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Supporting information to the characterisation factors of recommended EF Life Cycle Impact Assessment method

New models and differences with ILCD

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Contents

Foreword

This document provides supporting information related to the Life cycle impact assessment method recommended in the framework of the Environmental Footprint (EF) (2013/179/EU), which is derived from the International Life Cycle Data system (ILCD) scheme, developed by the European Commission since 2007, and published in 2010.

Within the document are listed the Life Cycle Impact Assessment (LCIA) models that have been adopted in the EF context, the changes (if any) in comparison with ILCD, and the deviations (if any) from the original references of the different models, and relates choices and assumption made in the development of Characterisation Factors for different impact categories.

In the annexes (within the document and available online through permalinks) the complete list of characterisation factor, changes, and assumptions for different methods are available.

Abstract

In 2013, the Environmental Footprint methodology has been established with a specific Recommendation (2013/179/EU), within the framework of the "Single Market for Green Products" communication (COM/2013/0196). The International Life Cycle Data system, developed since 2007, released in 2010 and continuously maintained by JRC, has been adopted in the EF framework. ILCD format and nomenclature were adopted as requirements for EF.

Given the different needs and goals of the EF, some methods for the Life Cycle Impact Assessment have been changed compared to ILCD (and therefore the elementary flows have been adapted accordingly, and to some extent, the format has been expanded).

The LCIA methods are developed within the database as ILCD-formatted xml files to allow electronic import into LCA software.The LCIA methods are implemented as separate data sets which contain all the descriptive metadata documentation and the characterisation factors assigned to different elementary flows (that are also xml files within the DB).

This document provide a view on the changes occurred within the models for the mid-point impact assessment (the EF is considering for now only impacts at the level of potential changes, not at the potential damage level, which was captured in ILCD scheme for the models at the end-point level).

The changes and adaptations occurred within the ILCD scheme, that led to the creation of the current EF set of models and a new package, based on ILCD format, containing new files for LCIA models, can be summarized as follows:

- 6 models are completely new, or updated according to the newest releases of the old models adopted in ILCD.
- The elementary flow list has been fixed and expanded according to the needs of the new models
- Within the new models several flows have been spatially differentiated (in ILCD format the location attribute is resolved at the model level, not at the elementary flow level)
- For several flows that were not characterized (both in newly added models and in the pre-existing ones that were not modified), a CF has been adopted, where a direct proxy for a specific substance/compartment was available.
- Specific exceptions, integrations or corrections have been implemented in different models.

All these aspects are detailed within the document. Furthermore, additional files have been released, containing an exhaustive view of all the changes occurred in the transition phase between the ILCD and the EF scheme (see annex2). Additional updates will be released through the website of the European Platform on LCA (http://eplca.jrc.ec.europa.eu/).

Other models (e.g. those related to toxicity aspects) are under development, during the editing of this document; therefore an updated version will be released as soon as the new recommended models are defined.

Acknowledgements

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1 Introduction

In 2013 a Communication from the Commission to the European Parliament (Building the Single Market for Green Products Facilitating Better information on the environmental performance of products and organizations COM/2013/0196) established the Product- and Organisation- Environmental Footprint (PEF and OEF, or more generally EF) framework. The common models to measure and communicate the life cycle environmental performances for PEF and OEF, have been defined in a specific EU recommendation (2013/179/EU).

Within this framework the International reference Life Cycle Data system (ILCD) format, nomenclature and recommended Life Cycle Impact Assessment (LCIA) models, have been adapted to fulfill the requirements of the EF scheme.

Compared to the ILCD scheme (EC-JRC 2011), in the EF scheme some LCIA models have been completely changed, some others have been just fine-tuned or not changed. The EF scheme only recommends models at midpoint level[1]. While ILCD was also recommending endpoint models[2].

The supplementing information is based on the structure and content of the database (Zip package) provided in ILCD format, in which characterisation factors (CFs) related to the recommended models for Environmental Footprint are compiled.

The database is meant to be used mainly in order to integrate the CFs used in the EF scheme into existing LCA software and database systems. Hence, this supporting document explains, where necessary, the choices made in adapting the source models to the needs of the EF scheme, and current limitations and methodological advice related to the CFs' use.

The CFs database consists of a database of ILCD-formatted xml files to allow electronic import into LCA software. The LCIA methods are each implemented as separate data sets which contain all the descriptive metadata documentation and the characterisation factors. The database contains moreover data sets of all elementary flows, flow properties and unit groups as well as the source and contact data sets (e.g. of the referenced data sources and publications as well as authors, data set developers, and so on).

In addition to the ILCD-formatted xml files, the data sets are available also in an MS Excel file, containing the flow list, the model list for EF scheme, and the CFs available for each model.

The content of this document represents a synthesis, recalling general considerations or decisions, which were applied for specific impact categories and, technical details with respect to each impact category, documenting specific choices made when implementing the characterization factors as well as problems/solutions encountered in the course of this implementation.

[1] The environmental categories through which a substance emissions and releases to the environment are modelled up to the changes in the natural environmental aspects.

[2] The environmental categories through which a substance emissions and releases to the environment are modelled up to the damage effect on the environmental aspects.

2 Summary of Recommended Models

The tables below present the summary of recommended models (models and associated characterisation factors) and their classification. Indicators and related unit are also reported for each recommended models.

Table 1 recommended models for EF scheme, including indicator, units and model package

Recommendation at midpoint				
Impact category	**Indicator**	**Unit**	**Recommended default LCIA model**	**Source of CFs**
Climate change[3]	Radiative forcing as Global Warming Potential (GWP100)	kg $CO_{2\ eq}$	Baseline model of 100 years of the IPCC (based on IPCC 2013)	EF-2017[4]
Ozone depletion	Ozone Depletion Potential (ODP)	kg CFC-11eq	Steady-state ODPs as in (WMO 1999)	EF - 2017
Human toxicity, cancer effects*	Comparative Toxic Unit for humans (CTU_h)	CTUh	USEtox model (Rosenbaum et al, 2008)	EF - 2017
Human toxicity, non- cancer effects*	Comparative Toxic Unit for humans (CTU_h)	CTUh	USEtox model (Rosenbaum et al, 2008)	EF - 2017
Particulate matter/Respiratory inorganics	Human health effects associated with exposure to $PM_{2.5}$	Disease incidences[5]	PM model recommended by UNEP (UNEP 2016)	EF - 2017
Ionising radiation, human health	Human exposure efficiency relative to U^{235}	kBq U^{235}	Human health effect model as developed by Dreicer et al. 1995 (Frischknecht et al, 2000)	EF - 2017
Photochemical ozone formation	Tropospheric ozone concentration increase	kg NMVOC eq	LOTOS-EUROS (Van Zelm et al, 2008) as applied in ReCiPe 2008	EF - 2017
Acidification	Accumulated Exceedance (AE)	mol H+ eq	Accumulated Exceedance (Seppälä et al. 2006, Posch et al, 2008)	EF - 2017
Eutrophication, terrestrial	Accumulated Exceedance (AE)	mol N eq	Accumulated Exceedance (Seppälä et al. 2006, Posch et al, 2008)	EF - 2017
Eutrophication, aquatic freshwater	Fraction of nutrients reaching freshwater end compartment (P)	kg P eq	EUTREND model (Struijs et al, 2009) as implemented in ReCiPe	EF - 2017
Eutrophication, aquatic marine	Fraction of nutrients reaching marine end compartment (N)	kg N eq	EUTREND model (Struijs et al, 2009) as implemented in ReCiPe	EF - 2017
Ecotoxicity (freshwater)*	Comparative Toxic Unit for ecosystems (CTU_e)	CTUe	USEtox model, (Rosenbaum et al, 2008)	EF - 2017
Land use	Soil quality index[6] (Biotic production, Erosion resistance, Mechanical filtration and Groundwater replenishment	Dimensionless, aggregated index of: kg biotic production/ (m^2*a)[7] kg soil/ (m^2*a) m^3 water/ (m^2*a) m^3 g.water/ (m2*a)	Soil quality index based on LANCA (Beck et al. 2010 and Bos et al. 2016)	EF - 2017

