European Commission

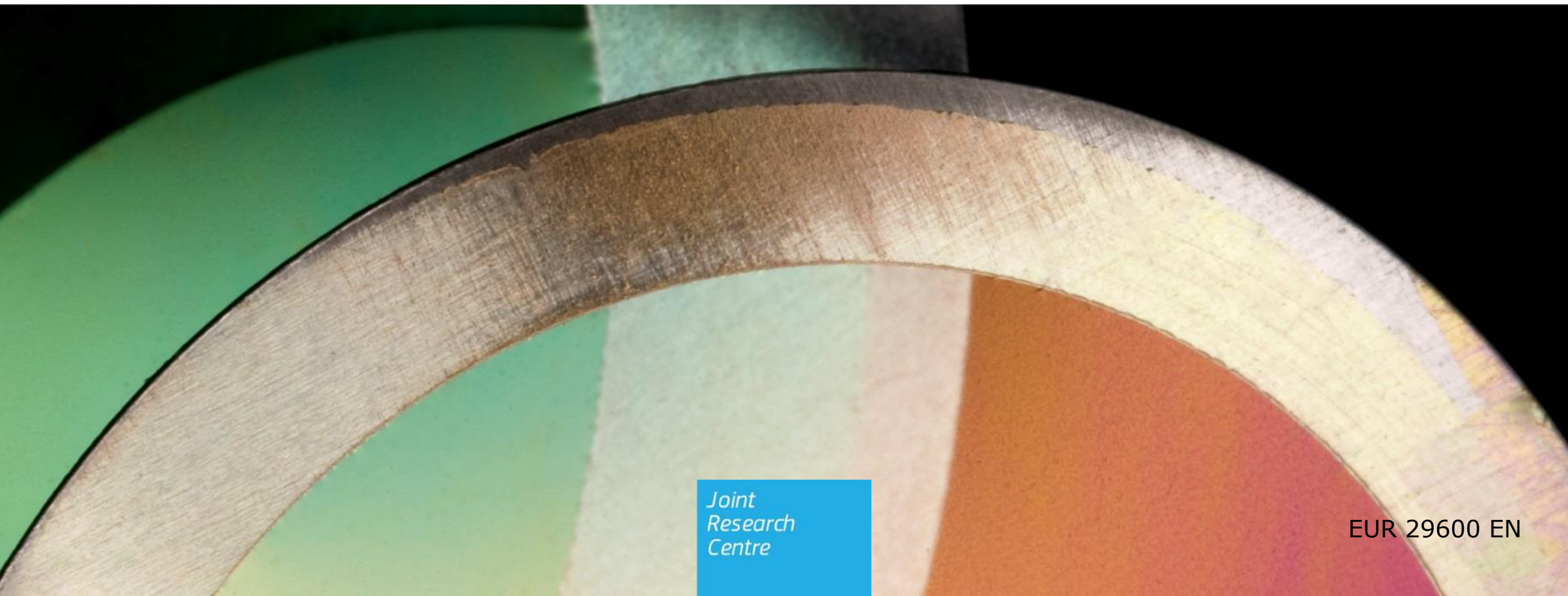
JRC TECHNICAL REPORTS

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

Version 2
from ILCD to EF 3.0

Fazio, S. Biganzioli, F. De Laurentiis, V., Zampori, L., Sala, S. Diaconu, E.

2018



Joint Research Centre

EUR 29600 EN

Contact information
Name: European Platform on LCA
Email: JRC-EPLCA@ec.europa.eu

JRC Science Hub
https://ec.europa.eu/jrc

JRC114822

EUR 29600 EN

PDF	ISBN 978-92-79-98584-3	ISSN 1831-9424	doi:10.2760/002447
Print	ISBN 978-92-79-98585-0	ISSN 1018-5593	doi:10.2760/090552

Ispra: European Commission, 2018

How to cite this report: Fazio, S. Biganzioli, F. De Laurentiis, V., Zampori, L., Sala, S. Diaconu, E. *Supporting information to the characterisation factors of recommended EF Life Cycle Impact Assessment methods, version 2, from ILCD to EF 3.0*, EUR 29600 EN, European Commission, Ispra, 2018, ISBN 978-92-79-98584-3, doi:10.2760/002447, PUBSY No. JRC114822.

Contents

Foreword

This document provides supporting information related to the methodologies 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) methods that have been adopted in the EF context, the changes (if any) in comparison with ILCD, and the previous release of the Environmentan Footprint reference package (May 2018). It also reports the deviations (if any) from the original references of the different methods, and relates choices and assumption made in the creation of Characterisation Factors for different impact categories.

.

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, in this release of the Reference Package (EF 3.0) 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), some changes also occurred in comparison to the EF 2.0 release (may 2018).

The 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 methods 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 methods 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 methods and a new package, based on ILCD format, containing new files for LCIA methods, can be summarized as follows:

- 3 methods are completely new, or updated according to the newest releases of the old methods adopted in ILCD/EF. 1 method has been deeply reviewed. 9 sub-methods (i.e. partial sets of CFs for specific group of substances, have been released for 3 impact categories).
- The elementary flow list has been fixed and expanded according to the needs of the new methods
- Within the new methods some flows have been spatially differentiated (in ILCD format the location attribute is resolved at the method level, not at the elementary flow level)
- For several flows that were not characterized (both in newly added methods 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 methods.

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 3.0 see http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml/ for details.

Acknowledgements

Documentation of the LCIA methods as ILCD formatted data set, mapping to the ILCD elementary flows, and additional quality checks were performed by the EC's JRC-D1 and with contractual support projects, partly financed under several Administrative Arrangements between JRC and DG ENV

Authors

Simone Fazio

Fabrizio Biganzoli

Valeria de Laurentiis

Luca Zampori

Serenella Sala

Edward Diaconu

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 methods 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) Methods, 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 methods have been completely changed, some others have been just fine-tuned or not changed. The EF scheme only recommends methods at midpoint level[1]. While ILCD was also recommending endpoint methods[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 methods 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 methods 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 method list for EF scheme, and the CFs available for each method.

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 Methods

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

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

Recommendation at midpoint				
Impact category	**Indicator**	**Unit**	**Recommended default LCIA method**	**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 3.0[4]
Ozone depletion	Ozone Depletion Potential (ODP)	kg CFC-11eq	Steady-state ODPs as in (WMO 1999)	EF 3.0
Human toxicity, cancer effects*[3]	Comparative Toxic Unit for humans (CTU_h)	CTUh	USEtox 2.1. model (Rosenbaum et al, 2008)	EF 3.0
Human toxicity, non- cancer effects*[3]	Comparative Toxic Unit for humans (CTU_h)	CTUh	USEtox 2.1. model (Rosenbaum et al, 2008)	EF 3.0
Particulate matter/Respiratory inorganics	Human health effects associated with exposure to $PM_{2.5}$	Disease incidences[5]	PM method recommended by UNEP (UNEP 2016)	EF 3.0
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 3.0
Photochemical ozone formation	Tropospheric ozone concentration increase	kg NMVOC eq	LOTOS-EUROS (Van Zelm et al, 2008) as applied in ReCiPe 2008	EF 3.0
Acidification	Accumulated Exceedance (AE)	mol H+ eq	Accumulated Exceedance (Seppälä et al. 2006, Posch et al, 2008)	EF 3.0
Eutrophication, terrestrial	Accumulated Exceedance (AE)	mol N eq	Accumulated Exceedance (Seppälä et al. 2006, Posch et al, 2008)	EF 3.0
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 3.0
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 3.0
Ecotoxicity freshwater*[3]	Comparative Toxic Unit for ecosystems (CTU_e)	CTUe	USEtox 2.1. (Rosenbaum et al, 2008)	EF 3.0
Land use	Soil quality index[6] (Biotic production, Erosion resistance, Mechanical filtration	Dimensionless, aggregated index of: kg biotic production/ (m^2*a)[7] kg soil/ (m^2*a)	Soil quality index based on LANCA (Beck et al. 2010 and Bos et al. 2016)	EF 3.0

[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 3.0) is available through 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 for assessing impacts due to land use as reported in De Laurentiis et al, 2018

[7] This refers to occupation and transformation

Recommendation at midpoint				
Impact category	**Indicator**	**Unit**	**Recommended default LCIA method**	**Source of CFs**
	and Groundwater replenishment	m^3 water/ (m^2*a) m^3 g.water/ (m2*a)		
Water use	User deprivation potential (deprivation-weighted water consumption)	kg world eq. deprived	Available WAter REmaining (AWARE) in UNEP, 2016	EF 3.0
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 3.0
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 3.0

* 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 method data set names, reference source, and associated unit groups for recommended and interim CFs in ILCD dataset

LCIA method	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)	III
EF - Non-cancer human health effects; midpoint; CTUh; USEtox™, Rosenbaum et al 2008	Comparative Toxic Unit for human (CTUh)	Units of items (cases)	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)	III
EF - Land use; midpoint; soil quality index; 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 method gives an overview of the method/model. In the LCIA method data 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 method or model, it is recommended to consult the original references of the methods or model. Some issues were noted in the course of documenting the recommended LCIA methods and mapping the factors to a common set of elementary flows. Only general problems that are not related to one specific LCIA method 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 method 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 Model (e.g. the new IPCC model for GWP is introducing 137 new substances, compared to the version released in 2007, new Use tox model adds ~ 3000 new substances compared to the previous version) see change log available at http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml.

