mass	m3/kg	1.62E-4	none
Water (fresh water)	water/surface water	Mass	m3/kg	1.62E-4	none
Water (groundwater from technosph...	water/fresh water	Mass	m3/kg	1.62E-4	none
Water (lake water from technospher...	water/fresh water	Mass	m3/kg	1.62E-4	none
Water (lake water from technospher...	water/fresh water	Mass	m3/kg	1.62E-4	none
Water (river water from technospher...	water/fresh water	Mass	m3/kg	1.62E-4	none
Water (river water from technospher...	water/fresh water	Mass	m3/kg	1.62E-4	none
Water (river water from technospher...	water/fresh water	Mass	m3/kg	1.62E-4	none
Water (river water from technospher...	water/fresh water	Mass	m3/kg	1.62E-4	none
Water (trona rich)	resource/in water	Mass	m3/kg	1.62E-4	none
Water Cooling fresh	resource/in water	Mass	m3/kg	1.62E-4	none
Water, barrage	resource/in water	Mass	m3/kg	1.62E-4	none
Water, barrage	resource/unspecified	Mass	m3/kg	1.62E-4	none
Water, BR	water/river	Volume	m3/m3	-0.162	none
Water, CH	water/river	Volume	m3/m3	-0.037	none
Water, cooling, drinking	resource/unspecified	Mass	m3/kg	1.62E-4	none
Water, cooling, surface	resource/unspecified	Mass	m3/kg	1.62E-4	none

Figure 2 Elementary flows characterized in ILCD 2011 v1.0.10 in openLCA (excerpt)

3.12 Resource depletion, mineral, fossils and renewables

3.12.1 Midpoint impact category

The midpoint impact category uses the method abiotic resource depletion (CML 2001) based on the extraction rate and the reserve base of the resource i relative to the depletion of the reference substance antimony (in kg antimony equivalents = kg Sb eq.). For the depletion of fossil fuels, the characterization factor (CF) provided by CML and used by ILCD is 7.79E-9 kg Sb eq. per net calorific value of the fossil fuel extracted from the reserve base (Oers et al., 2002). For fossil fuels and energy flows available in the openLCA reference list with reference flow property "Net calorific value", this factor stated by Oers et al. (2002) was used. For the rest of fossil fuels (i.e. with mass, volume or gross calorific value/energy as flow properties), their net calorific value was used to convert the CF in kg Sb eq./MJ net calorific value to the corresponding flow unit (e.g. kg Sb eq./kg, kg Sb eq./m3, kg Sb eq./MJ gross calorific value), as recommended by ILCD (JRC, 2012). Annex I contains the list of net calorific values used for each flow in openLCA for this impact category at midpoint level.

For "Uranium", JRC provides a characterization factor of 3.59E-7 kg Sb eq./MJ uranium based on a calorific value of 544,284 MJ/kg uranium. This factor was used for those uranium flows in openLCA with reference flow property "Energy" or "Net calorific value" because there is no difference between gross and net calorific values for uranium. For the uranium flows of openLCA with reference flow property "Mass", the calorific value applied was the one provided by the different databases available in Nexus (e.g. ecoinvent, GaBi, DataSmart, etc), which is 560,000 MJ/kg, if no other calorific value was specified in the flow name (e.g. "Uranium, 2291 GJ per kg, in ground"). Therefore, the CF for the flows "Uranium" and "Uranium, in ground" is 0.201 kg Sb eq./kg uranium, whereas for "Uranium, 2291 GJ per kg, in ground" is 0.799 kg Sb eq./kg uranium. Moreover, it should be noted that the factor provided in the newest list of CML CFs is 6.56E-2 kg Sb eq./kg uranium (Oers, 2016) which is several orders of magnitude lower than the one calculated using the factor per MJ of uranium provided by JRC. The exact calculation applied by ILCD or CML for obtaining each CF could not be found so it is currently not possible for us to identify the causes of that difference. Therefore, it was decided to use the value as provided by JRC in order to be consistent with the ILCD 2011 LCIA methodology.

3.12.2 Endpoint impact category

According to the ILCD report (JRC, 2012), the endpoint impact category is based on ReCiPe 2008 v1.05 (Goedkoop and De Schryver, 2009). The methodology report of ReCiPe 2008 v1.05 describes the calculation of the characterization factor of the fossil fuels as indicated by formula 1.

$$CF_{end,i} = CF_{mid,i} * CF_{oil.end.kg} \qquad (1)$$

$CF_{end,i}$ endpoint characterization factor for non-renewable resource i (in US$/unit of resource i)
$CF_{oil.end.kg}$ increased costs for extracting 1 kg of resource (i.e. 16.07 US$/kg oil for the Egalitarian and Hierarchist perspectives in ReCiPe v1.05[11])
$CF_{mid,i}$ midpoint characterization factor for the non-renewable resource i (in kg oil eq./unit of resource i)

The midpoint characterization factor of ReCiPe used in formula 1 is calculated as indicated by formula 2.

$$CF_{mid,i} = CED_i / CED_{ref} \qquad (2)$$

CED_i cumulative energy demand indicator of non-renewable resource i (in MJ gross calorific value/unit of resource i)
CED_{ref} cumulative energy demand indicator of the reference oil resource (in MJ gross calorific value/kg oil)

Although ReCiPe v1.05 (original method) uses gross calorific values for the CED indicator, ILCD uses net calorific values (JRC, 2012). A possible reason is that newer versions of ReCiPe (i.e. since

[11] The mid-to-endpoint factor used in newer versions of ReCiPe is 0.165 US$/kg oil for the Egalitarian and Hierarchist perspectives.

v1.07, 2012) also use net calorific values (ReCiPe, 2014). Other corrections/modifications implemented by ReCiPe in v1.07 or newer versions were not applied by ILCD though, i.e.:

- In ReCiPe v1.05 (original), the reference resource was "Oil, crude, feedstock, 42 MJ per kg, in ground". For instance, the characterization factor for the flow "Coal, 18 MJ per kg, in ground" is calculated as: (18/42)*16.07 = 6.89 US$/kg of coal. However, in v1.11 (ReCiPe, 2014) the reference flow is 1 kg of oil equivalent, as defined by the International Energy Agency (IEA) and the United Nations Statistics Division (i.e. 1 toe according to IEA = 41.868 GJ, net calorific value[12] (WEC, 2013)).
- Further, the mid-to-endpoint factor was also modified in ReCiPe v1.07 because initially 2030 was estimated as the year when fossil sources would be depleted. This estimation was corrected to 2100 in 2012, resulting in a change from 16.07 US$/kg oil in v1.05 to 0.165 US$/kg oil in v1.07 and newer.

To summarize, a combination of versions of ReCiPe 2008 for fossil depletion was implemented in the list of ILCD by JRC (2012): the net calorific values are used as in v1.07, while the mid-to-endpoint factor and the reference flow refer to v1.05 (Table 6).

Table 6 Summary of ReCiPe implementations in ILCD and the original methods

	Resource depletion - Mineral, fossils and renewables (ReCiPe 1.05 implementation in ILCD)	**Resource depletion - Mineral, fossils and renewables (original ReCiPe v1.05)**	**Resource depletion - Mineral, fossils and renewables (original ReCiPe v1.07 and newer)**
Cumulative energy demand indicator	Net calorific value	Gross calorific value	Net calorific value
Mid-to-endpoint factor	16.07 US$/kg oil	16.07 US$/kg oil	0.165 US$/kg oil
Reference flow	42 MJ/kg	42 MJ/kg	41.868 MJ/kg

As ReCiPe v1.05 is reported by ILCD as the methodology to use for the endpoint impact category (JRC, 2012), it was decided to use all the specifications from the original methodology, including the use of gross calorific values as cumulative energy demand indicator. However, as important corrections in the ReCiPe 2008 method (i.e. mid-to-endpoint factor) were implemented by the original method developers since v1.07, it was decided to create also an endpoint impact category according to those new specifications (Table 6). Therefore, there are two impact categories for resource depletion at endpoint level in the ILCD 2011 implementation of openLCA:

- "Resource depletion - Mineral, fossils and renewables (ReCiPe 1.05)", which is consistent with the original ReCiPe v1.05 methodology
- "Resource depletion - Mineral, fossils and renewables (ReCiPe 1.11)", which is consistent with the original ReCiPe v1.07 and newer versions

And, consequently, two "Resource – total" impact categories exist too:

- "Resource – total (ReCiPe 1.05)", which is consistent with the original ReCiPe v1.05 methodology

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[12] 1 toe according to the World Energy Council = 42 GJ, net calorific value

- "Resource – total (ReCiPe 1.11)", which is consistent with the original ReCiPe v1.07 and newer versions

Annex I contains the gross calorific values used for the endpoint impact category implemented in openLCA following the ReCiPe v1.05[13] methodology and the net calorific values used for the endpoint impact category implemented in openLCA following the ReCiPe v1.11 methodology (Table 6). When comparing the LCIA results of the resource depletion endpoint impact category of ILCD 2011 with other software and databases, it should be noted that a disparity of implementations exists in the LCIA community. For instance, ecoinvent and SimaPro v.8.2.3.0 use gross calorific values both for the ILCD mid- and endpoint categories, whereas GaBi SP30 uses net calorific values for both of them. As Gabi, SimaPro and ecoinvent use the mid-to-endpoint factor from v1.05, it is recommended to use the impact category "Resource depletion - Mineral, fossils and renewables (ReCiPe 1.05)" from openLCA when comparing the results with other ILCD 2011 implementations.