[3] Three additional sub-indicators may be requested for reporting, depending on the PEFCR. The sub-indicators are further described in dedicated section

[4] The full list of characterization factors (EF-2017) is available thorugh the link provided in annex 2

[5] The name of the unit is changed from "Deaths" in the original source (UNEP, 2016) to "Disease incidences". The CFs are the same as in the original source (except for adaptation of specific flows, as explained in chapter 4.4)

[6] This index is the result of the aggregation, performed by JRC, of the 4 indicators provided by LANCA model as indicators for land use

[7] This refers to occupation and transformation

Recommendation at midpoint				
Impact category	**Indicator**	**Unit**	**Recommended default LCIA model**	**Source of CFs**
Water scarcity	User deprivation potential (deprivation-weighted water consumption)	kg world eq. deprived	Available WAter REmaining (AWARE) in UNEP, 2016	EF - 2017
Resource use, minerals and metals	Abiotic resource depletion (ADP ultimate reserves)	kg Sb eq	CML Guinée et al. (2002) and van Oers et al. (2002).	EF - 2017
Resource use, energy carriers	Abiotic resource depletion – fossil fuels (ADP-fossil)[8]	MJ	CML Guinée et al. (2002) and van Oers et al. (2002)	EF - 2017

* excluding long-term emissions (occurring beyond 100 years).

[8] In the ILCD flow list, and for the current recommendation, Uranium is included in the list of energy carriers, and it is measured in MJ.

Table 2 LCIA model data set names, reference source, and associated unit groups for recommended and interim CFs in ILCD dataset

LCIA model	Flow property	Unit group[9] data set (+ ref. unit)	Level of recomme-ndation*
EF - Climate change; midpoint; GWP_{100}; IPPC2013	Mass CO_2-equivalents	Units of mass (kg)	I
EF - Ozone depletion; midpoint; ODP; WMO1999	Mass CFC-11-equivalents	Units of mass (kg)	I
EF - Cancer human health effects; midpoint; CTUh; USEtox™, Rosenbaum et al 2008	Comparative Toxic Unit for human (CTUh)	Units of items (cases)	II/III
EF - Non-cancer human health effects; midpoint; CTUh; USEtox™, Rosenbaum et al 2008	Comparative Toxic Unit for human (CTUh)	Units of items (cases)	II/III
EF - Respiratory inorganics; midpoint; PM2.5 eq; UNEP, Fantke et al. 2016	Mass $PM_{2.5}$-equivalents	Units of mass (kg)	I
EF- Ionizing radiation - human health; midpoint; ionising radiation potential; Frischknecht et al. (2000)	Mass U_{235}-equivalents	Units of mass (kg)	II
EF - Photochemical ozone formation; midpoint - human health; POCP; Van Zelm et al. (2008)	Mass NMVOC equivalents	Units of mass (kg)	II
EF - Acidification; midpoint; Accumulated Exceedance; Seppala et al 2006, Posch et al (2008);	Mole H^+-equivalents	Units of mole	II
EF - Eutrophication terrestrial; midpoint; Accumulated Exceedance; Seppala et al.2006, Posch et al 2008	Mole N-equivalents	Units of mole	II
EF - Eutrophication freshwater; midpoint; P equivalents; ReCiPe2008;	Mass P-equivalents	Units of mass (kg)	II
EF - Eutrophication marine; midpoint; N equivalents; ReCiPe2008;	Mass N-equivalents	Units of mass (kg)	II
EF - Ecotoxicity freshwater; midpoint; CTUe; USEtox™ , Rosenbaum et al 2008	Comparative Toxic Unit for ecosystems (CTUe)	Units of volume* time (m^3*a)	II/III
EF - Land use; midpoint; soil quality indicator; LANCA, Bos et al. 2016.	Soil Quality Index	Quality Score	III
EF – water use; midpoint; water scarcity; AWARE, Boulay et al. in UNEP 2016	Water scarcity	Units of mass (kg)[10]	III
EF - Resource use mineral and metals; midpoint; ADP ultimate reserve; Van Oers et al 2002	Mass Sb-equivalents	Units of mass (kg)	III
EF - Resource use energy carriers; midpoint; ADP energy; Van Oers et al 2002	MJ	Units of energy (MJ)	III
According to ILCD levels**: "Level I"** (recommended and satisfactory), "**Level II"** (recommended but in need of some improvements) or "**Level III**" (recommended, but to be applied with caution);ì			

[9] The unit group defines the reference unit of measure, for a specific (or a group of) Flow Property, assigned to a Elemetary flows, and includes the conversion factors to different units within the same measured parameter

[10] Volume (cubic meters) in the original method.

3 Content of the documentation

3.1 General issues related to the characterisation factors (CFs)

The metadata provided for each LCIA model gives an overview of the model. In the EF LCIA methoddata sets themselves, background models are only indicated succinctly in relation to their respective contributions to the modelling of the impact pathway (incl. geographical specifications, modelled compartments, etc.). In case the LCA practitioner requires more details on a specific model, it is recommended to consult the original references of the models. Some issues were noted in the course of documenting the recommended LCIA models and mapping the factors to a common set of elementary flows. Only general problems that are not related to one specific LCIA model are reported in this section. Other issues specific to each impact category are reported in chapter 4. A very limited number of elementary flows that have a characterisation factor in a LCIA model were not implemented. Such flows are mainly those selected groups of substances and measurement indicators, which are not compliant with the ILCD Nomenclature (e.g. “hydrocarbons, unspecified”, "heavy metals") and hence excluded from the flow list.

3.2 New flows added

Additional substances have been added to the former ILCD flowlist, according to the update of some models (e.g. the new IPCC model for GWP is introducing 137 new substances, compared to the version released in 2007) for a detailed list of flows deleted and added see excel file available in annex 2

3.3 Geographical differentiation

Some of the models behind the LCIA models allow calculating characterisation factors for further substances considering geographical differentiation. Within ILCD dataset, available country-specific factors are included in the LCIA model datasets for: land use; water scarcity[11]; acidification; terrestrial eutrophication. The spatial differentiation is detailed in the models, and during the creation of process datasets, the data developer has to assign one or more specific location attribute to the flows, in order to have a proper differentiation in the LCIA.

Table 3. Example of temporary flows accepted in ILCD[11] that have been converted in the proper format in the EF scheme, where the regionalization is resolved with specific location attributes assigned at the level of models and processes datasets, and NOT at the flow level.

ILCD UUID	ILCD name	EF UUID	EF name	EF location attribute
0bf7c70b-4a1d-4848-a78a-5c31a220f148	fresh water, regionalized, AR	6e70f994-480b-4836-a605-5f958a3d7ea4	freshwater	AR
6313ed6b-0091-433e-ba18-87092afa9346	fresh water, regionalized, AT	6e70f994-480b-4836-a605-5f958a3d7ea4	freshwater	AT
62835e9a-263f-48ff-a703-e6efa3dfcd7e	fresh water, regionalized, AU	6e70f994-480b-4836-a605-5f958a3d7ea4	freshwater	AU

[11] The temporary regionalized water flows released in August 2016, were converted to the fully compliant water flows in the ILCD structure. The temporary flows were not fully compliant, because the regionalization was resolved in the name of the flow, while the ILCD structure is not assigning the location attribute to the flow.

3.4 Filling gaps for missing CFs

In order to complete as much as possible the list of CFs available, some rules have been adopted in order to fulfill the gaps, and assign CFs to a number of substances, available in the ILCD and EF flow lists, where proxy factors were already available (and usable) in the models. The rules applied for the gap-filling are the following:

- The specific flow not characterized in a specific model has a direct proxy in the same model. This means that the substance or resource is already covered in the model, in the same main compartment, in another sub-compartment
    - Example: if the flow *1,1,2-trichlorotrifluoroethane* was characterized for "climate change" model under the main compartment "*Emissions to air*" sub-compartment "*Emissions to air, unspecified*", but not under the sub-compartment "*Emissions to lower stratosphere and upper stratosphere*", the CF assigned to the characterized flow is considered a direct proxy.
- In case the sub-compartment '*…… unspecified*' (e.g. the "*Emissions to air, unspecified*" in the example above) carries a CF, the CF of unspecified shall be expanded to all other uncharacterized sub-compartments within the same emission compartment.