3.3 Geographical differentiation

Some of the models behind the LCIA methods allow calculating characterisation factors for further substances considering geographical differentiation. Within ILCD dataset, available country-specific factors are included in the LCIA method datasets for: land use; water use[11](full list of locations available). The spatial differentiation is detailed in the methods, 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 methods 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.

For the flows previously (already in ILCD) regionalised in Eutrophication and Acidification methods, the regionalisation has been extended for all the other methods where the same substances are used as non-regionalised, to avoid uncharacterized results for substances that are actually captured in the method. In tables 4 and 5 are summarized the flows (UUID + substance name) and locations for which the allowed regionalisation has been extended. For the impact categories other than Eutrophication and Acidification, the CF for the non-regionalised flow has been applied to all the locations.

Table 4. list of flows regionalised in Acidification and/or Eutrophication in ILCD, and extended to other methods in EF 3.0 .

08a91e70-3ddc-11dd-96ae-0050c2490048	ammonia
2905c64e-6556-11dd-ad8b-0800200c9a66	ammonia
08a91e70-3ddc-11dd-a2aa-0050c2490048	ammonia
08a91e70-3ddc-11dd-a2a9-0050c2490048	ammonia
08a91e70-3ddc-11dd-96af-0050c2490048	ammonia
08a91e70-3ddc-11dd-96e5-0050c2490048	nitrogen dioxide
08a91e70-3ddc-11dd-96e6-0050c2490048	nitrogen dioxide
08a91e70-3ddc-11dd-96e7-0050c2490048	nitrogen dioxide
08a91e70-3ddc-11dd-96e8-0050c2490048	nitrogen dioxide
08a91e70-3ddc-11dd-96e9-0050c2490048	nitrogen dioxide
191b44d4-90c9-465a-8802-93a651b4fd52	Nitrogen oxides
1c952836-ea05-43db-9063-0c5e1ee65fa8	Nitrogen oxides
2f89fbbd-e428-4de1-8c33-9dd66e53310c	Nitrogen oxides
e575ebc3-0a3b-4c38-9a2a-13e42c72553b	Nitrogen oxides
f79d0f8f-2b0e-49cb-bed0-b1ea0fbd8625	Nitrogen oxides
fe0acd60-3ddc-11dd-ac49-0050c2490048	sulfur dioxide
fe0acd60-3ddc-11dd-ac48-0050c2490048	sulfur dioxide
fe0acd60-3ddc-11dd-ac4c-0050c2490048	sulfur dioxide
fe0acd60-3ddc-11dd-ac4b-0050c2490048	sulfur dioxide
fe0acd60-3ddc-11dd-ac4a-0050c2490048	sulfur dioxide
2905c636-6556-11dd-ad8b-0800200c9a66	sulfur oxides
fe0acd60-3ddc-11dd-a208-0050c2490048	sulfur oxides
fe0acd60-3ddc-11dd-a207-0050c2490048	sulfur oxides
fe0acd60-3ddc-11dd-a20a-0050c2490048	sulfur oxides
fe0acd60-3ddc-11dd-a209-0050c2490048	sulfur oxides

Table 5. Location codes allowed in inventories, for the substances mentioned in table 4

AL	CH	ES	HU	MD	RO
AT	CS	FI	IE	MK	RU
BA	CZ	FR	IT	NL	SE
BE	DE	GB	LT	NO	SI
BG	DK	GR	LU	PL	SK
BY	EE	HR	LV	PT	UA

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 methods. The rules applied for the gap-filling are the following:

- The specific flow not characterized in a specific method has a direct proxy in the same method. This means that the substance or resource is already covered in the method, in the same main compartment, in another sub-compartment
    - Example: if the flow *1,1,2-trichlorotrifluoroethane* was characterized for “climate change” method 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 method 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 methods (light green frames), and deviations or adaptations that have been adopted in comparison with the referenced method for each category (light blue frames)

A detailed list of all the changes made from ILCD to the different released versions of EF reference method are available at http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml (see "change log" excel file).

All the supporting documents and files (excel files, reference package and other documentation) related to the EF 3.0 Reference Package is available at http://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml

4.1 Climate change

What's new respect to ILCD:

the reference method for climate change, midpoint, in ILCD was the one proposed by IPCC 2007, while in the EF method 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 method, compared to ILCD.

Beyond the main method containing all the characterised substances in this category, three sub-methods for fossil, biogenic and land use emissions are available in EF 3.0.

Deviations or adaptations from the original method:

Some values have been adapted according to the PEFCR guidance document 6.2 (see table and ref. below).

Impact category	*Model*	*Indicator*
Climate change midpoint	IPPC, 2013 + adaptations	GWP_{100}

Compared to the values available in the PEFCR Guidance 6.3 and reported in EC-JRC 2018b, some modifications are included in the EF Reference Package 3.0 and they are reported in Table 6. Furthermore, the sub-indicator referring to "land use and land transformation" has been renamed to "land use and land use change".

The global warming potentials of the third assessment report of IPCC (2007) are applied. The GWPs were updated using the Fifth assessment report of IPCC (2013), including climate-change carbon feedbacks for both CO_2 and non-CO_2 substances (following the UNEP/SETAC recommendations of the Pellston Workshop, January 2016). The values with feedbacks are applied to ensure consistency, as feedbacks are already included for CO_2. The GWPs of well-mixed GHGs can be found in chapter 8 of the Scientific basis report, Tables 8.7 and 8.SM.16. The GWPs for near term GHGs are not recommended for use due to their complexity and high uncertainty. Near term GHGs refer to substances that are not well-mixed once emitted to the atmosphere because of their very rapid decay (black carbon, organic carbon, nitrogen oxides, sulphur oxides, volatile organic compounds, and carbon monoxide).

Table 6 Modifications in the EF reference package 3.0, compared to the PEFCR Guidance document (EC- DG ENV, 2016) developed in the Environmental Footprint pilot phase.

Substance	Compartment	GWP_{100}
Carbon dioxide (biogenic-100yr)	Resources from air	The flow has been erased from the package.
Carbon dioxide (fossil)	Resources from air	0

Characterisation factors of methane, carbon dioxide and carbon monoxide

The third assessment IPCC report (2007) estimated the global warming potential for methane at 25 for a time period of 100 years. This value factors in the indirect climate effects of methane emissions (such as the positive feedback on the methane lifetime and on the concentrations of ozone and stratospheric water vapour) but excludes the oxidation of methane into carbon dioxide. The Fifth assessment report of IPCC (2013) reports a global warming potential for methane at 34, still with the exclusion of methane oxidation into carbon dioxide and which is valid for biogenic methane only (IPCC 2013, Table 8.7). IPCC (2013) refers to Boucher et al. (2009) to add the methane oxidation for fossil methane, resulting in a GWP of 36. The added value of +2 includes only a partial oxidation of methane into CO_2. Boucher et al. (2009), calculated an upper limit of +2.5 when considering that all methane is converted into CO_2 and up to +2.75 with a longer time horizon. Within the context of the environmental footprint a simple stoichiometric calculation is used to compensate the avoided CO_2 uptake within the released methane (+2.75). It can be discussed which correction factor should be applied, (i) +2 following IPCC, (ii) +2.5 following the upper margin of Boucher et al. (2009) for a time horizon of 100 years or (iii) +2.75 using the stoichiometric balance (all emissions happens "now"). The last approach is chosen, as a GWP of 36.75 reassures the same outcome between a detailed modelling (modelling all carbon uptakes and releases) and a simplified modelling approach (only modelling the CH_4 release). Within the EF context, the same result between a detailed modelling approach or the EF proposed simplified modelling approach is considered to be essential. This means that for fossil methane a GWP of 36.75 shall be used.