Regarding uranium, the characterization factor for metal depletion of ReCiPe at endpoint level was used (i.e. 8.76 US$/kg uranium). For the uranium flows provided in MJ in openLCA, a calorific value of 560,000 MJ/kg uranium was used for calculating the corresponding factor, resulting in 1.56E-5 US$/MJ uranium. As ReCiPe 2008 characterizes uranium only for metal depletion, the flow "Nuclear energy" was not included in any of the endpoint impact categories for resource depletion.

Renewables were not characterised in the openLCA implementation of ILCD 2011 v1.0.10, as those elementary flows are not considered according to the methods based on Oers et al. (2002), CML 2002 (Guinée et al., 2002) and ReCiPe 2008 (Goedkoop, 2009). Table 7 shows elementary flows in openLCA which are not included in the original list of characterization factors provided the method developers or in the ILCD list, but which have been included in other ILCD method implementations (e.g. SimaPro, GaBi). Thus, differences in results compared to other ILCD method implementations may occur.

Table 7 Elementary flows not characterised by CML (2002) and ReCiPe 2008

Elementary flows not characterised by CML (2002) and ReCiPe 2008
Anhydrite, in ground
Kaolinite
Magnesite, 60% in crude ore, in ground
Olivine, in ground
Sodium
Colemanite, in ground
Kaolinite, 24% in crude ore, in ground
Magnesium, 0.13% in water
Phosphate ore, in ground
Sodium chloride, in ground

[13] The gross calorific value used for "Methane" was the one applied in ReCiPe v1.05. However, it should be noted that this value is wrong, as it refers to "m^3 methane", instead of kg. In order to keep the results consistent with ReCiPe v1.05, this value was kept in openLCA. However, the net calorific value used for the midpoint impact category and the endpoint impact category as in ReCiPe 1.11 is correct.

Elementary flows not characterised by CML (2002) and ReCiPe 2008
Kaolin
Magnesite
Nepheline
Rutile, in ground
Ulexite, in ground

It should be noted that the previous version of ILCD 2011 in openLCA contained less fossil fuel flows characterised than the current version. Thus, a considerable increase in the LCIA results is to be expected for this impact category as compared to the previous ILCD method implementation in openLCA.

4 Update procedure: Normalization and weighting factors

4.1 Normalization

The normalization factors of the updated openLCA ILCD 2011 v1.0.10 method are based on the list provided by the Joint Research Centre (JRC) of the European Commission under: eplca.jrc.ec.europa.eu/uploads/Table_ILCD_NFs_08-03-2016.xlsx.

The normalization sets, as provided by JRC in version 0.1.1, were implemented at midpoint level in openLCA as shown in table 8. Please note that there is no normalization factor provided by JRC for ionizing radiation - ecosystems and therefore, this impact category should not be included when analyzing the normalized or weighted results.

Table 8 Normalization sets implemented

Normalization set	Reference year	Literature reference	Description of normalized result
JRC - EU 27, per person	2010	Benini et al., 2014, Sala et al., 2015	Impact of one EU 27 inhabitant in 2010
JRC - EU 27, total	2010	Benini et al., 2014, Sala et al., 2015	Impact of the EU 27 in 2010
JRC Global, per person	2010 or 2013	Benini et al., 2016	Impact of one World inhabitant in 2010 or 2013
JRC Global, total	2010 or 2013	Benini et al., 2016	Impact of the World in 2010 or 2013
Prosuite Global, per person	2000 or 2010	Laurent et al., 2013	Impact of one World inhabitant in 2000 or 2010
Prosuite Global, total	2000 or 2010	Laurent et al., 2013	Impact of the World in 2000 or 2010

4.2 Weighting

For the weighting step in the Life Cycle Impact Assessment, the JRC (2016b) recommends to apply equal weighting, i.e. all impact categories should have the same weight (weighting factor = 1) (JRC, 2016b). The weighting factors at midpoint level in openLCA were implemented as 1/number of impact categories = 1/15 = 0.0667 .

5 How to import the ILCD 2011 v1.0.10 method in openLCA

The updated ILCD method is available free of charge and can be downloaded openLCA LCIA method v1.5.6 (including other LCIA methods) from the openLCA website (www.openlca.org/download/).

To import the updated ILCD 2011 method v1.0.10 in openLCA, right-click in the Navigation window and select "Import database" (Figure 3) and select the respective file in zolca-format.

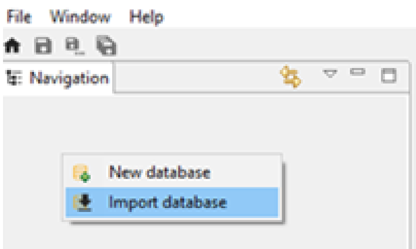


Figure 3 Import a zolca database

To import the updated ILCD 2011 method into an active database in openLCA, right-click in the Navigation window and select "Import..." (Figure 4), choose "Database Import" and select "Existing database" to find the respective zolca-File within the databases already imported in openLCA or "From exported zolca-File" to browse the respective zolca-File downloaded on your personal computer.

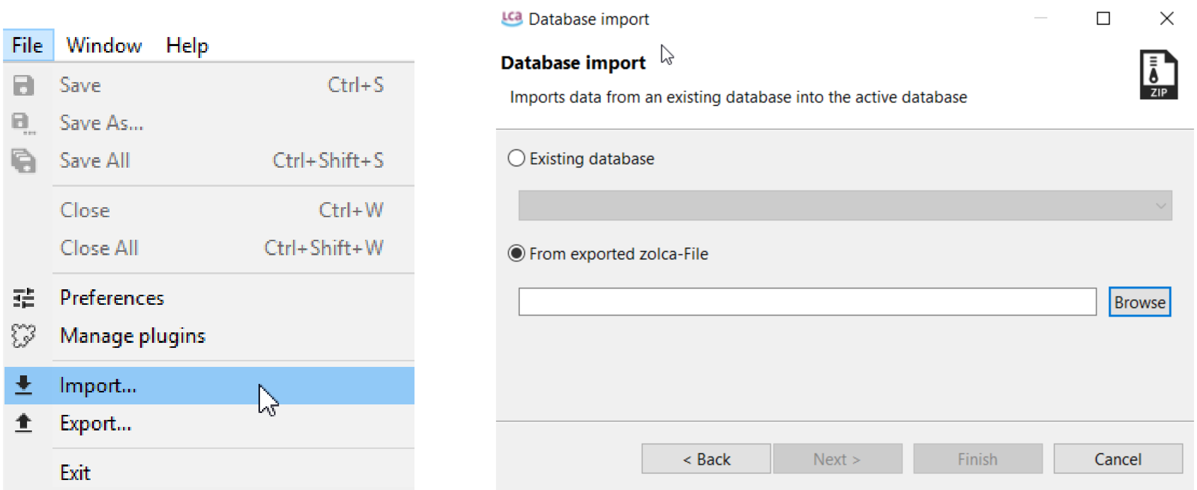


Figure 4 Import a zolca database

The imported zolca-File should appear in the navigation pane under "Indicators and parameters" (Figure 5).

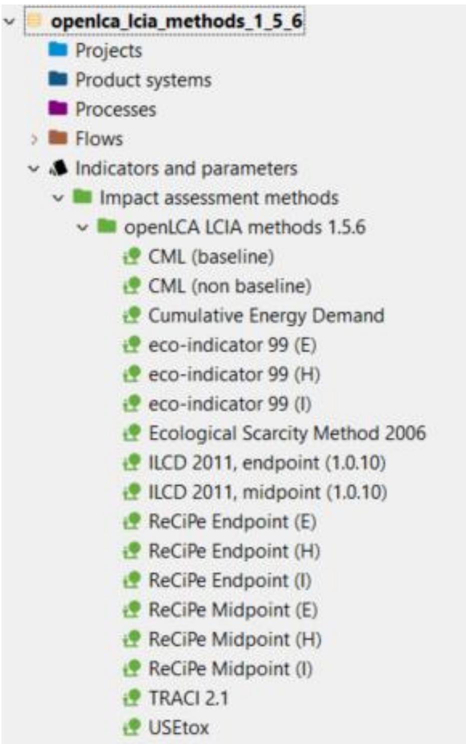
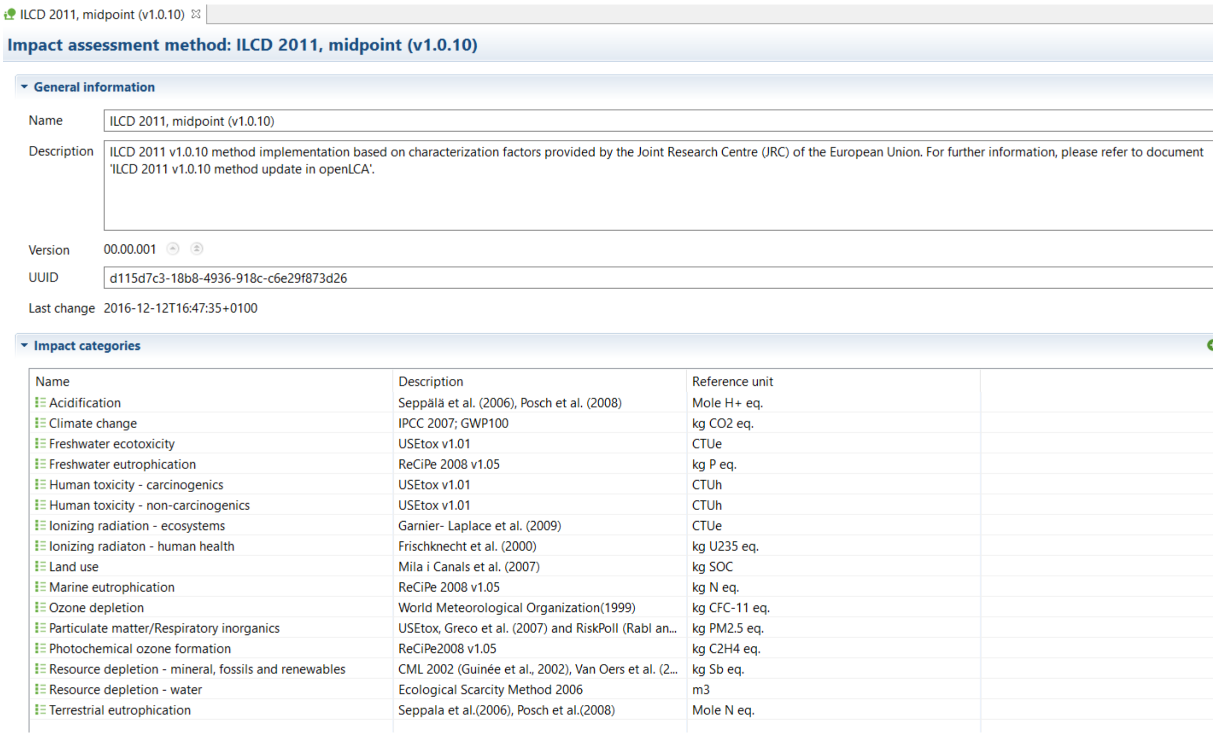


Figure 5 Imported ILCD methods in the navigation pane

In the general information tab you will find a short description of the ILCD method and the models used for each impact category (Figure 6).