There are seven exceptions to that rule, where for specific categories, the sub-compartment makes a difference respect to the CF assigned:

- EUTROPHICATION FRESHWATER: the sub-compartment 'sea water' carries a CF ZERO, the ratio is that the impacts on sea water are captured in the specific model for marine eutrophication.
- RESPIRATORY INORGANICS: the sub-compartment "lower stratosphere and upper troposphere" is put to ZERO, since the target (humans) is far from the emission source in that sub-compartment.
- RESPIRATORY INORGANICS: the sub-compartment "non-urban air ***or*** from high stacks" receives the same CF as "non-urban air high stack" (better proxy than "unspecified" sub-compartment)
- NON CANCER HH: the sub-compartment "lower stratosphere and upper troposphere" receives the same CF as "non urban air or from high stack" (better proxy than "unspecified" sub-compartment)
- NON CANCER HH: all the CFs for "long-term" emissions are set to zero.
- ECOTOXICITY FRESHWATER: the sub-compartment "lower stratosphere and upper troposphere" receives the same CF as "non urban air or from high stacks" (better proxy than "unspecified" sub-compartment)
- ECOTOXICITY FRESHWATER all the CFs for "long-term" emissions are set to zero.
- CANCER HH: the sub-compartment "lower stratosphere and upper troposphere" receives the same CF as "non urban air or from high stacks" (better proxy than "unspecified" sub-compartment)
- CANCER HH: all the CFs for "long-term" emissions are set to zero.

4 Additional information per impact category

Specific comments on the implementation of CFs as well as on their recommended use are provided below. Impact categories, which share the same remarks, are grouped.

Each chapter contains two frames with additional info on what's changed in comparison with ILCD method (light green frames), and deviations or adaptations that have been adopted in comparison with the referenced model for each category (light blue frames)

Complete lists for ILCD and EF (Latest available versions) are available at through the links provided in annex 2.

4.1 Climate change

What's new respect to ILCD:

The reference model for climate change, midpoint, in ILCD was the one proposed by IPCC 2007, while in the EF scheme IPCC 2013 is adopted. Furthermore, the values adopted for the Global Warming Potentials with time horizon 100 years (GWP-100) includes the carbon feedbacks for different substances, while the GWP-100 adopted in ILCD was accounting only the effect of single substances.

Several new substances have been characterised in the new model, compared to ILCD.

Deviations or adaptations from the original model:

Some values have been adapted according to the PEFCR guidance document 6.2

Impact category	*Model*	*Indicator*
Climate change	IPPC, 2013 + adaptations	Global Woarming Potential (GWP_{100})

The source for CFs for climate change at midpoint was the fifth assessment report of IPCC (2013), for a time horizon of 100 years including climate-change carbon feedbacks for both CO_2 and non-CO_2 substances. The values with feedbacks are applied to ensure consistency, as feedbacks are already included for CO_2. The Global Warming Potential (GWP) data reported in the IPPC (2013) have only one emission compartment ("to air"). Therefore, the values were assigned to the different emission compartments in the ILCD and EF(i.e. "emissions to lower stratosphere and upper troposphere", "emissions to non-urban air or from high stacks", "emissions to urban air close to ground", "emissions to air, unspecified (long term)", and "emissions to air, unspecified"). As the IPCC report does not report GWP values smaller than 1 (but lists these as <1), such values were calculated by using the Absolute Global Warming Potential (AGWP) (IPCC 2013). Some deviations from IPCC values were recommended in the Product Environmental Footprint Category Rules (PEFCR) guidance document, and are reported in table 4.

Table 4 The CFs for the following substances are taken from the PEFCR Guidance document (EC-DG ENV, 2016) developed in the Environmental Footprint pilot phase.

Substance	Compartment	GWP_{100}
Methane (fossil)	Air emissions	36.75
Carbon monoxide (fossil)	Air emission	1.57 [12]
Carbon dioxide (biogenic)	Resources from air	0
Carbon dioxide (biogenic-100yr)	Resources from air	-1
Carbon dioxide (biogenic)	Air emission	0
Carbon monoxide (biogenic)	Air emission	0
Carbon dioxide (land use change)	Resources from air	-1
Methane (land use change)	Air emission	36.75
Carbon monoxide (land use change)	Air emission	1.57

[12] The effects of near term climate forcers are uncertain and therefore excluded (following the UNEP/SETAC recommendations of the Pellston Workshop, UNEP 2016). The GWP presented here represents only the effects from degradation of CO into CO_2 (stoichiometric calculation).

4.2 Ozone depletion

What's new respect to ILCD:

The reference model for ozone depletion, midpoint, in ILCD was developed by the World Meteorological Organisation (WMO) in 1999, while in the EF scheme the WMO 2014 is adopted as reference model.

Deviations or adaptations from the original model:

Some substances were not characterised in WMO 2014, in this case values from other reference have been used to fill the gaps, adopting the same approach. See the explanation and annex 1 for further details.

Impact category	*Model*	*Indicator*
Ozone depletion	WMO,2014 + integrations	Ozone Depletion potential (ODP)

Most of the characterization factors (CFs) for ozone-depleting substances (ODS), which contribute to both climate change and ozone depletion impact categories, were implemented from the World Meteorological Organisation WMO (2014). Some substances were missing a CF from the WMO (2014) report: when this was the case, CFs from World Meteorological Organisation (2011) and Montreal Protocol (as cited and reported in WMO (2014)) have been adopted. ReCiPe2008 data sets (v1.05; Goedkoop et al., 2009) were used for missing CFs for the remaining substances. A detailed list of CFs and data sources is available in Annex 1.

4.3 Human and Eco Toxicity

What's new respect to ILCD:

The model used for calculating toxicity-related impact categories have not been changed.

Deviations or adaptations from the original model:

Specific rules have been adopted, already in ILCD scheme, for the characterisation factors for metals.

Human toxicity

Impact category	*Model*	*Indicator*
Human toxicity, cancer	USEtox (Rosenbaum et al 2008)	Comparative Toxic Unit for Human Health (CTUh)
Human toxicity, non cancer effects	USEtox (Rosenbaum et al 2008)	CTUh

Ecotoxicity

Impact category	*Model*	*Indicator*
Ecotoxicity freshwater, midpoint	USEtox (Rosenbaum et al 2008)	Comparative Toxic Unit for ecosystems (CTUe)

All USEtox^{TM} factors (v.1.01) were implemented in accordance to the correspondence in the emission compartments reported in the Table 5(next page).

Ecotoxicity is currently only represented by toxic effect on aquatic freshwater species in the water column. Impacts on other ecosystems, including sediments, are not reflected in current general practice.

Metals in USEtox^{TM} are specified according to their oxidation degree(s). In general, the following rules were applied to implement the CFs in the ILCD system (with approval from the USEtox^{TM} team):

- The metallic forms of the metals were assigned the CFs of the oxidized form listed in USEtox^{TM}. Although metals can have several oxidation degrees, e.g. Cu ($^{+1}$ or $^{+2}$), only one for each metal is currently reported in the USEtox^{TM} model (v.1.01), hence the direct assignment of Cfs to the metallic form (three exceptions are reported in the bullet point below). Comments were added in the data sets to indicate that the metallic forms were derived from the oxidized forms and apply to all ions of that metal.
- Three metals in USEtox^{TM} are characterized with two different oxidized forms, i.e. arsenic (As), chromium (Cr) and antimony (Sb). Two ionic forms were then indicated for each. The CFs for their metallic forms were allocated the CFs of As($^{+5}$), Sb$^{(+6)}$ and 50/50 CFs of Cr(+^{3}) / Cr(+^{6}) for As, Sb and Cr respectively.

In the version v.1.01 of the USEtox™ factors, characterized inorganics only comprise few metals. Other inorganics are not available in this version of USEtox™ (e.g. SO_2, NO_x, particles). Note, however, that primary particulate matter and precursors are considered in the "respiratory inorganics" impact category.