For biogenic carbon modelling the list of elementary flows and CFs in Table shall be applied.

Table 7. CFs (in CO_2-equivalents, with carbon feedbacks).

Substance	Compartment	GWP_{100}
Carbon dioxide (fossil)	Air emission	1
Methane (fossil)	Air emission	36.75
Carbon monoxide (fossil)	Air emission	1.57 [12]
Carbon dioxide (fossil)	Resources from air	0
Carbon dioxide (biogenic)	Resources from air	0
Carbon dioxide (biogenic)	Air emission	0
Methane (biogenic)	Air emission	34
Carbon monoxide (biogenic)	Air emission	0
Carbon dioxide (land use change)	Resources from air	-1
Carbon dioxide (land use change)	Air emission	1
Methane (land use change)	Air emission	36.75
Carbon monoxide (land use change)	Air emission	1.57

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 method WMO 2014 is adopted as reference.

Deviations or adaptations from the original method:

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, midpoint	WMO,2014 + integrations	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 of EC-JRC 2018b.

4.3 Toxicities

What's new respect to ILCD:

The most recent version of the USEtox® model (2.1) has been used.

Overall, CFs have been provided for more than 6700 substances. The list of chemicals has been enlarged: new added chemicals' CF have been calculated on the basis of data collected from REACH-IUCLID database, EFSA's OpenFoodTox database and PPDB database. Last, for data gap filling purposes, EPISuite and OECD QSAR toolbox have been investigated.

Deviations or adaptations from the original method:

For Ecotoxicity the Effect Factor is derived from log(HC20) instead from avlogEC50, in order to be in line with the most recent recommendations from UNEP – Pellston Workshop 2018. As consequence, the Effect Factor is calculated as follows: EF = 0.2/HC20.

USEtox® 2.1 model has been run for organics, inorganics and metals. However, being USEtox® built only for organic chemicals, some factors have been applied for cover uncertainty associated to inorganics and metals

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

Human toxicity

Impact category	*Model*	*Indicator*
Human toxicity midpoint, cancer effects	USEtox® 2.1 (Rosenbaum et al 2008)	Comparative Toxic Unit for Human Health (CTUh)
Human toxicity midpoint, non cancer effects	USEtox® 2.1 (Rosenbaum et al 2008)	CTUh

Ecotoxicity

Impact category	*Model*	*Indicator*
Ecotoxicity freshwater, midpoint	USEtox® 2.1 (Rosenbaum et al 2008)	Comparative Toxic Unit for ecosystems (CTUe)

All USEtox® factors (v.2.1) were implemented in accordance to the correspondence in the emission compartments reported in the Table 8 (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. USEtox® is currently working to implement sediment compartment or the next version of the multimedia model.

For Ecotoxicity, a more conservative approach has been applied: HC20 (concentration potentially hazardful for 20% percent of a biological community) has been used, instead of the avlogEC50 (proposed in USEtox®). This choice intends to reflect the most recent Pellston recommendation on aquatic ecotoxicity risk evaluation and assessment.

Being USEtox® model designed for organic chemicals, some uncertainty factors were applied to inorganics and metals:

- For organics, a factor of 1 is applied, *i.e.* no difference from the original CF result:
- For inorganics and non-essential metals, a factor of 0.1 is applied;
- For essential metals, a factor of 0.01 is applied.

A complete list of inorganics, and metals essentials and non-essential, is available in annex I.

The only inorganics included in USEtox® contains 27 cationic metals, the CFs for these chemicals were left as such, being these values agreed between USEtox® developers and industries.

In order to evaluate the quality of the characterization factors, additional parameters describing source and reliability of each parameter used to run the model were added.

Last, in order to reduce the number of uncharacterized chemicals, approximations were applied to few chemicals (or groups of chemicals, e.g. PAH) deemed as of high interest. Generally, they were calculated as the 50th percentile of all the characterized available chemicals belonging to the group, or simply associated to the most similar substance.

A fully detailed description can be found in EC-JRC 2018a

Table 8 Correspondence of emission compartments between USEtox® model and ILCD elementary flow system *

	ILCD emission compartments	USEtox® compartment
Air	Emissions to air, unspecified	Average urban/continental rural air
	Emissions to air, unspecified (long term)	0
	Emission to air, indoor	Avg. Household/industrial indoor air
	Emissions to non-urban air or from high stacks	Continental rural air
	Emissions to urban air close to ground	Urban air
	Emissions to lower stratosphere and upper troposphere	Continental rural air
Water	Emissions to fresh water	Freshwater
	Emissions to sea water	Seawater
	Emissions to water, unspecified	Average of Freshwater/seawater
	Emissions to water, unspecified (long term)	0
Soil	Emissions to soil, unspecified	Average of Natural/Agric. soil
	Emissions to agricultural soil	Agric. soil
	Emissions to non-agricultural soil	Natural soil

* 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. Some explanations are given more below in this document

4.4 Respiratory inorganics

What's new respect to ILCD:

The method 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 method is characterising the emissions as disease incidence due to the emission of PM, as defined by Fantke et al. (2016).

Deviations or adaptations from the original method:

Specific CFs for PM_{10} have been derived, since were not available in the original method, while for other particulates ($PM_{0.2}$ and $PM_{0.2-2.5}$), the factor associated to $PM_{2.5}$ has been adopted. Further explanations are reported below.

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

The recommended model is the one developed by the UNEP-SETAC Task Force (TF) on particulate matter (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 ($PM_{0.2-2.5}$)" 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 method adopted in ILCD for ionising radiation is not changed

Deviations or adaptations from the original method:

Proxy CFs have been adopted for some emissions to specific sub-compartments, the reference unit was adapted from kg to kBq, according to ILCD unit group for radioactivity.

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

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. method 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 method adopted in ILCD for Photochemical Ozone Formation is not changed.

Deviations or adaptations from the original method:

CFs for specific flows, not available in the original method, but contained in the elementary flow list, both for ILCD and EF, have been calculated (see below further details).

Impact category	*Model*	*Indicator*
Photochemical ozone formation, midpoint	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 method adopted in ILCD for Acidification is not changed.

Deviations or adaptations from the original method:

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

Impact category	*Model*	*Indicator*
Acidification, midpoint	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 method. 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 9 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 are provided in the LCIA method data sets at midpoint and for a number of countries (only for SO_2, NH_3, and NO_2).

4.8 Eutrophication

What's new respect to ILCD:

The methods adopted in ILCD for Eutrophication are not changed.

Deviations or adaptations from the original method:

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

Impact category	*Model*	*Indicator*
Eutrophication terrestrial, midpoint	Seppala et al 2006, Posch et al 2008	Accumulated Exceedance (AE)
Eutrophication aquatic-freshwater/marine, midpoint	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 method 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 method'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 methods, 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 10. 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 changed. In ILCD the model assessing Soil Organic Matter (SOM) loss, developed by Mila I Canals (2007) was adopted, in EF the method, a soil quality index built aggregating the indicators provided by the LANCA model (Bos et al, 2016) is implemented.

Deviations or adaptations from the original method:

The LANCA model is taking into account different indicators for a number of soil properties, as explained below. Tthose 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, midpoint	LANCA (as in Bos et al., 2016)	Soil quality index

The underlying model used for the calculation of CFs for land use at midpoint is the LANCA LCIA model (Bos et al. 2016). The LANCA model provides five indicators for assessing the impacts due to the use of soil: erosion resistance, mechanical filtration, physicochemical filtration, groundwater regeneration and biotic production. Starting from these indicators, as provided in the latest update (version 2.5) of LANCA CFs (Horn and Meier (2018), the JRC calculated a single score index by aggregating the indicators (as presented in De Laurentiis et al. 2018), according to 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 value corresponding to the 5th and 95th percentile of the distribution of characterization factors for "occupation" elementary flows (CF^5 and CF^{95}) and application of a cut-off to all the characterization factors smaller than CF^5 and larger than CF^{95}.