Name	Description	Reference unit
Acidification	Seppälä et al. (2006), Posch et al. (2008)	Mole H+ eq.
Climate change	IPCC 2007; GWP100	kg CO2 eq.
Freshwater ecotoxicity	USEtox v1.01	CTUe
Freshwater eutrophication	ReCiPe 2008 v1.05	kg P eq.
Human toxicity - carcinogenics	USEtox v1.01	CTUh
Human toxicity - non-carcinogenics	USEtox v1.01	CTUh
Ionizing radiation - ecosystems	Garnier- Laplace et al. (2009)	CTUe
Ionizing radiaton - human health	Frischknecht et al. (2000)	kg U235 eq.
Land use	Mila i Canals et al. (2007)	kg SOC
Marine eutrophication	ReCiPe 2008 v1.05	kg N eq.
Ozone depletion	World Meteorological Organization(1999)	kg CFC-11 eq.
Particulate matter/Respiratory inorganics	USEtox, Greco et al. (2007) and RiskPoll (Rabl an...	kg PM2.5 eq.
Photochemical ozone formation	ReCiPe2008 v1.05	kg C2H4 eq.
Resource depletion - mineral, fossils and renewables	CML 2002 (Guinée et al., 2002), Van Oers et al. (2...	kg Sb eq.
Resource depletion - water	Ecological Scarcity Method 2006	m3
Terrestrial eutrophication	Seppala et al.(2006), Posch et al.(2008)	Mole N eq.

Figure 6 General information tab of the ILCD 2011 v1.0.10 method in openLCA

In the Impact factors tab you can find all characterization factors implemented for each impact category (Figure 7).

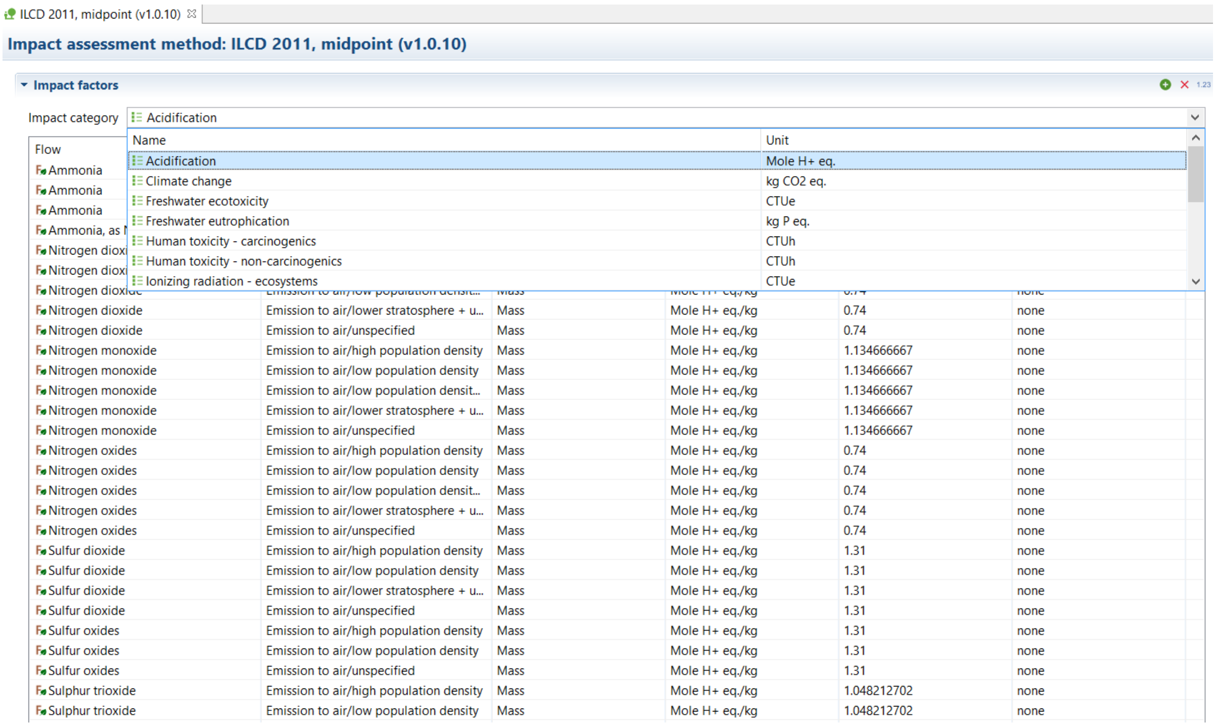


Figure 7 Impact factors tab of the ILCD 2011 v1.0.10 method in openLCA

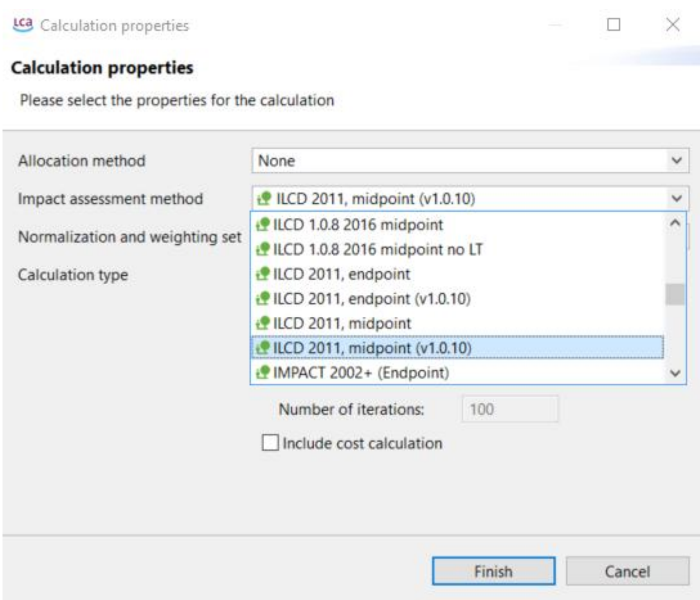


Figure 8 Selection of the impact assessment method to be used for the LCIA calculation in openLCA

6 Comparison of the updated ILCD method with other ILCD implementations

A quality assessment was conducted by comparing the LCIA results of the updated openLCA ILCD v1.0.10 method implementation with other ILCD method implementations at midpoint and endpoint levels.

6.1 LCIA results, midpoint

The LCIA results at midpoint of four different ILCD method implementations were analysed:

- openLCA ILCD 2011, v1.0.10 (LCIA method v1.5.5 using openLCA 1.5.0)
- openLCA ILCD 2011, v1.0.5 (LCIA method v1.5.5 using openLCA 1.5.0)
- ecoinvent ILCD 2011, v1.0.8 (LCIA method v3.3 using openLCA 1.5.0)
- SimaPro ILCD 2011, v1.0.8 (using SimaPro 8.2.3.0)

A selection of ecoinvent 3.2 unit processes (cut-off) was used for the assessment, as shown in table 9.

Table 9 Processes used in the quality assessment

Unit Process	Location	Functional Unit of the reference product
photovoltaic panel production, CIS | photovoltaic panel, CIS | cut-off, U	DE	1 m^2
glass fibre reinforced plastic production, polyamide, injection moulded | glass fibre reinforced plastic, polyamide, injection moulded | cut-off, U	RER	1 kg
market for cast iron | cast iron | cut-off, U	GLO	1 kg

Table 10 shows the LCIA total results at midpoint level for 1 m^2 of photovoltaic panel for the different ILCD method implementations under study.