For both ecotoxicity and human toxicity, distinction between recommended and interim CFs in USEtox™ was notified through different level of recommendations. According to USEtox model, the recommendation level for certain substances (such as substances belonging to the classes of metals and amphiphilic and dissociating chemicals) was downgraded. I.e. for "Human toxicity – cancer effect" at midpoint, the USEtox model is recommended as Level II, but the associated CFs have two different recommendation levels (II and III), reflecting different robustness of background data on effects.

Table 5 Correspondence of emission compartments between USEtox™ model and ILCD elementary flow system *

	ILCD emission compartments	USEtox™ compartments		Data derivation status
Air	Emissions to air, unspecified	*50 Em.airU / 50 Em.airC*	50/50 urban/continental	Estimated
	Emissions to air, unspecified (long term)	*50 Em.airU / 50 Em.airC*	50/50 urban/continental	Estimated
	Emissions to non-urban air or from high stacks	*Em.airC*	Continental air	Calculated
	Emissions to urban air close to ground	*Em.airU*	Urban air	Calculated
	Emissions to lower stratosphere and upper troposphere	*Em.airC*	Continental air	Estimated
Water	Emissions to fresh water	*Em.fr.waterC*	Freshwater	Calculated
	Emissions to sea water	*Em.sea waterC*	Seawater	Calculated
	Emissions to water, unspecified	*Em.fr.waterC*	Freshwater	Estimated
	Emissions to water, unspecified (long term)	*Em.fr.waterC*	Freshwater	Estimated
Soil	Emissions to soil, unspecified	*Em.nat.soilC*	Natural soil	Estimated
	Emissions to agricultural soil	*Em.agr.soilC*	Agric. soil	Calculated
	Emissions to non-agricultural soil	*Em.nat.soilC*	Natural soil	Calculated

* Shaded cells refer to the 6 compartments used in the USEtox™ model (hence the flag "Calculated"); the correspondence for the other emission compartments was agreed with the USEtox™ team.

4.4 Respiratory inorganics

What's new respect to ILCD:

The model adopted in ILCD characterized the impacts in kg of $PM_{2.5}$ equivalents, and was based on three different references (Rosenbaum et al. 2008, Greco et al. 2007, Rabl and Spadaro 2004), combined as proposed in Humbert (2009). The new model is characterising the emissions as deaths due to the emission of PM, as defined by Fantke et al. (2016).

Deviations or adaptations from the original model:

Specific CFs for PM_{10} have been derived, since were not available in the original model, while for other particulates ($PM_{0.2}$ and $PM_{0.2\text{-}2.5}$), the factor associated to $PM_{2.5}$ has been adopted.

Impact category	*Model*	*Indicator*
Particulate matter,	Fantke et al. (2016) in UNEP (2016)	Disease incidences

The recommended model is the one developed by the UNEP-SETAC Task Force (TF) on PM in 2016 (Fantke et al. 2016). It aims at assessing damage to human health from outdoor and indoor emissions of primary and secondary $PM_{2.5}$ in urban and rural areas.

According to Fantke et al (2016), the midpoint indicator is the change in mortality due to PM emissions, expressed in deaths/kg$PM_{2.5}$emitted. A different name is used in the present report and in the EF2017 method, namely disease incidences/kg$PM_{2.5}$emitted. The values of CFs are the same as in the original source.

The characterization factors provided by the model for the average ERF were collected as they are published by model developers and then mapped to the ILCD elementary flow list. Name correspondence and the similarity in the description of the archetype represented by the flow were the main criteria used.

For the flows of unspecified emissions, a precautionary approach was applied, by assigning the highest CF among those available for that kind of particle.

The model assessed does not provide a CF for the elementary flow "PM_{10}", because the $PM_{2.5}$ fraction is considered the main responsible of impacts on human health. However, some life cycle inventories include only PM_{10} and not $PM_{2.5}$. Hence, an assumption of the impact coming from emissions of PM_{10} (i.e. a related CF) is made, to avoid disregarding some of the emissions included in the inventory. In line with what was done for the previous recommendation, the CF for PM_{10} is calculated by multiplying the CF for $PM_{2.5}$ by 23% (i.e. by the fraction of $PM_{2.5}$over the total amount of PM_{10}).

The elementary flows "Particles ($PM_{0.2}$)" and "Particles ($PM_{0.2\text{-}2.5}$)" were not included in the original model. However, they could be part of the inventories currently used. Therefore, to avoid disregarding the emission of very small particles, the CF for $PM_{2.5}$ is assigned as a proxy to these flows (and related sub-compartments)

4.5 Ionising radiation

What's new respect to ILCD:
The model adopted in ILCD for ionising radiation is not changed

Deviations or adaptations from the original model:
Proxy CFs have been adopted for some emissions to specific sub-compartment. The reference unit was adapted from kg to kBq, according to ILCD unit group for radioactivity.

Impact category	*Model*	*Indicator*
Ionising radiation, human health,	Frischknecht et al 2000	Ionizing Radiation Potentials (IRP)

At midpoint CFs for "emissions to water (unspecified)" are used also as approximation for the flow compartment "emissions to freshwater". The modified flows are marked as "estimated" in the dataset. As the CFs were taken as applied in ReCiPe (v1.05, Goedkoop et al., 2009), and there CFs for iodine-129 are not reported, this CF was taken from the source directly (Frischknecht et al 2000). As many nuclear power stations are costal and use marine water, this has to be further considered and assessed in further developments.

The CFs were built in full compatibility with the USEtox^{TM} model (cf. model documentation). Therefore, the same framework as presented in section 3 was used to implement the CFs with regard to the different emission compartments. Emissions to lower stratosphere and upper troposphere were however excluded and so were most of the water-borne emission compartments (all but emissions to freshwater).

According to the current ILCD nomenclature, the elementary flows of radionuclides are expressed in kBq; the CFs were thus expressed per kBq.

4.6 Photochemical ozone formation

What's new respect to ILCD:

The model adopted in ILCD for Photochemical Ozone Formation is not changed.

Deviations or adaptations from the original model:

CFs for specific flows, not available in the original model, but listed in the elementary flow list, both for ILCD and EF, have been calculated

Impact category	*Model*	*Indicator*
Photochemical ozone formation	Van Zelm et al 2008 as applied in ReCiPe2008	Photochemical ozone creation potential (POCP)

The generic CF for Volatile Organic Compounds (VOCs) –not available in the original source CFs data set – was calculated as the emission-weighted combination of the CF of Non- methane VOCs (generic) and the CF of CH_4. Emission data (Vestreng et al. 2006) refer to emissions occurring in Europe (continent) in 2004, i.e. 14.0 Mt-NMVOC and 47.8 Mt-CH_4.

Factors were not provided for any other additional group of substances (except PM), because substance groups such as "metals" and "pesticides" are not easily covered by a single CF in a meaningful way. A few groups-of-substances indicators are still provided in the ReCiPe2008 method. However, many important compounds belonging to these groups are already characterized as individual substance.

4.7 Acidification

What's new respect to ILCD:

The model adopted in ILCD for Acidification is not changed.

Deviations or adaptations from the original model:

CFs for specific flows, not available in the original model, but contained in the elementary flow list, both for ILCD and EF, have been calculated. For the most relevant flows in the specific category, country-specific CFs have been calculated.

Impact category	*Model*	*Indicator*
Acidification	Seppälä et al 2006, Posch et al 2008	Accumulated Exceedance (AE)

Acidification is mainly caused by air emissions of NH_3, NO_2 and SO_X. In the data set, the elementary flow "sulphur oxides" (SO_X) was assigned the characterization factor for SO_2. Other compounds are of lower importance and are not considered in the recommended LCIA model. Few exceptions exist however for NO, SO_3, for which CFs were derived from those of NO_2 and SO_2 respectively. CFs for acidification are expressed in moles of charge (molc) per unit of mass emitted (Posch et al 2008). As NO and SO_3 lead to the same respective molecular ions released (nitrate and sulphate) as NO_2 and SO_2, their charges are still z=1 and z=2, respectively. Using conversion factors established as z/M (M: molecular weight), the CFs for NO and SO_3 have been derived as shown in following Table.