3- Linear re-scaling of the remaining occupation CFs, obtained by calculating the ratio between each value and the CF^{95} and multiplying by 100. ($\dot{CF}_{i,j} = \frac{CF_{i,j}}{CF_i^{95}} \times 100$)

4- 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 an index attributing to each elementary flow a score (namely, for occupation, ranging from -17 to 165 for the global set of CFs and from -47 and 318 for the country-specific set). This approach does not address modelling uncertainties that may be associated with each single impact indicator and it gives equal importance to the different soil quality indicators.

The 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, hence, 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 method:

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 methods 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 changed. In ILCD the model characterized the water depletion according to scarcity adjusted mass of water used (Swiss Ecoscarcity 2006; Frischknecht et al., 2008). In the EF method, the model AWARE (Boulay et al., 2016; UNEP 2016) is implemented, assessing the impact in terms of quantity of water deprived.

Deviations or adaptations from the original method:

The AWARE model is taking into account few resolution levels, however, for the EF recommendation, only the country scale is adopted (see below for further details)

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

Characterization 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 methods, additional updates will be released through the website of the European Platform on LCA (http://eplca.jrc.ec.europa.eu/).

References

[1] Bos U., Horn R., Beck T., Lindner J.P., Fischer M. (2016). LANCA® - Characterisation Factors for Life Cycle Impact Assessment, Version 2.0, 978-3-8396-0953-8Fraunhofer Verlag, Stuttgart (2016).

[2] Boulay A.M., Bare J., Benini L., Berger M., Lathuillière M.J., Manzardo A., Margni M., Motoshita M., Núñez M., Pastor A.V., Ridoutt B., Oki T., Worbe S., Pfister S. (2016). The WULCA consensus characterization model for water scarcity footprints: Assessing impacts of water consumption based on available water remaining (AWARE). The International Journal of Life Cycle Assessment 2017, 1– 11. DOI: 10.1007/s11367-017-1333-8

[3] CML method: http://cml.leiden.edu/software/data-cmlia.html

[4] De Laurentiis V., Secchi M., Bos U., Horn R., Laurent A., Sala S. (2018) Soil quality index: exploring options for a comprehensive assessment of land use impacts in LCA. Submitted to the Journal of Cleaner Production

[5] De Schryver A.M., Brakkee K.W., Goedkoop M.J., Huijbregts M.A.J. (2009). Characterization Factors for Global Warming in Life Cycle Assessment Based on Damages to Humans and Ecosystems. Environ Sci Technol 43 (6): 1689–1695.

[6] De Schryver and Goedkoop (2009). Mineral Resource. Chapter 12 in: Goedkoop, M., Heijungs, R., Huijbregts, M.A.J., De Schryver, A., Struijs, J., Van Zelm, R. (2009). ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Report I: Characterisation factors, first edition.

[7] Dreicer, M., Tort, V., Manen, P. (1995). ExternE, Externalities of Energy, Vol. 5 Nuclear, Centr d'étude sur l'Evaluation de la Protection dans le domaine nucléaire (CEPN), edited by the European Commission DGXII, Science, Research and development JOULE, Luxembourg.

[8] EC-DG ENV Schryver, AD, Galatola, M, Schau, EM, Benini, L, & Pant, R. (2016). Guidance and requirements for climate change modelling - PEFCRs Issue paper for the Environmental Footprint Technical Advisory Board. Brussels.

[9] EC-JRC (2010a). ILCD Handbook. Analysis of existing Environmental Impact Assessment methodologies for use in Life Cycle Assessment. p115. Available at http://lct.jrc.ec.europa.eu

[10] EC- JRC (2010b). ILCD Handbook. Framework and Requirements for LCIA models and indicators p112. Available at http://lct.jrc.ec.europa.eu

[11] EC- JRC (2011). ILCD Handbook. Recommendations for Life Cycle Impact assessment in the European context – based on existing environmental impact assessment models and factors. p181. Available at http://lct.jrc.ec.europa.eu

[12] EC- JRC (2018a) Saouter, E., Biganzoli, F., Ceriani, L., Versteeg, D., Crenna, E., Zampori, L., Sala, S, Pant, R. (2018). Environmental Footprint: Update of Life Cycle Impact Assessment Methods – Ecotoxicity freshwater, human toxicity cancer, and non-cancer. EUR 29495 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-79-98182-1, doi: 10.2760/178544, EC-JRC114227

[13] EC-JRC (2018b) Fazio, S. , Castellani, V. , Sala, S., Schau, EM., Secchi, M. , Zampori, L.,Diaconu E. Supporting information to the characterisation factors of recommended EF Life Cycle Impact Assessment methods. EUR 28888 EN, European Commission, Ispra , 2018 , ISBN 978-92-79-76742-5, doi:10.2760/671368, JRC109369

[14] Fantke, P., Evans, J., Hodas, N., Apte, J., Jantunen, M., Jolliet, O., McKone, T.E. (2016). Health impacts of fine particulate matter. In: Frischknecht, R., Jolliet, O. (Eds.), Global Guidance for Life Cycle Impact Assessment Indicators: Volume 1. UNEP/SETAC Life Cycle Initiative, Paris, pp. 76-99 (available at: www.lifecycleinitiative.org/applying-lca/lcia-cf/, accessed January 2017).

[15] Frischknecht, R., Braunschweig, A., Hofstetter P., Suter P. (2000). Modelling human health effects of radioactive releases in Life Cycle Impact Assessment. Environmental Impact Assessment Review, 20 (2) pp. 159-189.

[16] Frischknecht, R., Steiner, R., Jungbluth, N. (2008). The Ecological Scarcity Method – Eco-Factors 2006. A method for impact assessment in LCA. Environmental studies no. 0906. Federal Office for the Environment (FOEN), Bern: 188 pp.

[17] Garnier-Laplace J. C., Beaugelin-Seiller K, Gilbin R, Della-Vedova C, Jolliet O, Payet J, 2008. A Screening Level Ecological Risk Assessment and ranking method for liquid radioactive and chemical mixtures released by nuclear facilities under normal operating conditions. Proceedings of the International conference on radioecology and environmental protection, 15-20 june 2008, Bergen.

[18] Garnier-Laplace J. C., Beaugelin-Seiller K, Gilbin R, Della-Vedova C, Jolliet O, Payet J, (2009).A Screening Level Ecological Risk Assessment and ranking method for liquid radioactive and chemical mixtures released by nuclear facilities under normal operating conditions Radioprotection 44 (5) 903-908 DOI: 10.1051/radiopro/20095161

[19] Goedkoop and De Schryver (2009). Fossil Resource. Chapter 13 in: Goedkoop, M., Heijungs, R., Huijbregts, M.A.J., De Schryver, A., Struijs, J., Van Zelm, R. (2009). ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Report I: Characterisation factors, first edition.

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

[21] Greco, S.L., Wilson, A.M., Spengler J.D., and Levy J.I. (2007). Spatial patterns of mobile source particulate matter emissions-to-exposure relationships across the United States. Atmospheric Environment (41), 1011-1025.

[22] Guinée, J.B. (Ed.), Gorrée, M., Heijungs, R., Huppes, G., Kleijn, R., de Koning, A., Van Oers, L., Wegener Sleeswijk, A., Suh, S.,. Udo de Haes, H.A, De Bruijn, J.A., Van Duin R., Huijbregts, M.A.J. (2002). Handbook on Life Cycle Assessment: Operational Guide to the ISO Standards. Series: Eco-efficiency in industry and science. Kluwer Academic Publishers. Dordrecht (Hardbound, ISBN 1-4020-0228-9; Paperback, ISBN 1-4020-0557-1).