Table 10 LCIA midpoint total results for the product system "photovoltaic panel production, CIS | photovoltaic panel, CIS | cut-off, U"

Impact category ILCD midpoint	Reference unit	LCIA result openLCA 1.0.10	LCIA result openLCA 1.0.5	LCIA result ecoinvent 1.0.8	LCIA result SimaPro 1.0.8
Acidification	Mole H+ eq.	7.937E-01	7.937E-01	7.937E-01	7.934E-01
Climate change	kg CO2 eq.	1.298E+02	1.296E+02	1.293E+02	1.295E+02
Terrestrial eutrophication	Mole N eq.	1.355E+00	1.355E+00	1.355E+00	1.354E+00
Marine eutrophication	kg N eq.	1.360E-01	1.352E-01	1.360E-01	1.356E-01
Freshwater eutrophication	kg P eq.	1.342E-01	1.341E-01	1.342E-01	1.336E-01
Freshwater ecotoxicity	CTUe	5.079E+03	3.315E+02	5.079E+03	4.988E+03
Human toxicity - carcinogenics	CTUh	1.243E-05	1.213E-05	1.241E-05	1.136E-05
Human toxicity - non-carcinogenics	CTUh	1.306E-04	6.495E-05	1.305E-04	1.271E-04
Ionizing radiation - ecosystems	CTUe	4.623E-05	4.624E-05	5.166E-05	5.164E-05
Ionizing radiaton - human health	kg U235 eq.	1.707E+01	1.706E+01	1.706E+01	1.706E+01
Land use	kg SOC	1.705E+02	4.220E+01	1.574E+02	1.565E+02
Ozone depletion	kg CFC-11 eq.	7.455E-06	7.455E-06	7.455E-06	7.447E-06
Particulate matter/Respiratory inorganics	kg PM2.5 eq.	1.202E-01	1.171E-01	1.171E-01	1.170E-01
Photochemical ozone formation	kg C2H4 eq.	3.574E-01	3.520E-01	3.520E-01	3.517E-01
Resource depletion - mineral, fossils and renewables	kg Sb eq.	8.407E-02	3.944E-05	8.315E-02	8.395E-02
Resource depletion - water	m3	2.831E-01	5.986E-02	Not available	-1.418E-02

Table 11 shows the LCIA total results at midpoint level for 1 kg of glass fibre reinforced plastic for the different ILCD method implementations under study.

Table 11 LCIA midpoint total results for the product system "glass fibre reinforced plastic production, polyamide, injection moulded | glass fibre reinforced plastic, polyamide, injection moulded | cut-off, U"

Impact category	Reference unit	LCIA result openLCA 1.0.10	LCIA result openLCA 1.0.5	LCIA result ecoinvent 1.0.8	LCIA result SimaPro 1.0.8
Acidification	Mole H+ eq.	3.979E-02	3.979E-02	3.979E-02	3.978E-02
Climate change	kg CO2 eq.	8.853E+00	8.850E+00	8.905E+00	8.847E+00
Terrestrial eutrophication	Mole N eq.	6.319E-02	6.319E-02	6.319E-02	6.318E-02
Marine eutrophication	kg N eq.	1.206E-02	1.203E-02	1.206E-02	1.205E-02
Freshwater eutrophication	kg P eq.	8.508E-04	8.213E-04	8.508E-04	8.435E-04
Freshwater ecotoxicity	CTUe	2.504E+01	1.207E+01	2.507E+01	2.361E+01
Human toxicity - carcinogenics	CTUh	3.332E-07	3.299E-07	3.346E-07	3.224E-07
Human toxicity - non-carcinogenics	CTUh	4.101E-07	2.449E-07	4.098E-07	3.658E-07
Ionizing radiation - ecosystems	CTUe	7.731E-07	7.733E-07	8.494E-07	8.490E-07
Ionizing radiaton - human health	kg U235 eq.	2.601E-01	2.600E-01	2.600E-01	2.599E-01
Land use	kg SOC	2.570E+00	1.212E+00	2.415E+00	2.404E+00
Ozone depletion	kg CFC-11 eq.	1.558E-07	1.558E-07	1.558E-07	1.557E-07
Particulate matter/Respiratory inorganics	kg PM2.5 eq.	6.013E-03	5.447E-03	5.448E-03	5.448E-03
Photochemical ozone formation	kg C2H4 eq.	2.174E-02	2.135E-02	2.135E-02	2.135E-02
Resource depletion - mineral, fossils and renewables	kg Sb eq.	4.876E-05	6.147E-07	4.641E-05	4.672E-05
Resource depletion - water	m3	3.483E-02	7.092E-04	Not available	2.704E-02

Table 12 shows the LCIA total results at midpoint level for 1 kg of cast iron (market for cast iron, global) for the different ILCD method implementations under study.

Table 12 LCIA midpoint total results for the product system "market for cast iron | cast iron | cut-off, U"

Impact category	Reference unit	LCIA result openLCA 1.0.10	LCIA result openLCA 1.0.5	LCIA result ecoinvent 1.0.8	LCIA result SimaPro 1.0.8
Acidification	Mole H+ eq.	1.009E-02	1.009E-02	1.009E-02	1.009E-02
Climate change	kg CO2 eq.	1.806E+00	1.805E+00	1.860E+00	1.805E+00
Terrestrial eutrophication	Mole N eq.	1.861E-02	1.861E-02	1.862E-02	1.861E-02
Marine eutrophication	kg N eq.	1.761E-03	1.759E-03	1.761E-03	1.760E-03
Freshwater eutrophication	kg P eq.	7.357E-04	7.345E-04	7.357E-04	7.318E-04
Freshwater ecotoxicity	CTUe	4.620E+01	2.861E+01	4.631E+01	4.578E+01
Human toxicity - carcinogenics	CTUh	2.804E-06	2.800E-06	2.794E-06	2.787E-06
Human toxicity - non-carcinogenics	CTUh	2.762E-06	2.595E-06	2.762E-06	2.742E-06
Ionizing radiation - ecosystems	CTUe	3.433E-07	3.434E-07	3.719E-07	3.718E-07
Ionizing radiaton - human health	kg U235 eq.	1.014E-01	1.013E-01	1.013E-01	1.013E-01
Land use	kg SOC	2.477E+00	1.420E+00	2.381E+00	2.375E+00

Impact category	Reference unit	LCIA result openLCA 1.0.10	LCIA result openLCA 1.0.5	LCIA result ecoinvent 1.0.8	LCIA result SimaPro 1.0.8
Ozone depletion	kg CFC-11 eq.	1.093E-07	1.093E-07	1.093E-07	1.092E-07
Particulate matter/Respiratory inorganics	kg PM2.5 eq.	2.243E-03	1.912E-03	1.921E-03	1.921E-03
Photochemical ozone formation	kg C2H4 eq.	8.722E-03	7.445E-03	7.446E-03	7.444E-03
Resource depletion - mineral, fossils and renewables	kg Sb eq.	2.514E-05	1.617E-08	2.367E-05	2.386E-05
Resource depletion - water	m3	4.463E-03	3.410E-04	Not available	2.412E-03

6.1.1 openLCA ILCD v1.0.10 compared to openLCA ILCD v1.0.5, midpoint

Table 13 shows the ratio of the LCIA midpoint results between the openLCA ILCD v1.0.10 and openLCA ILCD v1.0.5 method implementation for three processes studied. The impact categories acidification, climate change, terrestrial eutrophication, freshwater eutrophication, marine eutrophication, human toxicity - carcinogenics, ionizing radiation - ecosystems, ionizing radiation - human health and ozone depletion have the same result (i.e. ratio = 1).

Table 13 Ratio of LCIA midpoint results between openLCA ILCD v1.0.10 and openLCA ILCD v1.0.5 method implementation

Ratio of ILCD implementation 0.90 < x < 1.10

Ratio of ILCD implementation 0.90 > x or 1.10 < x

Impact category ILCD midpoint	Photovoltaic panel LCIA openLCA 1.0.10 / LCIA openLCA 1.0.05	Glass fibre plastic LCIA openLCA 1.0.10 / LCIA openLCA 1.0.05	Market cast iron LCIA openLCA 1.0.10 / LCIA openLCA 1.0.05	Average LCIA openLCA 1.0.10 / LCIA openLCA 1.0.05
Acidification	1.00	1.00	1.00	1.00
Climate change	1.00	1.00	1.00	1.00
Terrestrial eutrophication	1.00	1.00	1.00	1.00
Marine eutrophication	1.01	1.00	1.00	1.00
Freshwater eutrophication	1.00	1.04	1.00	1.01
Freshwater ecotoxicity	15.32	2.07	1.62	6.34
Human toxicity - carcinogenics	1.02	1.01	1.00	1.01
Human toxicity - non-carcinogenics	2.01	1.67	1.06	1.58
Ionizing radiation - ecosystems	1.00	1.00	1.00	1.00
Ionizing radiaton - human health	1.00	1.00	1.00	1.00
Land use	4.04	2.12	1.74	2.64
Ozone depletion	1.00	1.00	1.00	1.00
Particulate matter/Respiratory inorganics	1.03	1.10	1.17	1.10
Photochemical ozone formation	1.02	1.02	1.17	1.07
Resource depletion - mineral, fossils and renewables	2131.67	79.32	1555.31	1255.43
Resource depletion - water	4.73	49.12	13.09	22.31

To identify the differences in LCIA results between the openLCA ILCD v1.0.10 and v1.0.5 methods implementation, a detailed analysis of the results was conducted for the rest of impact categories:

Freshwater ecotoxicity: "Copper, Ion", "Zinc, ion", "Vanadium, ion" and "Nickel, ion" are not characterized in the ILCD v1.0.5 method implementation, but are included in the current openLCA ILCD v1.0.10. The different ratios for each product system studied vary depending on the relative flow contribution to the product system.

Human toxicity - non-carcinogenics: "Zinc, ion", "Cadmium, ion", "Vanadium, ion", "Copper, ion", "Arsenic, ion", "Silver, ion", "Nickel, ion", "2,4-DB", "Fungicides, unspecified", "Imazethapyr", "Lambda-cyhalothrin", "Quizalofop ethyl ester " and "Tribufos" are not characterized in the openLCA ILCD v1.0.5 method implementation for none compartments, while they are included in the current openLCA ILCD v1.0.10. The different ratios for each product system studied vary depending on the relative flow contribution to the product system.