Table 6 Derived additional CFs for acidification at midpoint

	Conversion factors		CFs	
SO_2	3.12E-02	eq/g	1.31	eq/kg
NO_2	2.17E-02	eq/g	0.74	eq/kg
NH_3	5.88E-02	eq/g	3.02	eq/kg
NO	3.33E-02	eq/g	1.13	eq/kg
SO_3	2.50E-02	eq/g	1.05	eq/kg

* CFs for SO_2, NO_2 and NH_3 provided in Posh et al. (2008)

Note that, in addition to generic factors, country-specific characterisation factors (for some countries relevant for the EU market) are provided for SO_2, NH_3, and NO_2.

4.8 Eutrophication

What's new respect to ILCD:

The models adopted in ILCD for the three impacts related to Eutrophication are not changed.

Deviations or adaptations from the original model:

CFs for specific flows, not available in the original models, have been calculated. For terrestrial eutrophication, country-specific CFs have been calculated for ammonia, nitrogen oxides and nitrogen dioxide.

Impact category	*Model*	*Indicator*
Eutrophication terrestrial	Seppala et al 2006, Posch et al 2008	Accumulated Exceedance (AE)
Eutrophication aquatic-freshwater/marine	ReCiPe2008 (EUTREND model -Struijs et al 2009b)	P equivalents and N equivalents

With respect to terrestrial eutrophication, only the concentration of nitrogen is the limiting factor and hence important, therefore, original data sets include CFs for NH_3, NO_2 emitted to air. The CF for NO was derived using stoichiometry, based on the molecular weight of the considered compounds. Likewise, the ions NH^{4+} and NO^{3-} were also characterized since life cycle inventories often refer to their releases to air.

Site-independent CFs are available for ammonia, ammonium, nitrate, nitrite, nitrogen dioxide, and nitrogen monoxide. Note that country-specific characterisation factors for ammonia and nitrogen dioxide are provided for a number of countries (in the LCIA model data sets for terrestrial midpoint).

As for acidification and terrestrial eutrophication, CFs for "emissions to air, unspecified", available in ReCiPe2008, were used for mapping CFs for all emissions to air, emissions to "air, unspecified (long term)". This omission needs to be further evaluated for its relevance and may need to be corrected. In freshwater environments, phosphorus is considered the limiting factor. Therefore, only P-compounds are provided for assessment of freshwater eutrophication. In marine water environments, nitrogen is the limiting factor, hence the recommended model's inclusion of only N compounds in the characterization of marine eutrophication. The characterisation of impact of N-compound emitted into rivers that subsequently may reach the sea has to be further investigated. At midpoint, marine eutrophication CFs were calculated for the flow compartment "emissions to water, unspecified". These factors have been added as approximation for the compartments "emissions to water, unspecified (long-term)", "emissions to sea water", and "emissions to fresh water". No impact assessment models, which were reviewed, included iron as a relevant nutrient to be characterized. Therefore, no CFs for iron is available.

Only main contributors to the impact were reported in the current documentation of factors (see following table). However, if other relevant N- or P-compounds are inventoried, the LCA practitioners can calculate their inventories in total N or total P – depending on the impact to assess – via stoichiometric balance and use the CFs provided for “total nitrogen” or “total phosphorus”. Additional elementary flows were generated for “nitrogen, total” and “phosphorus, total” in that purpose. Double-counting is of course to be avoided in the inventories, and - given that the reporting of individual substances is preferred - the "nitrogen, total" and "phosphorus, total" flows should only be used if more detailed elementary flow data is unavailable.

Table 7. Substances for which CFs were indicated for assessing aquatic eutrophication

Impact category	Characterized substances
Freshwater eutrophication	Phosphate, phosphoric acid, phosphorus total *
Marine eutrophication	Ammonia, ammonium ion, nitrate, nitrite**, nitrogen dioxide, nitrogen monoxide**, nitrogen total

* Phosphorus pentoxide, which has a factor in the original paper, is not implemented in the ILCD flow list due to its high reactivity and hence its low probability to be emitted as such. Inventories where phosphorus pentoxide is indicated should therefore be adapted/scaled and be inventoried e.g. as "phosphorus, total", based on stoichiometric consideration (P content).

** CFs not listed in ReCiPe data set; these were derived using stoichiometry balance calculations.

4.9 Land use

What's new respect to ILCD:

The model for land use impact assessment is completely changed. In ILCD the moldel evaluating Soil Organic Matter (SOM) loss, developed by Mila I Canals (2007) was adopted, in EF the model LANCA (Bos et al, 2016) is implemented.

Deviations or adaptations from the original model:

LANCA model is taking into account different indicators for different soil properties, as explained below. Those indicators have been pooled and re-scaled, in order to obtain a dimensionless soil quality index, accounting for the different properties evaluated by the model. The model assigns both global and spatially differentiated CFs at country level.

Impact category	*Model*	*Indicator*
Land use	LANCA (as in Bos et al., 2016)	Soil quality index

The CFs for land use at midpoint were calculated starting from the sets presented in Bos et al. (2016) for the LANCA LCIA model. LANCA provides five indicators for assessing the impacts due to the use of soil: erosion resistance, mechanical filtration, physico-chemical filtration, groundwater regeneration and biotic production. Starting from these indicators, JRC calculated a single score index by aggregating the indicators which showed the lowest correlation coefficients in order to avoid redundancy. The development of the aggregation procedure included the following steps:

1- Identification of the most representative indicators avoiding redundancy in the type of information they provide. In the case of LANCA model, physicochemical filtration and mechanical filtration showed a very high correlation (i.e. 1). Therefore, in this aggregation the physicochemical filtration was not taken into account.

2- Identification, for each indicator separately, of the minimum and the maximum value amongst the global characterization factors for "occupation" elementary flows. Then, these values were respectively replaced by the values 1 and 100.

3- Linear re-scaling of the remaining occupation CFs to the 1÷100 range.

4- As a part of the country-specific re-scaled CFs fell outside the 1÷100 range (due to the fact that the original set of country-specific CFs presented a larger variability compared to the global set), the following measures were taken:

   a. Re-scaled CFs larger than 150 were replaced by 150

   b. Re-scaled CFs smaller than 1 were re-calculated according to the following criteria: (i) those falling within an interval between a chosen cutoff value and the minimum of the global CFs were rescaled in order to vary between 0.1 and 1; (ii) those smaller than the chosen cutoff value were replaced by 0.1. The cutoff value was chosen in order to ensure that less than 1% of the total CFs would be smaller than this value

5- In this way the set of re-scaled “occupation” CFs ranged between 0.1 and 150, with the global CFs included in the subinterval 1÷100. As the CFs for “transformation to” flows in LANCA correspond to the “occupation” CFs, and the CFs for “transformation from” flows correspond to the opposite of the “occupation” CFs, by applying the same logic to these flows the rescaled “transformation to” values ranged between 0.1 and 150 (1÷100 for the global CFs), while the rescaled “transformation from” values ranged between -150 and -0.1 (-100÷-1 for the global CFs).

6- The rescaled values thus obtained for each indicator were aggregated by adding them together in order to obtain just one number for each elementary flow. This number represents the characterization factor.

The result is a single indicator attributing to each elementary flow a score (namely, for occupation, ranging from 55 to 301 for the global set of CFs and from 6 and 460 for the country-specific set). This approach does not address modelling uncertainties that may be associated with each single impact indicator and applies a 1-1-1-1 weighting reference for the different indicators.

LANCA model already provides CFs associated to a list of elementary flows compatible with the ILCD nomenclature. Therefore, no mapping was needed. The main difference with the original model presented in Bos et al. (2016) is the absence of CFs for elementary flows related to water bodies: the land use indicator recommended for EF has no CFs for water bodies’ occupation/transformation. The reason behind this choice is that at the moment, LANCA addresses only the terrestrial biomes and not the aquatic ones.