[23] Horn, R.; Maier, S. (2018): LANCA®- Characterization Factors for Life Cycle Impact Assessment, Version 2.5, November 2018, Available at: http://publica.fraunhofer.de/documents/N-379310.html

[24] Huijbregts, M.A.J., Rombouts, L.J.A., Ragas A.M.J., Van de Meent, D. (2005a). Human-toxicological effect and damage factors of carcinogenic and non carcinogenic chemicals for life cycle impact assessment. Integrated Environ. Assess. Manag. 1: 181-244.

[25] Huijbregts, M.A.J., Struijs, J., Goedkoop, M., Heijungs, R., Hendriks, A.J., Van de Meent, D. (2005b). Human population intake fractions and environmental fate factors of toxic pollutants in life cycle impact assessment. Chemosphere 61: 1495-1504.

[26] Huijbregts, M.A.J., Thissen, U., Guinée, J.B., Jager, T., Van de Meent, D., Ragas, A.M.J., Wegener Sleeswijk, A., Reijnders, L. (2000). Priority assessment of toxic substances in life cycle assessment, I: Calculation of toxicity potentials for 181 substances with the nested multi-media fate, exposure and effects model USES-LCA. Chemosphere 41:541-573.

[27] Huijbregts, M.A.J., Van Zelm, R. (2009). Ecotoxicity and human toxicity. Chapter 7 in: Goedkoop, M., Heijungs, R., Huijbregts, M.A.J., Struijs, J., De Schryver, A., Van Zelm, R. (2009): ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Report I: Characterisation factors, first edition.

[28] Humbert, S. (2009). Geographically Differentiated Life-cycle Impact Assessment of Human Health. Doctoral dissertation, University of California, Berkeley, California, USA.

[29] Koellner T., de Baan L., Beck T., Brandão M., Civit B., Margni M., Milà i Canals L., Saad R., Maia de Sousa D., Müller-Wenk R., (2012). UNEP-SETAC Guideline on Global Land Use Impacts on Biodiversity and Ecosystem Services in LCA. In publication in the International Journal of Life Cycle Assessment

[30] Kramer D. (2001): Magnesium, its alloys and compounds. U. S. Geological Survey Open-File Report 01-341. http://pubs.usgs.gov/of/2001/of01-341/of01-341.pdf, accessed 21 June 2011.

[31] Kramer D. (2002): Magnesium. In: U. S. Geological Survey Minerals Yearbook 2002. http://minerals.usgs.gov/minerals/pubs/commodity/magnesium/magnmyb02.pdf, accessed June 2011.

[32] IPCC (2013). Myhre, G., D. Shindell, F.-M. Bréon, W. Collins, J. Fuglestvedt, J. Huang, D. Koch, J.-F. Lamarque, D. Lee, B. Mendoza, T. Nakajima, A. Robock, G. Stephens, T. Takemura and H. Zhang, 2013: Anthropogenic and Natural Radiative Forcing. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

[33] Milà i Canals, L., Bauer, C., Depestele, J., Dubreuil, A., Freiermuth Knuchel, R., Gaillard, G., Michelsen, O., Müller-Wenk, R., Rydgren B. (2007a). Key elements in a framework for land use impact assessment within LCA. Int J LCA 12:5-15

[34] Milà i Canals L, Romanyà J, Cowell SJ (2007b). Method for assessing impacts on life support functions (LSF) related to the use of 'fertile land' in Life Cycle Assessment (LCA). J Clean Prod 15 1426-1440

[35] Pfister S., Koehler A. and Hellweg S., 2009. Assessing the Environmental Impacts of Freshwater Consumption in LCA. Eniron. Sci. Technol. (43), p.4098–4104

[36] Pope, C.A., Burnett R.T., Thun, M.J., Calle, E.E., Krewski, D., Ito, K., Thurston, G.D. (2002). Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. Journal of the American Medical Association 287, 1132-1141.

[37] Posch, M., Seppälä, J., Hettelingh, J.P., Johansson, M., Margni M., Jolliet, O. (2008). The role of atmospheric dispersion models and ecosystem sensitivity in the determination of characterisation factors for acidifying and eutrophying emissions in LCIA. International Journal of Life Cycle Assessment (13) pp.477–486

[38] Rabl, A. and Spadaro, J.V. (2004). The RiskPoll software, version is 1.051 (dated August 2004). www.arirabl.com.

[39] Rosenbaum, R.K., Bachmann, T.M., Gold, L.S., Huijbregts, M.A.J., Jolliet, O., Juraske, R., Köhler, A., Larsen, H.F., MacLeod, M., Margni, M., McKone, T.E., Payet, J., Schuhmacher, M., van de Meent, D., Hauschild, M.Z. (2008): USEtox - The UNEP-SETAC toxicity model: recommended characterisation factors for human toxicity and freshwater ecotoxicity in Life Cycle Impact Assessment. International Journal of Life Cycle Assessment, 13(7): 532-546, 2008

[40] Seppälä, J., Posch, M., Johansson, M., Hettelingh, J.P. (2006). Country-dependent Characterisation Factors for Acidification and Terrestrial Eutrophication Based on Accumulated Exceedance as an Impact Category Indicator. International Journal of Life Cycle Assessment 11(6): 403-416.

[41] Struijs, J., van Wijnen, H.J., van Dijk, A. and Huijbregts, M.A.J. (2009a). Ozone layer depletion. Chapter 4 in: Goedkoop, M., Heijungs, R., Huijbregts, M.A.J., De Schryver, A., Struijs, J., Van Zelm, R. (2009). ReCiPe 2008.A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Report I: Characterisation factors, first edition.

[42] Struijs, J., Beusen, A., van Jaarsveld, H. and Huijbregts, M.A.J. (2009b). Aquatic Eutrophication. Chapter 6 in: Goedkoop, M., Heijungs, R., Huijbregts, M.A.J., De Schryver, A., Struijs, J., Van Zelm, R. (2009). ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Report I: Characterisation factors, first edition.

[43] Struijs J., van Dijk A., SlaperH., van Wijnen H.J., VeldersG. J. M., Chaplin G., HuijbregtsM. A. J. (2010). Spatial- and Time-Explicit Human Damage Modeling of Ozone Depleting Substances in Life Cycle Impact Assessment. Environmental Science & Technology 44 (1): 204-209

[44] UNEP: UNEP-SETAC Life Cycle Initiative (2016) – Global Guidance for Life Cycle Impact Assessment Indicators. Volume 1.

[45] Van Oers L, de Koning A, Guinee JB, Huppes G (2002): Abiotic Resource Depletion in LCA. Road and Hydraulic Engineering Institute, Ministry of Transport and Water, Amsterdam.

[46] Van Zelm R., Huijbregts M.A.J., Van Jaarsveld H.A., Reinds G.J., De Zwart D., Struijs J., Van de Meent D. (2007). Time horizon dependent characterisation factors for acidification in life-cycle impact assessment based on the disappeared fraction of plant species in European forests. Environmental Science and Technology 41(3): 922-927.

[47] Van Zelm, R., Huijbregts, M.A.J., Den Hollander, H.A., Van Jaarsveld, H.A., Sauter, F.J., Struijs, J., Van Wijnen, H.J., Van de Meent, D. (2008). European characterization factors for human health damage of PM10 and ozone in life cycle impact assessment. Atmospheric Environment 42, 441-453.

[48] Vestreng et al., (2006). Inventory Review 2006. Emission data reported to the LRTAP Convention and NEC directive. Stage 1, 2 and 3 review. Evaluation of inventories of HMs and POPs.

[49] WMO (1999). Scientific Assessment of Ozone Depletion: 1998. Global Ozone Research and Monitoring Project - Report No. 44, ISBN 92-807-1722-7, Geneva.

[50] WMO (2011), Scientific Assessment of Ozone Depletion: 2010, Global Ozone Research and Monitoring Project–Report No. 52, Geneva, Switzerland, 2011

[51] WMO (2014), Scientific Assessment of Ozone Depletion: 2014, Global Ozone Research and Monitoring Project Report No. 55, Geneva, Switzerland, 2014.

[52] World Energy Council, 2009, Survey of Energy Resources Interim Update 2009, World Energy Council, London, ISBN: 0 946121 34 6; http://www.worldenergy.org/publications/survey_of_energy_resources_interim_update_2009/default.asp

[53] World Nuclear Institute (2010). Data on Supply of Uranium. http://www.world-nuclear.org/info/inf75.html, accessed June 2011.