"Atrazine", "Bentazone", "Bromoxynil ", "Carbaryl", "Dicamba", "Ethephon", "Glyphosate", "MCPA", "MCPB", "Methomyl", "Propiconazole" and "Tebuconazole" are not characterized for the compartment "Emission to water/surface water" in the previous ILCD method implementation in openLCA, while they are included in the current ILCD method. As these flows were added in the reference list of ecoinvent v3.1 and 3.2 and were also implemented as openLCA elementary flows after the ILCD method implementation v1.0.5 in openLCA, they are not considered in ILCD v1.0.5.

Land use: Changes in the ILCD 2011 method in version 1.0.6 included logical modifications for land use (i.e. negative values for all "from" flows as contrary to all "to" flows). Additionally, new elementary flows were added and characterization factors were changed in the list provided by ILCD in version 1.0.6 and 1.0.8 for this impact category. Thus, great differences in results between the current ILCD method implementation based on v1.0.10 compared to the previous ILCD v1.0.5 method implementation in openLCA occur for this impact category.

Particulate matter/Respiratory inorganics: In the previous ILCD method implementation, "Particulates > 2.5 µm and < 10 µm" were not characterized. Whether or not PM 2.5-10 should be considered as primary PM is debated among the original methods (see also section 3.5). In the openLCA ILCD v1.0.10 method implementation a conservative approach is taken, thus, PM2.5, PM2.5-10 and PM 10 are characterized, as recommended by the RiskPoll model.

Photochemical ozone formation: In the previous ILCD method implementation "Carbon monoxide, fossil" is not considered, while it is included in the updated openLCA ILCD method. Thus, differences in results between the ILCD method implementations occur for this impact category depending on the relative flow contribution to the product system.

Resource depletion - mineral, fossils and renewables: A considerable increase in the LCIA results of the current openLCA ILCD method implementation can be observed for this impact category. The current ILCD version includes more fossil flows characterized than the previous ILCD method implementation in openLCA. Thus, the impacts for the processes studied are much higher based on the ILCD v1.0.10 implementation.

Resource depletion - water: A considerable increase in the LCIA results of the current openLCA ILCD method implementation can be observed. The current ILCD version includes more water flows characterized than the previous ILCD method implementation in openLCA. Therefore, the impacts for the processes studied are much higher using the ILCD v1.0.10 implementation.

6.1.2 openLCA ILCD v1.0.10 compared to ecoinvent ILCD v1.0.8, midpoint

Table 14 shows the ratio of the LCIA midpoint results between the openLCA ILCD v1.0.10 and the ecoinvent ILCD v1.0.8 implementation for three processes studied. Apart from the impact categories particulate matter/respiratory inorganics and photochemical ozone formation, the LCIA total results for the other impact categories are equal (i.e. ratio = 1) using the openLCA ILCD v1.0.10 and ecoinvent ILCD v1.0.8 method implementation.

Table 14 Ratio of LCIA midpoint results between openLCA ILCD v1.0.10 and ecoinvent ILCD v1.0.8 method implementation

Ratio of ILCD implementation 0.90 < x < 1.10

Ratio of ILCD implementation 0.90 > x or 1.10 < x

Impact category ILCD midpoint	Photovoltaic panel LCIA openLCA 1.0.10 / LCIA ecoinvent 1.0.8	Glass fibre plastic LCIA openLCA 1.0.10 / LCIA ecoinvent 1.0.8	Market cast iron LCIA openLCA 1.0.10 / LCIA ecoinvent 1.0.8	Average LCIA openLCA 1.0.10 / LCIA ecoinvent 1.0.8
Acidification	1.00	1.00	1.00	1.00
Climate change	1.00	0.99	0.97	0.99
Terrestrial eutrophication	1.00	1.00	1.00	1.00
Marine eutrophication	1.00	1.00	1.00	1.00
Freshwater eutrophication	1.00	1.00	1.00	1.00
Freshwater ecotoxicity	1.00	1.00	1.00	1.00
Human toxicity - carcinogenics	1.00	1.00	1.00	1.00
Human toxicity - non-carcinogenics	1.00	1.00	1.00	1.00
Ionizing radiation - ecosystems	0.89	0.91	0.92	0.91
Ionizing radiaton - human health	1.00	1.00	1.00	1.00
Land use	1.08	1.06	1.04	1.06
Ozone depletion	1.00	1.00	1.00	1.00
Particulate matter/Respiratory inorganics	1.03	1.10	1.17	1.10
Photochemical ozone formation	1.02	1.02	1.17	1.07
Resource depletion - mineral, fossils and renewables	1.01	1.05	1.06	1.04
Resource depletion - water	Not available	Not available	Not available	Not available

Particulate matter/Respiratory inorganics: The ecoinvent ILCD method implementation only considers "Particulates < 2.5 μm" as primary particulate matter (PM), while the current openLCA ILCD method includes PM2.5, PM2.5-10 and PM10. Thus, differences in results between the ILCD method implementations occur for this impact category.

Photochemical ozone formation: In the ecoinvent ILCD method implementation "Carbon monoxide" is not considered, while it is included in the updated openLCA ILCD method. Thus, differences in results between the ILCD method implementations occur for this impact category depending on the relative flow contribution to the product system.

6.1.3 openLCA ILCD v1.0.10 compared to SimaPro v1.0.8, midpoint

Table 15 shows the ratio of the LCIA midpoint results between the openLCA ILCD v1.0.10 and the SimaPro ILCD v1.0.8 implementation for three processes studied. Apart from the impact categories particulate matter/respiratory inorganics, photochemical ozone formation and water depletion, the LCIA total results for the other impact categories are equal (i.e. ratio = 1) in both ILCD implementations.

Table 15 Ratio of LCIA midpoint results between openLCA ILCD v1.0.10 and SimaPro ILCD v1.0.8 method implementation

Ratio of ILCD implementation 0.90 < x < 1.10
Ratio of ILCD implementation 0.90 > x or 1.10 < x

Impact category ILCD midpoint	Photovoltaic panel LCIA openLCA 1.0.10 / LCIA SimaPro 1.0.8	Glass fibre plastic LCIA openLCA 1.0.10 / LCIA SimaPro 1.0.8	Market cast iron LCIA openLCA 1.0.10 / LCIA SimaPro 1.0.8	Average LCIA openLCA 1.0.10 / LCIA SimaPro 1.0.8
Acidification	1.00	1.00	1.00	1.00
Climate change	1.00	1.00	1.00	1.00
Terrestrial eutrophication	1.00	1.00	1.00	1.00
Marine eutrophication	1.00	1.00	1.00	1.00
Freshwater eutrophication	1.00	1.01	1.01	1.01
Freshwater ecotoxicity	1.02	1.06	1.01	1.03
Human toxicity - carcinogenics	1.09	1.03	1.01	1.04
Human toxicity - non-carcinogenics	1.03	1.12	1.01	1.05
Ionizing radiation - ecosystems	0.90	0.91	0.92	0.91
Ionizing radiaton - human health	1.00	1.00	1.00	1.00
Land use	1.09	1.07	1.04	1.07
Ozone depletion	1.00	1.00	1.00	1.00
Particulate matter/Respiratory inorganics	1.03	1.10	1.17	1.10
Photochemical ozone formation	1.02	1.02	1.17	1.07
Resource depletion - mineral, fossils and renewables	1.00	1.04	1.05	1.03
Resource depletion - water	-19.96	1.29	1.85	-5.61

Particulate matter/Respiratory inorganics: The SimaPro ILCD method implementation considers "Particulates < 2.5 µm" and "Particulates < 10 µm" as primary particulate matter (PM), In the openLCA ILCD v1.0.10 method implementation a conservative approach is taken, thus, PM2.5, PM2.5-10 and PM 10 are characterized, as recommended by the RiskPoll model. Thus, differences in results between the ILCD method implementations occur for this impact category.

Photochemical ozone formation: In the SimaPro ILCD method implementation "Carbon monoxide" is not considered, but is included in the updated openLCA ILCD method. Thus, differences in results between the ILCD method implementations occur for this impact category depending on the relative flow contribution to the product system.

Resource depletion - water: Differences in "Resource depletion - water" occur because the Life Cycle Inventory of water flows in SimaPro is different as compared to openLCA. Since the ILCD v1.0.3 method implementation (February 2014) in SimaPro, regionalized water flows are included as elementary flows in SimaPro which are characterized with regionalized impact factors. In openLCA the location is not included in the flow name. Instead, the regionalized LCIA calculation approach derives the location of the flow from the location of the process where the flow is used. For further information, see also section 2.1.3. Taken the different approaches for regionalization between openLCA and SimaPro into account, the LCIA results for this impact category are not comparable due to differences in the Life Cycle Inventory for water flows.

6.2 LCIA results, endpoint

The LCIA results at endpoint of openLCA ILCD v1.0.10 method implementation were analysed and compared to the ILCD v1.0.5 and ReCiPe 1.11 method implementations of the openLCA LCIA method pack v1.5.5.

Table 16 shows the LCIA total results at endpoint level for 1 m2 of photovoltaic panel for the ILCD 2011 v1.0.10 and v1.0.5, ReCiPe v1.11 and USEtox v1.01 implementations in openLCA.