4.10 Resource use

What's new respect to ILCD:

The overall approach (abiotic resource depletion – ADP, Guinée et al., 2002 and Van Oers et al., 2002) is not changed. However the reference model for resource depletion of minerals and metals has changed from reserve base to ultimate reserves. A more recent version of CFs (corresponding to CML v. 4.8) is recommended. Energy carriers are now considered separately, and characterised as MJ equivalents, while mineral and metal resources are characterised in Sb-equivalents.

Deviations or adaptations from the original model:

The CFs adopted are those implemented in the CML method v. 4.8 (2016). Minor adaptations, explained below, have been adopted, in order to match the flow properties and units used in ILCD/EF flow list.

Impact category	*Model*	*Indicator*
Resource depletion – Minerals and metals	Van Oers et al 2002	ADP ultimate reserves
Resource depletion – Energy Carriers	Van Oers et al 2002	ADP fossil

Resource depletion – Minerals and metals

For resources depletion at midpoint, the model recommended is the Abiotic Resource Depletion, "ultimate reserves" version, described in van Oers et al. (2002), based on the models of Guinée et al. (2002). CFs are given as Abiotic Depletion Potential (ADP), quantified in kg of antimony-equivalent (Sb-eq) per kg extraction. The CFs recommended are the ones in the CML method, version 4.8 (2016).

Resource depletion – Energy carriers

As suggested by van Oers et al. (2002), and implemented in CML method since 2009 version, a separate impact category for fossil fuels is defined, based on their similar function as energy carriers. CFs for fossil fuels are expressed as MJ/MJ, i.e. the CF is equal to 1 for all fossil resources.

In the original model, the CF for Uranium was referred to an elementary flow in mass (kg). On the contrary, in the ILCD flow list, Uranium is included in the list of energy carriers, and measured in MJ. Therefore, a CF equal to 1 is assigned to uranium.

4.11 Water scarcity

What's new respect to ILCD:

The model for water use impact assessment is new. In ILCD, the model characterized the water depletion according to scarcity adjusted mass of water used (Swiss Ecoscarcity 2006; Frischknecht et al., 2008), in EF the model AWARE (Boulay et al., 2018; UNEP 2016) is implemented, and evaluates the impact in quantity of water deprived.

Deviations or adaptations from the original model:

The AWARE model is taking into account different resolution levels, however, for the EF recommendation, only the country scale is adopted

Impact category	*Model*	*Indicator*
Water scarcity	AWARE, 2016	Scarcity-adjusted water use

Factors for assessing water scarcity were implemented based on the AWARE model (UNEP 2016). The AWARE model provides characterization factors resolved at:

- Monthly and watershed scale,
- Watershed aggregated over time (yearly-scale) and separated by agricultural or non-agricultural water consumption,
- At temporal scale (months) aggregated over space at country-scale, separated by agricultural or non-agricultural water consumption,
- Country specific scale, averaged over space and time, separated by agricultural or non-agricultural water consumption,
- Country specific scale, default CF averaged over space and time,
- Continental/region-specific, averaged over space and time,
- Global scale, averaged over space (watersheds) and time (months).

The requirement for the PEF/OEF is that all assessments are as default to be conducted at country specific scale, using default CF averaged over space and time. Characterisation factors are recommended for blue water consumption only, where consumption is defined as the difference between withdrawal and release of blue water. Green water, rainwater, seawater and fossil water, are not characterized by AWARE. The original flows developed for AWARE, available at http://www.wulca-waterlca.org/project.html, were mapped to updated ILCD elementary flows.

Notwithstanding the characterization factors of AWARE are available at different temporal and spatial scales (e.g. month, watershed and continental/region) as well as water use types (e.g. agriculture), due to applicability reasons, they are not part of the recommendation.

5 Conclusions and further steps

The Environmental Footprint scheme led to significant changes to the ILCD structure and recommendations for LCIA models, additional updates will be released through the website of the European Platform on LCA (http://eplca.jrc.ec.europa.eu/).

Other models (e.g. those related to toxicity) are under further refinement, during the editing of this document. Therefore, an updated version will be released as soon as the new model and calculation principle will be defined.

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List of abbreviations and definitions

ADP	Abiotic Depletion Potential
AE	Accumulated Exceedance
CF/CFs	Characterisation factor(s)
CTUe	Comparative Toxic Units ecosystems
CTUh	Comparative Toxic Units human health
EC	European Commission
EF	Environmental Footprint
GWP	Global Warming Potential
ILCD	International Life Cycle Data system
IPCC	Intergovernmental Panel on Climate Change
JRC	Joint Research Centre
LCA	Life Cycle Assessment
LCIA	Life Cycle Impact Assessment
NMVOC	Non-Methane Volatile Organic Compounds
ODP	Ozone Depletion Potential
OEF	Organisation Environmental Footprint
PEF	Product Environmental Footprint
PM	Particulate Matter
POCP	Photochemical Ozone Creation Potential
SOM	Soil Organic Matter
UNEP	United Nations Environment Programme
UUID	Universally Unique Identifier
VOC	Volatile Organic Compounds
WMO	World Meteorological Organisation

List of tables

Annexes

Annex 1. List of CFs and Sources adopted for ODP Category

UUID	Substance	Sub-compartment	CF	Source
fe0acd60-3ddc-11dd-a324-0050c2490048	1,1,1-trichloroethane	Emissions to urban air close to ground	0.14	WMO2014
fe0acd60-3ddc-11dd-a323-0050c2490048	1,1,1-trichloroethane	Emissions to air, unspecified (long-term)	0.14	WMO2014
e2fb04c3-6555-11dd-ad8b-0800200c9a66	1,1,1-trichloroethane	Emissions to lower stratosphere and upper troposphere	0.14	WMO2014
fe0acd60-3ddc-11dd-a325-0050c2490048	1,1,1-trichloroethane	Emissions to non-urban air or from high stacks	0.14	WMO2014
08a91e70-3ddc-11dd-9304-0050c2490048	1,1,1-trichloroethane	Emissions to air, unspecified	0.14	WMO2014
ad6ce603-d4a9-4064-80e7-5a6acc818057	1,1,2-trichlorotrifluoroethane	Emissions to urban air close to ground	0.81	WMO2014
cb864c47-95d8-4d91-8e97-96d018abb949	1,1,2-trichlorotrifluoroethane	Emissions to air, unspecified (long-term)	0.81	WMO2014
a3fe3630-a497-45c3-a1ed-7b20f9d6e51a	1,1,2-trichlorotrifluoroethane	Emissions to air, unspecified	0.81	WMO2014
58c05f46-fb00-470e-aa98-16c62176748c	1,1,2-trichlorotrifluoroethane	Emissions to non-urban air or from high stacks	0.81	WMO2014
fe0acd60-3ddc-11dd-a929-0050c2490048	CFC-10	Emissions to air, unspecified	0.72	WMO2014
d86c61db-6555-11dd-ad8b-0800200c9a66	CFC-10	Emissions to lower stratosphere and upper troposphere	0.72	WMO2014
fe0acd60-3ddc-11dd-a92b-0050c2490048	CFC-10	Emissions to urban air close to ground	0.72	WMO2014
fe0acd60-3ddc-11dd-a92a-0050c2490048	CFC-10	Emissions to air, unspecified (long-term)	0.72	WMO2014
fe0acd60-3ddc-11dd-a92c-0050c2490048	CFC-10	Emissions to non-urban air or from high stacks	0.72	WMO2014
fe0acd60-3ddc-11dd-9e54-0050c2490048	CFC-11	Emissions to non-urban air or from high stacks	1	WMO2014
e2fa8f9c-6555-11dd-ad8b-0800200c9a66	CFC-11	Emissions to lower stratosphere and upper troposphere	1	WMO2014
fe0acd60-3ddc-11dd-9e51-0050c2490048	CFC-11	Emissions to air, unspecified	1	WMO2014
fe0acd60-3ddc-11dd-9e52-0050c2490048	CFC-11	Emissions to air, unspecified (long-term)	1	WMO2014
fe0acd60-3ddc-11dd-9e53-0050c2490048	CFC-11	Emissions to urban air close to ground	1	WMO2014
fe0acd60-3ddc-11dd-ab9b-0050c2490048	CFC-114	Emissions to non-urban air or from high stacks	0.5	WMO2014
08a91e70-3ddc-11dd-98b4-0050c2490048	CFC-114	Emissions to air, unspecified (long-term)	0.5	WMO2014
1f308835-6556-11dd-ad8b-0800200c9a66	CFC-114	Emissions to lower stratosphere and upper troposphere	0.5	WMO2014
08a91e70-3ddc-11dd-98b5-0050c2490048	CFC-114	Emissions to urban air close to ground	0.5	WMO2014
08a91e70-3ddc-11dd-98b3-0050c2490048	CFC-114	Emissions to air, unspecified	0.5	WMO2014
fe0acd60-3ddc-11dd-a3a8-0050c2490048	CFC-115	Emissions to air, unspecified	0.26	WMO2014
fe0acd60-3ddc-11dd-a3ab-0050c2490048	CFC-115	Emissions to non-urban air or from high stacks	0.26	WMO2014
e2fab6bb-6555-11dd-ad8b-0800200c9a66	CFC-115	Emissions to lower stratosphere and upper troposphere	0.26	WMO2014
fe0acd60-3ddc-11dd-a3aa-0050c2490048	CFC-115	Emissions to urban air close to ground	0.26	WMO2014