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

ANNEX 1

Uncertainity factors applied to Usetox® calculated values, for each substance the uncertainity factor is applied in all sub-compartments

Inorganics (factor 0.1)

CAS. Number	EC. Number	Flow name	Final.com.type	Final.origin
144-55-8	205-633-8	sodium hydrogen carbonate	Mono-constituent substance	inorganic
7697-37-2	231-714-2	nitric acid	Mono-constituent substance	inorganic
7558-80-7	231-449-2	sodium dihydrogen phosphate	Mono-constituent substance	inorganic
18480-07-4	242-367-1	strontium dihydroxide	Mono-constituent substance	inorganic
471-34-1	207-439-9	calcium carbonate	Mono-constituent substance	inorganic
10043-52-4	233-140-8	calcium dichloride	Mono-constituent substance	inorganic
17439-11-1	241-460-4	hexafluorotitanate(2-)	Mono-constituent substance	inorganic
1314-23-4	215-227-2	zirconium dioxide	Mono-constituent substance	inorganic
7758-19-2	231-836-6	sodium chlorite	Mono-constituent substance	inorganic
7778-77-0	231-913-4	potassium dihydrogen phosphate	Mono-constituent substance	inorganic
7681-57-4	231-673-0	disodium disulphite	Mono-constituent substance	inorganic
6484-52-2	229-347-8	ammonium nitrate	Mono-constituent substance	inorganic
10124-43-3	233-334-2	cobalt(2+) sulfate	Mono-constituent substance	inorganic
7487-88-9	231-298-2	magnesium sulphate	Mono-constituent substance	inorganic
7790-94-5	232-234-6	chlorosulphuric acid	Mono-constituent substance	inorganic
7727-21-1	231-781-8	dipotassium peroxodisulphate	Mono-constituent substance	inorganic
7783-20-2	231-984-1	diammonium sulfate	Mono-constituent substance	inorganic
18282-10-5	242-159-0	tin dioxide	Mono-constituent substance	inorganic
7664-41-7	231-635-3	ammonia	Mono-constituent substance	inorganic
10043-35-3	233-139-2	boric acid	Mono-constituent substance	inorganic
513-77-9	208-167-3	barium carbonate	Mono-constituent substance	inorganic
7783-28-0	231-987-8	diammonium hydrogen phosphate	Mono-constituent substance	inorganic
21645-51-2	244-492-7	aluminium hydroxide	Mono-constituent substance	inorganic
7757-79-1	231-818-8	potassium nitrate	Mono-constituent substance	inorganic
7664-38-2	231-633-2	phosphoric acid	Mono-constituent substance	inorganic
1305-62-0	215-137-3	calcium hydroxide	Mono-constituent substance	inorganic
7782-50-5	231-959-5	chlorine	Mono-constituent substance	inorganic
1305-78-8	215-138-9	oxocalcium	Mono-constituent substance	inorganic
1310-73-2	215-185-5	sodium hydroxide	Mono-constituent substance	inorganic
7647-14-5	231-598-3	sodium chloride	Mono-constituent substance	inorganic
7646-78-8	231-588-9	tin tetrachloride	Mono-constituent substance	inorganic
10049-04-4	233-162-8	chlorine dioxide	Mono-constituent substance	inorganic
7664-93-9	231-639-5	sulphuric acid	Mono-constituent substance	inorganic
1344-28-1	215-691-6	oxo(oxoalumanyloxy)alumane	Mono-constituent substance	inorganic
53988-05-9	258-901-1	calcium bis(7-methyloctanoate)	Mono-constituent substance	inorganic
7757-83-7	231-821-4	disodium sulfite	Mono-constituent substance	inorganic
1330-43-4	215-540-4	disodium tetraborate	Mono-constituent substance	inorganic
21041-93-0	244-166-4	cobalt(2+) dihydroxide	Mono-constituent substance	inorganic
1310-65-2	215-183-4	lithium hydroxide	Mono-constituent substance	inorganic

7758-11-4	231-834-5	dipotassium hydrogenorthophosphate	Mono-constituent substance	inorganic
1314-62-1	215-239-8	divanadium pentaoxide	Mono-constituent substance	inorganic
7786-30-3	232-094-6	magnesium chloride	Mono-constituent substance	inorganic
7681-11-0	231-659-4	potassium iodide	Mono-constituent substance	inorganic
10025-78-2	233-042-5	trichlorosilane	Mono-constituent substance	inorganic
7722-84-1	231-765-0	hydrogen peroxide	Mono-constituent substance	inorganic
584-08-7	209-529-3	dipotassium carbonate	Mono-constituent substance	inorganic
7631-86-9	231-545-4	silicon dioxide	Mono-constituent substance	inorganic
1303-86-2	215-125-8	bicyclo[1.1.1]diboroxane	Mono-constituent substance	inorganic
7786-81-4	232-104-9	nickel(2+) sulfate	Mono-constituent substance	inorganic
497-19-8	207-838-8	disodium carbonate	Mono-constituent substance	inorganic
7631-99-4	231-554-3	sodium nitrate	Mono-constituent substance	inorganic
1332-77-0	215-575-5	dipotassium tetraborate	Mono-constituent substance	inorganic
553-72-0	209-047-3	zinc dibenzoate	Mono-constituent substance	inorganic
7722-76-1	231-764-5	ammonium phosphate	Mono-constituent substance	inorganic
10361-37-2	233-788-1	barium dichloride	Mono-constituent substance	inorganic
13598-36-2	237-066-7	phosphonic acid	Mono-constituent substance	inorganic
1302-42-7	215-100-1	aluminium sodium dioxide	Mono-constituent substance	inorganic
21351-79-1	244-344-1	caesium hydroxide	Mono-constituent substance	inorganic
10124-37-5	233-332-1	calcium dinitrate	Mono-constituent substance	inorganic
10099-74-8	233-245-9	lead dinitrate	Mono-constituent substance	inorganic
7722-88-5	231-767-1	tetrasodium diphosphate	Mono-constituent substance	inorganic
373-02-4	206-761-7	nickel (ii) acetate	Mono-constituent substance	inorganic
10377-60-3	233-826-7	magnesium dinitrate	Mono-constituent substance	inorganic
13463-67-7	236-675-5	titanium dioxide	Mono-constituent substance	inorganic
7664-39-3	231-634-8	hydrogen fluoride	Mono-constituent substance	inorganic
7758-23-8	231-837-1	calcium dihydrogen phosphate	Mono-constituent substance	inorganic
57219-64-4	260-633-5	[({[hydroxy(oxo)zirconio]oxy}carbonyl)oxy]zirconiumoylol	Mono-constituent substance	inorganic
7558-79-4	231-448-7	disodium hydrogen phosphate	Mono-constituent substance	inorganic
1308-38-9	215-160-9	chromium (iii) oxide	Mono-constituent substance	inorganic
7758-98-7	231-847-6	copper (ii) sulfate	Mono-constituent substance	inorganic
7681-52-9	231-668-3	sodium hypochlorite	Mono-constituent substance	inorganic
1308-14-1	215-158-8	chromium (iii) hydroxide	Mono-constituent substance	inorganic
1314-36-9	215-233-5	yttrium oxide	Mono-constituent substance	inorganic
1633-05-2	216-643-7	strontium carbonate	Mono-constituent substance	inorganic
1313-82-2	215-211-5	disodium sulfide	Mono-constituent substance	inorganic
13845-18-6	237-572-8	sodium sulfamate	Mono-constituent substance	inorganic
1314-13-2	215-222-5	zinc oxide	Mono-constituent substance	inorganic
598-62-9	209-942-9	manganese(2+) carbonate	Mono-constituent substance	inorganic
1314-56-3	215-236-1	1,3-dioxodiphosphoxane 1,3-dioxide	Mono-constituent substance	inorganic
20427-59-2	243-815-9	copper(ii) hydroxide	Mono-constituent substance	inorganic
7778-80-5	231-915-5	dipotassium sulfate	Mono-constituent substance	inorganic
12021-95-3	234-666-0	hexafluorozirconate(2-)	Mono-constituent substance	inorganic
7757-82-6	231-820-9	disodium sulfate	Mono-constituent substance	inorganic