Table 16 LCIA endpoint total results for the product system "photovoltaic panel production, CIS | photovoltaic panel, CIS | cut-off, U"

Impact category ILCD endpoint	**Reference unit**	**LCIA result openLCA 1.0.10**	**LCIA result openLCA 1.0.5**	**LCIA result openLCA ReCiPe v.1.11**
Ecosystems - Acidification	PNOF	3.516E-09	3.516E-09	3.516E-09
Ecosystems - Climate change	PDF	1.029E-06	1.028E-06	1.024E-06
Ecosystems - Eutrophication freshwater	PDF	5.898E-09	5.891E-09	5.980E-09
Ecosystems - Land use	PDF	1.248E-07	4.467E-08	2.997E-07
Ecosystems - total	species*year	1.163E-06	1.082E-06	1.342E-06
Human health - total	DALY	8.939E-04	7.073E-04	Not comparable
Human health - Climate change	DALY	1.818E-04	1.814E-04	1.808E-04
Human health - Ionizing radiation	DALY	2.800E-07	2.798E-07	2.803E-07
Human health - Ozone depletion	DALY	1.796E-08	1.796E-08	1.801E-08
Human health - Photochemical ozone formation	DALY	1.394E-08	1.373E-08	1.395E-08
Resource depletion - Mineral, fossils and renewables (ReCiPe 1.05)	$	5.706E+02	2.579E-03	Not comparable
Resource depletion - total (ReCiPe 1.05)	$	5.706E+02	2.579E-03	Not comparable
Resource depletion - Mineral, fossils and renewables (ReCiPe 1.11)	$	8.413E+00	Not comparable	8.389E+00
Resource depletion - total (ReCiPe 1.11)	$	8.413E+00	Not comparable	8.389E+00
Human health - Human toxicity, carcinogenics	DALY	1.429E-04	1.395E-04	Not comparable
Human health - Human toxicity, non-carcinogenics	DALY	3.525E-04	1.754E-04	Not comparable
Human health - Particulate matter/Respiratory inorganics	DALY	2.164E-04	2.107E-04	Not comparable

Table 17 shows the LCIA total results at endpoint level for 1 kg of glass fibre reinforced plastic for the ILCD 2011 v1.0.10 and v1.0.5 and ReCiPe v1.11 implementations in openLCA.

Table 17 LCIA endpoint total results for the product system "glass fibre reinforced plastic production, polyamide, injection moulded | glass fibre reinforced plastic, polyamide, injection moulded | cut-off, U"

Impact category ILCD endpoint	Reference unit	LCIA result openLCA 1.0.10	LCIA result openLCA 1.0.5	LCIA result openLCA ReCiPe v1.11
Ecosystems - Acidification	PNOF	1.758E-10	1.758E-10	1.758E-10
Ecosystems - Climate change	PDF	7.019E-08	7.017E-08	7.050E-08
Ecosystems - Eutrophication freshwater	PDF	3.740E-11	3.609E-11	3.790E-11
Ecosystems - Land use	PDF	3.325E-09	6.380E-10	2.219E-08
Ecosystems - total	species*year	7.368E-08	7.102E-08	9.295E-08
Human health - total	DALY	2.816E-05	2.666E-05	Not comparable
Human health - Climate change	DALY	1.239E-05	1.239E-05	1.245E-05
Human health - Ionizing radiation	DALY	4.266E-09	4.264E-09	4.269E-09
Human health - Ozone depletion	DALY	3.782E-10	3.782E-10	3.788E-10
Human health - Photochemical ozone formation	DALY	8.480E-10	8.328E-10	8.568E-10
Resource depletion - Mineral, fossils and renewables (ReCiPe 1.05)	$	4.847E+01	2.142E-06	Not comparable
Resource depletion - total (ReCiPe 1.05)	$	4.847E+01	2.142E-06	Not comparable
Resource depletion - Mineral, fossils and renewables (ReCiPe 1.11)	$	4.663E-01	Not comparable	4.654E-01
Resource depletion - total (ReCiPe 1.11)	$	4.663E-01	Not comparable	4.654E-01
Human health - Human toxicity, carcinogenics	DALY	3.832E-06	3.794E-06	Not comparable
Human health - Human toxicity, non-carcinogenics	DALY	1.107E-06	6.612E-07	Not comparable
Human health - Particulate matter/Respiratory inorganics	DALY	1.082E-05	9.805E-06	Not comparable

Table 18 shows the LCIA total results at midpoint level for 1 kg of cast iron (market for cast iron, global) for the ILCD 2011 v1.0.10 and v1.0.5 and ReCiPe v1.11 in openLCA.

Table 18 LCIA endpoint total results for the product system "market for cast iron | cast iron | cut-off, U"

Impact category ILCD endpoint	Reference unit	LCIA result openLCA 1.0.10	LCIA result openLCA 1.0.5	LCIA result openLCA ReCiPe v1.11
Ecosystems - Acidification	PNOF	4.462E-11	4.462E-11	4.462E-11
Ecosystems - Climate change	PDF	1.432E-08	1.431E-08	1.440E-08
Ecosystems - Eutrophication freshwater	PDF	3.233E-11	3.227E-11	3.277E-11
Ecosystems - Land use	PDF	1.219E-09	7.451E-10	2.017E-09
Ecosystems - total	species*year	1.562E-08	1.513E-08	1.659E-08
Human health - total	DALY	4.633E-05	4.518E-05	Not comparable
Human health - Climate change	DALY	2.528E-06	2.527E-06	2.543E-06

Impact category ILCD endpoint	Reference unit	LCIA result openLCA 1.0.10	LCIA result openLCA 1.0.5	LCIA result openLCA ReCiPe v1.11
Human health - Human toxicity, carcinogenics	DALY	3.225E-05	3.220E-05	1.665E-09
Human health - Human toxicity, non-carcinogenics	DALY	7.457E-06	7.006E-06	3.171E-10
Human health - Ionizing radiation	DALY	1.663E-09	1.662E-09	3.415E-10
Resource depletion - Mineral, fossils and renewables (ReCiPe 1.05)	$	8.025E+00	2.503E-06	Not comparable
Resource depletion - total (ReCiPe 1.05)	$	8.025E+00	2.503E-06	Not comparable
Resource depletion - Mineral, fossils and renewables (ReCiPe 1.11)	$	1.470E-01	Not comparable	1.464E-01
Resource depletion - total (ReCiPe 1.11)	$	1.470E-01	Not comparable	1.464E-01
Human health - Ozone depletion	DALY	3.169E-10	3.169E-10	Not comparable
Human health - Particulate matter/Respiratory inorganics	DALY	4.037E-06	3.442E-06	Not comparable
Human health - Photochemical ozone formation	DALY	3.402E-10	2.904E-10	Not comparable

6.2.1 openLCA ILCD v1.0.10 compared to openLCA ILCD v1.0.5, endpoint

Table 19 shows the ratio of the LCIA endpoint results between the openLCA ILCD v1.0.10 and openLCA ILCD v1.0.5 method implementation for three processes studied. The impact categories ecosystems - acidification, ecosystems - climate change, ecosystems - eutrophication freshwater, human health - climate change, human health - human toxicity, carcinogenics, human health - ionizing radiation, human health - ozone depletion have the same result (i.e. ratio = 1).

Table 19 Ratio of LCIA endpoint results between openLCA ILCD v1.0.10 and v1.0.5 method implementation

Ratio of ILCD implementation 0.90 < x < 1.10
Ratio of ILCD implementation 0.90 > x or 1.10 < x

Impact category ILCD endpoint	Photovoltaic panel LCIA openLCA 1.0.10 / LCIA openLCA 1.0.5	Glass fibre plastic LCIA openLCA 1.0.10 / LCIA openLCA 1.0.5	Market cast iron LCIA openLCA 1.0.10 / LCIA openLCA 1.0.5
Ecosystems - Acidification	1.00	1.00	1.00
Ecosystems - Climate change	1.00	1.00	1.00
Ecosystems - Eutrophication freshwater	1.00	1.04	1.00
Ecosystems - Land use	2.79	5.21	1.64
Ecosystems - total	1.07	1.04	1.03
Human health - total	1.26	1.06	1.02
Human health - Climate change	1.00	1.00	1.00
Human health - Human toxicity, carcinogenics	1.02	1.01	1.00
Human health - Human toxicity, non-carcinogenics	2.01	1.67	1.06
Human health - Ionizing radiation	1.00	1.00	1.00
Human health - Ozone depletion	1.00	1.00	1.00

Impact category ILCD endpoint	Photovoltaic panel LCIA openLCA 1.0.10 / LCIA openLCA 1.0.5	Glass fibre plastic LCIA openLCA 1.0.10 / LCIA openLCA 1.0.5	Market cast iron LCIA openLCA 1.0.10 / LCIA openLCA 1.0.5
Human health - Particulate matter/Respiratory inorganics	1.03	1.10	1.17
Human health - Photochemical ozone formation	1.02	1.02	1.17
Resource depletion - Mineral, fossils and renewables (ReCiPe 1.05)	221289.68	22631503.86	3206251.55
Resource depletion - total (ReCiPe 1.05)	221289.68	22631503.86	3206251.55

To identify the differences in LCIA results between the openLCA ILCD v1.0.10 and v1.0.5 methods implementation, a detailed analysis of the results was conducted for the rest of impact categories:

Ecosystems - Land use: Changes in the ILCD 2011 method in version 1.0.6 included logical modifications for land use (i.e. negative values for all "from" flows as contrary to all "to" flows). Additionally, new elementary flows were added and characterization factors were changed in the list provided by ILCD in version 1.0.6 and 1.0.8 for this impact category. Thus, great differences in results between the current ILCD method implementation based on v1.0.10 compared to the previous ILCD v1.0.5 method implementation in openLCA occur for this impact category.

Human health - Human toxicity, non-carcinogenics: "Zinc, ion", "Cadmium, ion", "Vanadium, ion", "Copper, ion", "Arsenic, ion", "Silver, ion", "Nickel, ion", "2,4-DB", "Fungicides, unspecified", "Imazethapyr", "Lambda-cyhalothrin", "Quizalofop ethyl ester " and "Tribufos" are not characterized in the openLCA ILCD v1.0.5 method implementation for none compartments, while they are included in the current openLCA ILCD v1.0.10.