UUID	Substance	Sub-compartment	CF	Source
fe0acd60-3ddc-11dd-a3a9-0050c2490048	CFC-115	Emissions to air, unspecified (long-term)	0.26	WMO2014
08a91e70-3ddc-11dd-9657-0050c2490048	CFC-12	Emissions to non-urban air or from high stacks	0.73	WMO2014
e2fa8f9d-6555-11dd-ad8b-0800200c9a66	CFC-12	Emissions to lower stratosphere and upper troposphere	0.73	WMO2014
08a91e70-3ddc-11dd-9656-0050c2490048	CFC-12	Emissions to urban air close to ground	0.73	WMO2014
fe0acd60-3ddc-11dd-9efe-0050c2490048	CFC-12	Emissions to air, unspecified	0.73	WMO2014
08a91e70-3ddc-11dd-9655-0050c2490048	CFC-12	Emissions to air, unspecified (long-term)	0.73	WMO2014
fe0acd60-3ddc-11dd-a8f0-0050c2490048	Halon-1001	Emissions to air, unspecified (long-term)	0.57	WMO2014
fe0acd60-3ddc-11dd-a8f1-0050c2490048	Halon-1001	Emissions to urban air close to ground	0.57	WMO2014
fe0acd60-3ddc-11dd-a8ef-0050c2490048	Halon-1001	Emissions to air, unspecified	0.57	WMO2014
d86cb000-6555-11dd-ad8b-0800200c9a66	Halon-1001	Emissions to lower stratosphere and upper troposphere	0.57	WMO2014
fe0acd60-3ddc-11dd-a8f2-0050c2490048	Halon-1001	Emissions to non-urban air or from high stacks	0.57	WMO2014
fe0acd60-3ddc-11dd-a906-0050c2490048	Halon-1201	Emissions to air, unspecified (long-term)	1.4	ILCD 2017; EN 15804; Recipe
fe0acd60-3ddc-11dd-a907-0050c2490048	Halon-1201	Emissions to urban air close to ground	1.4	ILCD 2017; EN 15804; Recipe
fe0acd60-3ddc-11dd-a908-0050c2490048	Halon-1201	Emissions to non-urban air or from high stacks	1.4	ILCD 2017; EN 15804; Recipe
1f30af3f-6556-11dd-ad8b-0800200c9a66	Halon-1201	Emissions to lower stratosphere and upper troposphere	1.4	ILCD 2017; EN 15804; Recipe
08a91e70-3ddc-11dd-90c6-0050c2490048	Halon-1201	Emissions to air, unspecified	1.4	ILCD 2017; EN 15804; Recipe
fe0acd60-3ddc-11dd-9eea-0050c2490048	Halon-1202	Emissions to air, unspecified	1.7	WMO2014
e2fa8f8b-6555-11dd-ad8b-0800200c9a66	Halon-1202	Emissions to lower stratosphere and upper troposphere	1.7	WMO2014
08a91e70-3ddc-11dd-9454-0050c2490048	Halon-1202	Emissions to urban air close to ground	1.7	WMO2014
08a91e70-3ddc-11dd-9455-0050c2490048	Halon-1202	Emissions to non-urban air or from high stacks	1.7	WMO2014
08a91e70-3ddc-11dd-9805-0050c2490048	Halon-1202	Emissions to air, unspecified (long-term)	1.7	WMO2014
fe0acd60-3ddc-11dd-a8f9-0050c2490048	Halon-1211	Emissions to air, unspecified (long-term)	6.9	WMO2014
fe0acd60-3ddc-11dd-a8fa-0050c2490048	Halon-1211	Emissions to urban air close to ground	6.9	WMO2014
04202055-6556-11dd-ad8b-0800200c9a66	Halon-1211	Emissions to lower stratosphere and upper troposphere	6.9	WMO2014
fe0acd60-3ddc-11dd-a8f8-0050c2490048	Halon-1211	Emissions to air, unspecified	6.9	WMO2014
fe0acd60-3ddc-11dd-a8fb-0050c2490048	Halon-1211	Emissions to non-urban air or from high stacks	6.9	WMO2014
fe0acd60-3ddc-11dd-a90a-0050c2490048	Halon-1301	Emissions to air, unspecified (long-term)	15.2	WMO2014
fe0acd60-3ddc-11dd-a90b-0050c2490048	Halon-1301	Emissions to urban air close to ground	15.2	WMO2014
fe0acd60-3ddc-11dd-a90c-0050c2490048	Halon-1301	Emissions to non-urban air or from high stacks	15.2	WMO2014
fe0acd60-3ddc-11dd-a909-0050c2490048	Halon-1301	Emissions to air, unspecified	15.2	WMO2014

UUID	Substance	Sub-compartment	CF	Source
e2fa8f92-6555-11dd-ad8b-0800200c9a66	Halon-1301	Emissions to lower stratosphere and upper troposphere	15.2	WMO2014
fe0acd60-3ddc-11dd-a349-0050c2490048	Halon-2311	Emissions to air, unspecified (long-term)	0.14	ILCD 2017; EN 15804; Recipe
fe0acd60-3ddc-11dd-a348-0050c2490048	Halon-2311	Emissions to air, unspecified	0.14	ILCD 2017; EN 15804; Recipe
fe0acd60-3ddc-11dd-a3a3-0050c2490048	Halon-2311	Emissions to non-urban air or from high stacks	0.14	ILCD 2017; EN 15804; Recipe
fe0acd60-3ddc-11dd-a34a-0050c2490048	Halon-2311	Emissions to urban air close to ground	0.14	ILCD 2017; EN 15804; Recipe
041fd235-6556-11dd-ad8b-0800200c9a66	Halon-2311	Emissions to lower stratosphere and upper troposphere	0.14	ILCD 2017; EN 15804; Recipe
08a91e70-3ddc-11dd-9457-0050c2490048	Halon-2401	Emissions to air, unspecified (long-term)	0.25	ILCD 2017; EN 15804; Recipe
041f83f0-6556-11dd-ad8b-0800200c9a66	Halon-2401	Emissions to lower stratosphere and upper troposphere	0.25	ILCD 2017; EN 15804; Recipe
08a91e70-3ddc-11dd-9459-0050c2490048	Halon-2401	Emissions to non-urban air or from high stacks	0.25	ILCD 2017; EN 15804; Recipe
08a91e70-3ddc-11dd-9456-0050c2490048	Halon-2401	Emissions to air, unspecified	0.25	ILCD 2017; EN 15804; Recipe
08a91e70-3ddc-11dd-9458-0050c2490048	Halon-2401	Emissions to urban air close to ground	0.25	ILCD 2017; EN 15804; Recipe
041f83f8-6556-11dd-ad8b-0800200c9a66	Halon-2402	Emissions to lower stratosphere and upper troposphere	15.7	WMO2014
fe0acd60-3ddc-11dd-a651-0050c2490048	Halon-2402	Emissions to urban air close to ground	15.7	WMO2014
fe0acd60-3ddc-11dd-a650-0050c2490048	Halon-2402	Emissions to air, unspecified (long-term)	15.7	WMO2014
08a91e70-3ddc-11dd-945a-0050c2490048	Halon-2402	Emissions to air, unspecified	15.7	WMO2014
fe0acd60-3ddc-11dd-a652-0050c2490048	Halon-2402	Emissions to non-urban air or from high stacks	15.7	WMO2014
fe0acd60-3ddc-11dd-a346-0050c2490048	HCFC-123	Emissions to urban air close to ground	0.01	WMO2011 (as reported in WMO 2014)
fe0acd60-3ddc-11dd-a344-0050c2490048	HCFC-123	Emissions to air, unspecified	0.01	WMO2011 (as reported in WMO 2014)
fe0acd60-3ddc-11dd-a345-0050c2490048	HCFC-123	Emissions to air, unspecified (long-term)	0.01	WMO2011 (as reported in WMO 2014)
041ff94b-6556-11dd-ad8b-0800200c9a66	HCFC-123	Emissions to lower stratosphere and upper troposphere	0.01	WMO2011 (as reported in WMO 2014)
fe0acd60-3ddc-11dd-a347-0050c2490048	HCFC-123	Emissions to non-urban air or from high stacks	0.01	WMO2011 (as reported in WMO 2014)
fe0acd60-3ddc-11dd-ab9c-0050c2490048	HCFC-124	Emissions to air, unspecified	0.022	Montreal Protocol (as reported in WMO 2014)
fe0acd60-3ddc-11dd-ab9d-0050c2490048	HCFC-124	Emissions to air, unspecified (long-term)	0.022	Montreal Protocol (as reported in WMO 2014)
fe0acd60-3ddc-11dd-ab9e-0050c2490048	HCFC-124	Emissions to urban air close to ground	0.022	Montreal Protocol (as reported in WMO 2014)
fe0acd60-3ddc-11dd-ab9f-0050c2490048	HCFC-124	Emissions to non-urban air or from high stacks	0.022	Montreal Protocol (as reported in WMO 2014)