2551-62-4	219-854-2	correction flow for delayed emission of sulphur hexafluoride (within first 100 years)	Mono-constituent substance	inorganic
1313-99-1	215-215-7	nickel (ii) oxide	Mono-constituent substance	inorganic
5329-14-6	226-218-8	sulfamic acid	Mono-constituent substance	inorganic
7723-14-0	231-768-7	phosphorus	Mono-constituent substance	inorganic
136-52-7	205-250-6	cobalt(2+) bis(2-ethylhexanoate)	Mono-constituent substance	inorganic
1314-35-8	215-231-4	trioxotungsten	Mono-constituent substance	inorganic
1304-76-3	215-134-7	bismuth trioxide	Mono-constituent substance	inorganic
143-33-9	205-599-4	sodium cyanide	Mono-constituent substance	inorganic
1314-34-7	215-230-9	divanadium trioxide	Mono-constituent substance	inorganic
1307-96-6	215-154-6	cobalt oxide	Mono-constituent substance	inorganic
13138-45-9	236-068-5	nickel(2+) dinitrate	Mono-constituent substance	inorganic
17194-00-2	241-234-5	barium dihydroxide	Mono-constituent substance	inorganic
16940-66-2	241-004-4	sodium tetrahydridoborate	Mono-constituent substance	inorganic
7733-02-0	231-793-3	zinc sulfate	Mono-constituent substance	inorganic
7779-88-6	231-943-8	zinc dinitrate	Mono-constituent substance	inorganic
14807-96-6	238-877-9	talc	Mono-constituent substance	inorganic
15396-00-6	239-415-9	3-isocyanatopropyl(trimethoxy)silane	Mono-constituent substance	inorganic
7727-43-7	231-784-4	barium sulfate	Mono-constituent substance	inorganic
7646-85-7	231-592-0	zinc dichloride	Mono-constituent substance	inorganic
7757-93-9	231-826-1	calcium dihydrogen phosphate	Mono-constituent substance	inorganic
7720-78-7	231-753-5	iron (ii) sulphate	Mono-constituent substance	inorganic
7785-87-7	232-089-9	manganese sulphate	Mono-constituent substance	inorganic
7761-88-8	231-853-9	silver nitrate	Mono-constituent substance	inorganic
409-21-2	206-991-8	silicon carbide	Mono-constituent substance	inorganic
7446-70-0	231-208-1	aluminum trichloride	Mono-constituent substance	inorganic
1309-64-4	215-175-0	dioxodistiboxane	Mono-constituent substance	inorganic
7726-95-6	231-778-1	bromine	Mono-constituent substance	inorganic
13473-90-0	236-751-8	aluminum trinitrate	Mono-constituent substance	inorganic
7553-56-2	231-442-4	iodine	Mono-constituent substance	inorganic
7447-39-4	231-210-2	copper(ii) chloride	Mono-constituent substance	inorganic
7790-28-5	232-197-6	sodium periodate	Mono-constituent substance	inorganic
7647-15-6	231-599-9	sodium bromide	Mono-constituent substance	inorganic
4075-81-4	223-795-8	calcium dipropionate	Mono-constituent substance	inorganic
7550-35-8	231-439-8	lithium bromide	Mono-constituent substance	inorganic
1317-36-8	215-267-0	lead monoxide	Mono-constituent substance	inorganic
12016-80-7	234-614-7	cobalt hydroxide oxide	Mono-constituent substance	inorganic
1312-81-8	215-200-5	lanthanum oxide	Mono-constituent substance	inorganic
14075-53-7	237-928-2	potassium tetrafluoroborate	Mono-constituent substance	inorganic
7681-49-4	231-667-8	sodium fluoride	Mono-constituent substance	inorganic
7790-69-4	232-218-9	lithium nitrate	Mono-constituent substance	inorganic
7775-27-1	231-892-1	disodium peroxodisulphate	Mono-constituent substance	inorganic
1306-38-3	215-150-4	cerium dioxide	Mono-constituent substance	inorganic
7631-90-5	231-548-0	sodium hydrogensulfite	Mono-constituent substance	inorganic
7681-65-4	231-674-6	copper (i) iodide	Mono-constituent substance	inorganic

7789-38-0	232-160-4	sodium bromate	Mono-constituent substance	inorganic
7783-18-8	231-982-0	diammonium thiosulfate	Mono-constituent substance	inorganic
136-51-6	205-249-0	calcium bis(2-ethylhexanoate)	Mono-constituent substance	inorganic
7775-09-9	231-887-4	sodium chlorate	Mono-constituent substance	inorganic
1313-27-5	215-204-7	molybdenum trioxide	Mono-constituent substance	inorganic
546-93-0	208-915-9	magnesium carbonate	Mono-constituent substance	inorganic
12054-48-7	235-008-5	nickel (ii) hydroxide	Mono-constituent substance	inorganic
544-60-5	208-873-1	ammonium octadec-9-enoate	Mono-constituent substance	inorganic
11128-29-3	234-371-7	potassium pentaborate	Mono-constituent substance	inorganic
7631-95-0	231-551-7	disodium tetraoxomolybdate dihydrate	Mono-constituent substance	inorganic
12125-02-9	235-186-4	ammonium chloride	Mono-constituent substance	inorganic
7778-53-2	231-907-1	tripotassium phosphate	Mono-constituent substance	inorganic
20667-12-3	243-957-1	silver(i) oxide	Mono-constituent substance	inorganic
1317-38-0	215-269-1	copper (ii) oxide	Mono-constituent substance	inorganic
7320-34-5	230-785-7	tetrapotassium diphosphate	Mono-constituent substance	inorganic
3251-23-8	221-838-5	copper(2+) dinitrate	Mono-constituent substance	inorganic
7446-07-3	231-193-1	oxotellane oxide	Mono-constituent substance	inorganic
302-01-2	206-114-9	hydrazine	Mono-constituent substance	inorganic
16721-80-5	240-778-0	sodium hydrogensulfide	Mono-constituent substance	inorganic
7757-87-1	231-824-0	trimagnesium diphosphate	Mono-constituent substance	inorganic
12070-12-1	235-123-0	tungsten carbide	Mono-constituent substance	inorganic
554-13-2	209-062-5	lithium carbonate	Mono-constituent substance	inorganic
7601-90-3	231-512-4	perchloric acid	Mono-constituent substance	inorganic
10599-90-3	234-217-9	chloramide	Mono-constituent substance	inorganic
1345-07-9	215-716-0	dibismuth trisulphide	Mono-constituent substance	inorganic
1309-42-8	215-170-3	magnesium dihydroxide	Mono-constituent substance	inorganic
27774-13-6	248-652-7	oxovanadium(2+) sulfate	Mono-constituent substance	inorganic
10042-76-9	233-131-9	strontium dinitrate	Mono-constituent substance	inorganic
12008-41-2	234-541-0	disodium octaborate	Mono-constituent substance	inorganic
6834-92-0	229-912-9	disodium oxosilanediolate	Mono-constituent substance	inorganic
7718-54-9	231-743-0	nickel(2+) dichloride	Mono-constituent substance	inorganic
7783-82-6	232-029-1	tungsten hexafluoride	Mono-constituent substance	inorganic
1317-35-7	215-266-5	trimanganese tetraoxide	Mono-constituent substance	inorganic
10141-05-6	233-402-1	cobalt(2+) dinitrate	Mono-constituent substance	inorganic
7681-53-0	231-669-9	sodium phosphinate	Mono-constituent substance	inorganic
13472-45-2	236-743-4	disodium wolframate	Mono-constituent substance	inorganic
1344-43-0	215-695-8	oxomanganese	Mono-constituent substance	inorganic
7789-75-5	232-188-7	calcium difluoride	Mono-constituent substance	inorganic
7783-00-8	231-974-7	selenous acid	Mono-constituent substance	inorganic
7632-00-0	231-555-9	sodium nitrite	Mono-constituent substance	inorganic
638-38-0	211-334-3	manganese(2+) diacetate	Mono-constituent substance	inorganic
12035-72-2	234-829-6	nickel subsulfide	Mono-constituent substance	inorganic
1111-78-0	214-185-2	ammonium carbamate	Mono-constituent substance	inorganic
2530-83-8	219-784-2	trimethoxy[3-(oxiran-2-ylmethoxy)propyl]silane	Mono-constituent substance	inorganic
12612-50-9	235-721-1	molybdenum disulfide	Mono-constituent substance	inorganic