"Atrazine", "Bentazone", "Bromoxynil ", "Carbaryl", "Dicamba", "Ethephon", "Glyphosate", "MCPA", "MCPB", "Methomyl", "Propiconazole" and "Tebuconazole" are not characterized for the compartment "Emission to water/surface water" in the previous ILCD method implementation in openLCA, while they are included in the current ILCD method. As these flows were added in the reference list of ecoinvent v3.1 and 3.2 and were also implemented as openLCA elementary flows after the ILCD method implementation v1.0.5 in openLCA, they are not considered in ILCD v1.0.5.

The different ratios for each product system studied vary depending on the relative flow contribution to the product system.

Human health - Particulate matter/Respiratory inorganics: In the previous ILCD method implementation, "Particulates > 2.5 µm and < 10 µm" were not characterized. Whether or not "Particulates > 2.5 µm and < 10 µm" should be considered as primary particulate matter is debated among the original methods (see also section 3.5). In the openLCA ILCD v1.0.10 method implementation a conservative approach is taken, thus, PM2.5, PM2.5-10 and PM 10 are characterized, as recommended by the RiskPoll model.

Human health - Photochemical ozone formation: In the previous ILCD method implementation "Carbon monoxide" is not considered, while it is included in the updated openLCA ILCD method.

Thus, differences in results between the ILCD method implementations occur for this impact category depending on the relative flow contribution to the product system.

Resource depletion - Mineral, fossils and renewables: A considerable increase in the LCIA results of the current openLCA ILCD method implementation can be observed for this impact category. The current ILCD version includes more fossil flows characterized than the previous ILCD method implementation in openLCA. Thus, the impacts for the processes studied are much higher based on the ILCD v1.0.10 implementation.

6.2.2 openLCA ILCD v1.0.10 compared to openLCA ReCiPe 2008 H v1.11, endpoint

Impact categories which are based on ReCiPe as recommended model in ILCD can be compared to the openLCA ReCiPe 2008 method. Table 20 shows the ratio of the LCIA endpoint results between the openLCA ILCD v1.0.10 and the ReCiPe 2008 H v1.11 implementation in openLCA for three processes studied.

As in the updated ILCD method implementation, ReCiPe v1.05 is used, the LCIA results obtained can be compared to ReCiPe v1.11, unless the CFs changed between both versions. But apart from ecosystems- land use, the LCIA total results for the other impact categories are equal (i.e. ratio = 1) for both implementations.

Table 20 Ratio of LCIA endpoint results between openLCA ILCD v1.0.10 and openLCA ReCiPe 1.11 method implementation

Ratio of ILCD implementation 0.90 < x < 1.10

Ratio of ILCD implementation 0.90 > x or 1.10 < x

Impact category ILCD endpoint	**Photovoltaic panel LCIA openLCA 1.0.10 / LCIA openLCA ReCiPe v1.11**	**Glass fibre plastic LCIA openLCA 1.0.10 / LCIA openLCA ReCiPe v1.11**	**Market cast iron LCIA openLCA 1.0.10 / LCIA openLCA ReCiPe v1.11**
Ecosystems - Acidification	1.00	1.00	1.00
Ecosystems - Climate change	1.01	1.00	0.99
Ecosystems - Eutrophication freshwater	0.99	0.99	0.99
Ecosystems - Land use	0.42	0.15	0.60
Ecosystems - total	0.87	0.79	0.94
Human health - total	Not comparable	Not comparable	Not comparable
Human health - Climate change	1.01	1.00	0.99
Human health - Ionizing radiation	1.00	1.00	1.00
Human health - Ozone depletion	1.00	1.00	1.00
Human health - Photochemical ozone formation	1.00	0.99	1.00
Resource depletion - Mineral, fossils and renewables (ReCiPe 1.11)	1.00	1.00	1.00
Resource depletion - total (ReCiPe 1.11)	1.00	1.00	1.00

Ecosystems - land use: The openLCA ReCiPe method implementation is based on characterization factors ReCiPe v1.11, while the factors provided by ILCD for this impact category and implemented in the openLCA ILCD v1.0.10 method are based on ReCiPe v1.05. Because the CFs for many elementary flows in this impact category have changed between both ReCiPe versions[14], the LCIA results of implementations for this impact category are not comparable.

6.3 Conclusions

The same LCIA results are obtained for most impact categories using the different ILCD implementations studied. However, differences in LCIA results occur, amongst others due to different approaches taken during the technical method implementation. Differences obtained in the LCIA results based on the openLCA ILCD v1.0.10 method compared to other ILCD implementations are commented by providing supplementing information related to the updated ILCD 2011 method in openLCA and the assumptions considered when assigning the characterization factors to the elementary flows.

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Annex I. Gross and net calorific values used in the resource depletion impact categories

Gross calorific values are used in the endpoint categories "Resource depletion - Mineral, fossils and renewables (ReCiPe v1.05)" and "Resource depletion - total (ReCiPe v1.05)", and net calorific values are used in the midpoint category "Resource depletion - Mineral, fossils and renewables", in the endpoint categories "Resource depletion - Mineral, fossils and renewables (ReCiPe v1.11)" and "Resource depletion - total (ReCiPe v1.11)".

Flow name	Flow property	Reference unit	Gross calorific value (MJ/ref. unit of flow)	Source	Net calorific value (MJ/ref. unit of flow)	Source
brown coal; 11.9 MJ/kg	Net calorific value	MJ	1.13	GaBi SP30 (Gross Calorific Value information of Lignite (in MJ))	1	Flow property
Coal, 18 MJ per kg, in ground	Mass	kg	18	ReCiPe 1.05	17.12	ReCiPe 1.11
Coal, 18 MJ per kg, in ground	Mass	kg	18	ReCiPe 1.05	17.12	ReCiPe 1.11
Coal, 26.4 MJ per kg, in ground	Mass	kg	26.4	ReCiPe 1.05	25.10	ReCiPe 1.11
Coal, 26.4 MJ per kg, in ground	Mass	kg	26.4	ReCiPe 1.05	25.10	ReCiPe 1.11
Coal, 29.3 MJ per kg, in ground	Mass	kg	29.3	ReCiPe 1.05	27.85	ReCiPe 1.11
Coal, 29.3 MJ per kg, in ground	Mass	kg	29.3	ReCiPe 1.05	27.85	ReCiPe 1.11
Coal, bituminous, 24.8 MJ per kg, in ground	Mass	kg	24.8	ReCiPe 1.05	24.77	SimaPro
Coal, bituminous, 24.8 MJ per kg, in ground	Mass	kg	24.8	ReCiPe 1.05	24.77	SimaPro
Coal, brown, 10 MJ per kg, in ground	Mass	kg	10	ReCiPe 1.05	9.50	ReCiPe 1.11
Coal, brown, 10 MJ per kg, in ground	Mass	kg	10	ReCiPe 1.05	9.50	ReCiPe 1.11
Coal, brown, 8 MJ per kg, in ground	Mass	kg	8	ReCiPe 1.05	7.58	ReCiPe 1.11
Coal, brown, 8 MJ per kg, in ground	Mass	kg	8	ReCiPe 1.05	7.58	ReCiPe 1.11
Coal, brown, in ground	Net calorific value	MJ	1.05	ReCiPe 1.05/1.11	1	Flow property

Flow name	Flow property	Reference unit	Gross calorific value (MJ/ref. unit of flow)	Source	Net calorific value (MJ/ref. unit of flow)	Source
Coal, brown, in ground	Mass	kg	9.9	ReCiPe 1.05	9.42	ReCiPe 1.11
Coal, brown, in ground	Mass	kg	9.9	ReCiPe 1.05	9.42	ReCiPe 1.11
Coal, feedstock, 26.4 MJ per kg, in ground	Mass	kg	26.4	ReCiPe 1.05	25.10	ReCiPe 1.11
Coal, feedstock, 26.4 MJ per kg, in ground	Mass	kg	26.4	ReCiPe 1.05	25.10	ReCiPe 1.11
Coal, hard, 30.7 MJ per kg, in ground	Mass	kg	30.7	ReCiPe 1.05	30.70	Proxy, no data NCV
Coal, hard, unspecified, in ground	Mass	kg	19.1	ReCiPe 1.05	18.37	GaBi SP30
Coal, hard, unspecified, in ground	Mass	kg	19.1	ReCiPe 1.05	18.37	GaBi SP30
crude oil; 42.3 MJ/kg	Net calorific value	MJ	1.07	GaBi SP30 (Gross Calorific Value information of Crude oil (in MJ))	1	Flow property
Energy, from coal	Energy	MJ	1	Flow property	0.95	ReCiPe 1.11
Energy, from coal	Net calorific value	MJ	1.05	ReCiPe 1.11	1	Flow property
Energy, from coal, brown	Energy	MJ	1	Flow property	0.95	ReCiPe 1.11
Energy, from gas, natural	Energy	MJ	1	Flow property	0.90	ReCiPe 1.11
Energy, from oil	Energy	MJ	1	Flow property	0.95	ReCiPe 1.11
Energy, from sulfur	Net calorific value	MJ	1	ReCiPe 1.11	1	Flow property
Energy, unspecified	Energy	MJ	1	Flow property	0.95	Estimated based on values from ReCiPe 1.11 for more specific energy flows
Energy, unspecified	Energy	MJ	1	Flow property	0.95	Estimated based on values from ReCiPe 1.11 for more specific energy flows
Gas, mine, off-gas, process, coal mining	Volume	m3	39.82	ReCiPe 1.05	35.86	GaBi SP30