UUID	Substance	Sub-compartment	CF	Source
3e4d77a4-6556-11dd-ad8b-0800200c9a66	HCFC-124	Emissions to lower stratosphere and upper troposphere	0.022	Montreal Protocol (as reported in WMO 2014)
fe0acd60-3ddc-11dd-aba0-0050c2490048	HCFC-141b	Emissions to air, unspecified	0.102	WMO2014
fe0acd60-3ddc-11dd-aba3-0050c2490048	HCFC-141b	Emissions to non-urban air or from high stacks	0.102	WMO2014
fe0acd60-3ddc-11dd-aba1-0050c2490048	HCFC-141b	Emissions to air, unspecified (long-term)	0.102	WMO2014
fe0acd60-3ddc-11dd-aba2-0050c2490048	HCFC-141b	Emissions to urban air close to ground	0.102	WMO2014
1f30d651-6556-11dd-ad8b-0800200c9a66	HCFC-141b	Emissions to lower stratosphere and upper troposphere	0.102	WMO2014
8de74f71-8c0d-433e-97bf-99c0972f2fe2	HCFC-142b	Emissions to non-urban air or from high stacks	0.057	WMO2014
d217e3a3-24b6-4214-8ca1-8c2f3ac4fedf	HCFC-142b	Emissions to air, unspecified	0.057	WMO2014
7e49f1f4-ca15-4102-ab2c-9faada47311b	HCFC-142b	Emissions to air, unspecified (long-term)	0.057	WMO2014
7384eac7-7526-49a2-9842-b6f211d9872a	HCFC-142b	Emissions to urban air close to ground	0.057	WMO2014
fe0acd60-3ddc-11dd-a90f-0050c2490048	HCFC-22	Emissions to urban air close to ground	0.034	WMO2014
e2fa689d-6555-11dd-ad8b-0800200c9a66	HCFC-22	Emissions to lower stratosphere and upper troposphere	0.034	WMO2014
fe0acd60-3ddc-11dd-a90d-0050c2490048	HCFC-22	Emissions to air, unspecified	0.034	WMO2014
fe0acd60-3ddc-11dd-a90e-0050c2490048	HCFC-22	Emissions to air, unspecified (long-term)	0.034	WMO2014
fe0acd60-3ddc-11dd-a910-0050c2490048	HCFC-22	Emissions to non-urban air or from high stacks	0.034	WMO2014
08a91e70-3ddc-11dd-9861-0050c2490048	HCFC-225ca	Emissions to urban air close to ground	0.025	Montreal Protocol (as reported in WMO 2014)
08a91e70-3ddc-11dd-985f-0050c2490048	HCFC-225ca	Emissions to air, unspecified	0.025	Montreal Protocol (as reported in WMO 2014)
0d795078-6556-11dd-ad8b-0800200c9a66	HCFC-225ca	Emissions to lower stratosphere and upper troposphere	0.025	Montreal Protocol (as reported in WMO 2014)
08a91e70-3ddc-11dd-9862-0050c2490048	HCFC-225ca	Emissions to non-urban air or from high stacks	0.025	Montreal Protocol (as reported in WMO 2014)
08a91e70-3ddc-11dd-9860-0050c2490048	HCFC-225ca	Emissions to air, unspecified (long-term)	0.025	Montreal Protocol (as reported in WMO 2014)
08a91e70-3ddc-11dd-90c5-0050c2490048	HCFC-225cb	Emissions to urban air close to ground	0.033	Montreal Protocol (as reported in WMO 2014)
fe0acd60-3ddc-11dd-ab25-0050c2490048	HCFC-225cb	Emissions to air, unspecified (long-term)	0.033	Montreal Protocol (as reported in WMO 2014)
08a91e70-3ddc-11dd-985a-0050c2490048	HCFC-225cb	Emissions to non-urban air or from high stacks	0.033	Montreal Protocol (as reported in WMO 2014)
0d79ecb7-6556-11dd-ad8b-0800200c9a66	HCFC-225cb	Emissions to lower stratosphere and upper troposphere	0.033	Montreal Protocol (as reported in WMO 2014)

UUID	Substance	Sub-compartment	CF	Source
fe0acd60-3ddc-11dd-ab24-0050c2490048	HCFC-225cb	Emissions to air, unspecified	0.033	Montreal Protocol (as reported in WMO 2014)
08a91e70-3ddc-11dd-9677-0050c2490048	R-40	Emissions to air, unspecified	0.015	WMO2014
08a91e70-3ddc-11dd-9679-0050c2490048	R-40	Emissions to urban air close to ground	0.015	WMO2014
08a91e70-3ddc-11dd-9678-0050c2490048	R-40	Emissions to air, unspecified (long-term)	0.015	WMO2014
d86cb009-6555-11dd-ad8b-0800200c9a66	R-40	Emissions to lower stratosphere and upper troposphere	0.015	WMO2014
08a91e70-3ddc-11dd-967a-0050c2490048	R-40	Emissions to non-urban air or from high stacks	0.015	WMO2014

Annex 2. Permalinks of supplementary files

Here following the permanent links to the supplementary files cited in this document, referred to the versions used in the preparation of this report (updated in April 2018)

ILCD Method excel: http://eplca.jrc.ec.europa.eu/permalink/ILCD_Method_DEC_2017.xlsx

ILCD zip package: http://eplca.jrc.ec.europa.eu/permalink/ILCD_DEC_2017.zip

EF Method excel file: http://eplca.jrc.ec.europa.eu/permalink/EF-LCIAMethod_CF(EF-v2.0).xlsx

EF zip package: http://eplca.jrc.ec.europa.eu/permalink/EF-v2.0.zip

Change Log ILCD-EF: http://eplca.jrc.ec.europa.eu/permalink/ChangeLog_COMPLETE_ILCDtoEF2.0.xlsx

NB. Those files are linked to the content of this document. For different uses it's recommended to download the most updated versions available through the developer's page of the Life Cycle Data Network, and therein links to EF and ILCD:

http://eplca.jrc.ec.europa.eu/LCDN/ under ILCD and EF pages

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