Flow name	Flow property	Reference unit	Gross calorific value (MJ/ref. unit of flow)	Source	Net calorific value (MJ/ref. unit of flow)	Source
Gas, mine, off-gas, process, coal mining	Volume	m3	39.82	ReCiPe 1.05	35.86	GaBi SP30
Gas, mine, off-gas, process, coal mining/kg	Mass	kg	49.98	ReCiPe 1.05	44.98	ReCiPe 1.11
Gas, mine, off-gas, process, coal mining/kg	Mass	kg	49.98	ReCiPe 1.05	44.98	ReCiPe 1.11
Gas, natural, 30.3 MJ per kg, in ground	Mass	kg	30.3	ReCiPe 1.05	30.28	ReCiPe 1.11
Gas, natural, 30.3 MJ per kg, in ground	Mass	kg	30.3	ReCiPe 1.05	30.28	ReCiPe 1.11
Gas, natural, 35 MJ per m3, in ground	Volume	m3	35.0	ReCiPe 1.05	34.99	ReCiPe 1.11
Gas, natural, 35 MJ per m3, in ground	Volume	m3	35.0	ReCiPe 1.05	34.99	ReCiPe 1.11
Gas, natural, 36.6 MJ per m3, in ground	Volume	m3	36.6	ReCiPe 1.05	36.58	ReCiPe 1.11
Gas, natural, 36.6 MJ per m3, in ground	Volume	m3	36.6	ReCiPe 1.05	36.58	ReCiPe 1.11
Gas, natural, 46.8 MJ per kg, in ground	Mass	kg	46.8	ReCiPe 1.05	46.62	ReCiPe 1.11
Gas, natural, 46.8 MJ per kg, in ground	Mass	kg	46.8	ReCiPe 1.05	46.62	ReCiPe 1.11
Gas, natural, at extraction site	Mass	kg	48.88	GaBi SP30 (Gross Calorific Value information of Gas natural (in kg))	44.03	GaBi SP30
Gas, natural, feedstock, 35 MJ per m3, in ground	Volume	m3	35	ReCiPe 1.05	34.99	ReCiPe 1.11
Gas, natural, feedstock, 35 MJ per m3, in ground	Volume	m3	35	ReCiPe 1.05	34.99	ReCiPe 1.11
Gas, natural, feedstock, 46.8 MJ per kg, in ground	Mass	kg	46.8	ReCiPe 1.05	46.62	ReCiPe 1.11
Gas, natural, feedstock, 46.8 MJ per kg, in ground	Mass	kg	46.8	ReCiPe 1.05	46.62	ReCiPe 1.11
Gas, natural, in ground	Volume	m3	38.3	ReCiPe 1.05	34.47	ReCiPe 1.11

Flow name	Flow property	Reference unit	Gross calorific value (MJ/ref. unit of flow)	Source	Net calorific value (MJ/ref. unit of flow)	Source
Gas, natural, in ground	Net calorific value	MJ	1.11	ReCiPe 1.05/1.11	1.00	Flow property
Gas, natural, in ground	Volume	m3	38.30	ReCiPe 1.05	34.47	ReCiPe 1.11
Gas, off-gas, oil production, in ground	Volume	m3	39.82	ReCiPe 1.05	35.83	ReCiPe 1.11
Gas, off-gas, oil production, in ground	Volume	m3	39.82	ReCiPe 1.05	35.83	ReCiPe 1.11
Gas, petroleum, 35 MJ per m3, in ground	Volume	m3	35	ReCiPe 1.05	34.99	ReCiPe 1.11
Gas, petroleum, 35 MJ per m3, in ground	Volume	m3	35	ReCiPe 1.05	34.99	ReCiPe 1.11
hard coal; 26.3 MJ/kg	Net calorific value	MJ	1.04	GaBi SP30 (Gross Calorific Value information of Hard coal (in MJ))	1	Flow property
Lignite, 11 MJ per kg, in ground	Mass	kg	11	ReCiPe 1.05 approach followed	11.00	Proxy, no data NCV
metallurgical coal	Mass	kg	27.35	GaBi SP30 (Gross Calorific Value information)	26.31	GaBi SP30
natural gas; 44.1 MJ/kg	Net calorific value	MJ	1.11	GaBi SP30 gross calorific value Gas natural (in MJ)	1	Flow property
Nuclear energy	Energy	MJ	1	Flow property	1	No difference between gross and net calorific value
Nuclear energy	Gross calorific value	MJ	1	Flow property	1	No difference between gross and net calorific value
Oil sand (10% bitumen) (in MJ)	Net calorific value	MJ	1.1	GaBi SP30 (Gross Calorific Value information)	1	Flow property
Oil sand (100% bitumen) (in MJ)	Net calorific value	MJ	1.1	GaBi SP30 (Gross Calorific Value information)	1	Flow property
Oil, crude, 38400 MJ per m3, in ground	Volume	m3	38400	ReCiPe 1.05	38388	ReCiPe 1.11
Oil, crude, 38400 MJ per m3, in ground	Volume	m3	38400	ReCiPe 1.05	38388	ReCiPe 1.11
Oil, crude, 41 MJ per kg, in ground	Mass	kg	41	ReCiPe 1.05	40.99	ReCiPe 1.11

Flow name	Flow property	Reference unit	Gross calorific value (MJ/ref. unit of flow)	Source	Net calorific value (MJ/ref. unit of flow)	Source
Oil, crude, 41 MJ per kg, in ground	Mass	kg	41	ReCiPe 1.05	40.99	ReCiPe 1.11
Oil, crude, 42 MJ per kg, in ground	Mass	kg	42	ReCiPe 1.05	42	ReCiPe 1.11
Oil, crude, 42 MJ per kg, in ground	Mass	kg	42	ReCiPe 1.05	42	ReCiPe 1.11
Oil, crude, 42.6 MJ per kg, in ground	Mass	kg	42.6	ReCiPe 1.05	42.42	ReCiPe 1.11
Oil, crude, 42.6 MJ per kg, in ground	Mass	kg	42.6	ReCiPe 1.05	42.42	ReCiPe 1.11
Oil, crude, 42.7 MJ per kg, in ground	Mass	kg	42.7	ReCiPe 1.05	42.84	ReCiPe 1.11
Oil, crude, 42.7 MJ per kg, in ground	Mass	kg	42.7	ReCiPe 1.05	42.84	ReCiPe 1.11
Oil, crude, feedstock, 41 MJ per kg, in ground	Mass	kg	41	ReCiPe 1.05	40.99	ReCiPe 1.11
Oil, crude, feedstock, 41 MJ per kg, in ground	Mass	kg	41	ReCiPe 1.05	40.99	ReCiPe 1.11
Oil, crude, feedstock, 42 MJ per kg, in ground	Mass	kg	42	ReCiPe 1.05	42	ReCiPe 1.11
Oil, crude, feedstock, 42 MJ per kg, in ground	Mass	kg	42	ReCiPe 1.05	42	ReCiPe 1.11
Oil, crude, in ground	Mass	kg	45.78	ReCiPe 1.05	43.49	ReCiPe 1.11
Oil, crude, in ground	Mass	kg	45.78	ReCiPe 1.05	43.49	ReCiPe 1.11
Oil, crude, in ground	Net calorific value	MJ	1.05	ReCiPe 1.05/1.11	1.00	Flow property
Pit gas	Mass	kg	44.77	GaBi SP30 (Gross Calorific Value information)	40.35	GaBi SP30
Pit gas	Normal Volume	m3	36.05	GaBi SP30 (Gross Calorific Value and density information)	32.49	GaBi SP30 (Net Calorific Value and density information)
Pit Methane (in MJ)	Net calorific value	MJ	1.11	GaBi SP30 (Gross Calorific Value information)	1	Flow property
Uranium	Net calorific value	MJ	1	No difference between gross and net calorific value	1	Flow property

Flow name	Flow property	Reference unit	Gross calorific value (MJ/ref. unit of flow)	Source	Net calorific value (MJ/ref. unit of flow)	Source
Uranium	Mass	kg	560000	GaBi SP30, ecoinvent, SimaPro. ILCD uses 544284 MJ/kg	560000	GaBi SP30, ecoinvent, SimaPro. ILCD uses 544284 MJ/kg
Uranium ore, 1.11 GJ per kg	Mass	kg	1100	ReCiPe 1.05 approach followed	1100	No difference between gross and net calorific value
Uranium oxide (U3O8), 332 GJ per kg, in ore	Mass	kg	332000	ReCiPe 1.05 approach followed	332000	No difference between gross and net calorific value
Uranium oxide (U3O8), 332 GJ per kg, in ore	Mass	kg	332000	ReCiPe 1.05 approach followed	332000	No difference between gross and net calorific value
Uranium, 2291 GJ per kg, in ground	Mass	kg	2291000	ReCiPe 1.05 approach followed	2291000	No difference between gross and net calorific value
Uranium, in ground	Mass	kg	560000	GaBi SP30, ecoinvent, SimaPro. ILCD uses 544284 MJ/kg	560000	GaBi SP30, ecoinvent, SimaPro. ILCD uses 544284 MJ/kg
Methane	Mass	kg	35.91	ReCiPe 1.05[15]	50	ReCiPe 1.11
Methane	Mass	kg	35.91	ReCiPe 1.05[14]	50	ReCiPe 1.11
Peat, in ground	Net calorific value	MJ	1.05	ReCiPe 1.05/1.11, ecoinvent	1	ReCiPe 1.11
Peat, in ground	Mass	kg	9.9	Same as "Coal, brown"; ecoinvent	9.42	ReCiPe 1.11 (GaBi SP30 uses a net calorific value of 8.40)
Peat, in ground	Mass	kg	9.9	Same as "Coal, brown"; ecoinvent	9.42	ReCiPe 1.11 (GaBi SP30 uses a net calorific value of 8.40)

[15] Value in the original ReCiPe 1.05 was wrong, as it referred to m^3 instead of kg, which was the actual unit of the flow. In order to be consistent with ReCiPe 1.05, the wrong GCV has been used.