12124-97-9	235-183-8	ammonium bromide	Mono-constituent substance	inorganic
14024-48-7	237-855-6	cobalt(2+) bis(4-oxopent-2-en-2-olate)	Mono-constituent substance	inorganic
10124-56-8	233-343-1	sodium metaphosphate	Mono-constituent substance	inorganic
1333-83-1	215-608-3	sodium hydrogendifluoride	Mono-constituent substance	inorganic
7447-41-8	231-212-3	lithium chloride	Mono-constituent substance	inorganic
1314-80-3	215-242-4	diphosphorus pentasulphide	Mono-constituent substance	inorganic
16812-54-7	240-841-2	nickel sulphide	Mono-constituent substance	inorganic
3164-85-0	221-625-7	potassium 2-ethylhexanoate	Mono-constituent substance	inorganic
513-79-1	208-169-4	cobalt(2+) carbonate	Mono-constituent substance	inorganic
85392-66-1	286-925-2	potassium difluoro(dihydroxy)borate(1-)	UVCB	inorganic
1315-01-1	215-252-9	tin disulfide	Mono-constituent substance	inorganic
10124-41-1	233-333-7	calcium thiosulfate	Mono-constituent substance	inorganic
7758-29-4	231-838-7	pentasodium triphosphate	Mono-constituent substance	inorganic
13770-89-3	237-396-1	nickel (2+) disulfamate	Mono-constituent substance	inorganic
7446-11-9	231-197-3	sulfur trioxide	Mono-constituent substance	inorganic
10025-87-3	233-046-7	phosphoric trichloride	Mono-constituent substance	inorganic
7782-78-7	231-964-2	hydroxy(nitrosooxy)sulfane dioxide	Mono-constituent substance	inorganic
10026-13-8	233-060-3	phosphorus pentachloride	Mono-constituent substance	inorganic
7758-94-3	231-843-4	iron (ii) chloride	Mono-constituent substance	inorganic
513-78-0	208-168-9	cadmium carbonate	Mono-constituent substance	inorganic
4861-19-2	225-464-3	urea phosphate	Mono-constituent substance	inorganic
10377-66-9	233-828-8	manganese(2+) dinitrate	Mono-constituent substance	inorganic
7681-82-5	231-679-3	sodium iodide	Mono-constituent substance	inorganic
7773-01-5	231-869-6	manganese(2+) dichloride	Mono-constituent substance	inorganic
18820-29-6	242-599-3	manganese sulphide	Mono-constituent substance	inorganic
1344-00-9	215-684-8	silicic acid, aluminum sodium salt	UVCB	inorganic
7719-12-2	231-749-3	phosphorus trichloride	Mono-constituent substance	inorganic
10476-85-4	233-971-6	strontium dichloride	Mono-constituent substance	inorganic
1341-49-7	215-676-4	ammonium fluoride hydrofluoride	Mono-constituent substance	inorganic
1314-98-3	215-251-3	thioxozinc	Mono-constituent substance	inorganic
7803-51-2	232-260-8	phosphine	Mono-constituent substance	inorganic
27253-31-2	248-373-0	neodecanoic acid, cobalt salt	UVCB	inorganic
7601-54-9	231-509-8	trisodium phosphate	Mono-constituent substance	inorganic
7783-06-4	231-977-3	hydrogen sulfide	Mono-constituent substance	inorganic
10043-01-3	233-135-0	aluminium sulfate	Mono-constituent substance	inorganic
4454-16-4	224-699-9	nickel(2+) bis(2-ethylhexanoate)	Mono-constituent substance	inorganic
7758-89-6	231-842-9	copper (i) chloride	Mono-constituent substance	inorganic
1318-23-6	215-284-3	aluminum oxygen(2-) hydroxide	Mono-constituent substance	inorganic
12125-01-8	235-185-9	ammonium fluoride	Mono-constituent substance	inorganic
75-20-7	200-848-3	calcium ethynediide	Mono-constituent substance	inorganic
2457-01-4	219-535-8	barium bis(2-ethylhexanoate)	Mono-constituent substance	inorganic
7681-38-1	231-665-7	sodium hydrogen sulfate	Mono-constituent substance	inorganic
1066-33-7	213-911-5	ammonium hydrogen carbonate	Mono-constituent substance	inorganic
7772-99-8	231-868-0	tin(ii) chloride (1:2)	Mono-constituent substance	inorganic
12190-79-3	235-362-0	cobalt lithium dioxide	Mono-constituent substance	inorganic

22464-99-9	245-018-1	2-ethylhexanoic acid, zirconium salt	Mono-constituent substance	inorganic
12042-91-0	234-933-1	dialuminium chloride pentahydroxide	Mono-constituent substance	inorganic
917-61-3	213-030-6	sodium cyanate	Mono-constituent substance	inorganic
7783-03-1	231-975-2	dihydrogen wolframate	Mono-constituent substance	inorganic
7447-40-7	231-211-8	potassium chloride	Mono-constituent substance	inorganic
7785-84-4	232-088-3	sodium trimetaphosphate	Mono-constituent substance	inorganic
7775-19-1	231-891-6	sodium metaborate, anhydrous	Mono-constituent substance	inorganic
590-28-3	209-676-3	potassium cyanate	Mono-constituent substance	inorganic
7784-18-1	232-051-1	aluminum trifluoride	Mono-constituent substance	inorganic
10102-18-8	233-267-9	disodium selenite	Mono-constituent substance	inorganic
10294-66-3	233-666-8	dipotassium thiosulfate	Mono-constituent substance	inorganic
1317-42-6	215-273-3	/ncobalt(2+) sulfide	Mono-constituent substance	inorganic
85203-81-2	286-272-3	hexanoic acid, 2-ethyl-, zinc salt, basic	Mono-constituent substance	inorganic
16872-11-0	240-898-3	fluoboric acid	Mono-constituent substance	inorganic
7699-45-8	231-718-4	zinc dibromide	Mono-constituent substance	inorganic
14644-61-2	238-694-4	zirconium (iv) sulfate	Mono-constituent substance	inorganic
12069-69-1	235-113-6	copper(ii) carbonate--copper(ii) hydroxide (1:1)	Mono-constituent substance	inorganic
7758-95-4	231-845-5	lead dichloride	Mono-constituent substance	inorganic
12578-12-0	235-702-8	dioxobis(stearato)trilead	UVCB	inorganic
13825-74-6	237-523-0	titanium oxide sulphate	Mono-constituent substance	inorganic
107-05-1	203-457-6	allyl chloride	Mono-constituent substance	inorganic
10022-31-8	233-020-5	barium dinitrate	Mono-constituent substance	inorganic
10124-36-4	233-331-6	cadmium sulfate	Mono-constituent substance	inorganic
630-08-0	211-128-3	carbon monoxide (fossil)	Mono-constituent substance	inorganic
10099-58-8	233-237-5	lanthanum chloride, anhydrous	Mono-constituent substance	inorganic
534-16-7	208-590-3	disilver(1+) carbonate	Mono-constituent substance	inorganic
7647-17-8	231-600-2	cesium chloride	Mono-constituent substance	inorganic
71-48-7	200-755-8	cobalt(2+) diacetate	Mono-constituent substance	inorganic
7758-05-6	231-831-9	potassium iodate	Mono-constituent substance	inorganic
7646-79-9	231-589-4	cobalt(2+) dichloride	Mono-constituent substance	inorganic
12207-63-5	235-384-0	ammonium trivanadium octaoxide	Mono-constituent substance	inorganic
1344-37-2	215-693-7	lead sulfochromate yellow	Mono-constituent substance	inorganic
8017-16-1	232-417-0	polyphosphoric acids	Multi-constituent substance	inorganic
10192-30-0	233-469-7	ammonium hydrogensulfite	Mono-constituent substance	inorganic
1327-43-1	215-478-8	aluminium(3+)magnesium(2+)oxosilanediolate	UVCB	inorganic
12033-89-5	234-796-8	silicon nitride	Mono-constituent substance	inorganic
10361-43-0	233-790-2	reaction product of bismuth trinitrate and sodium hydroxide	UVCB	inorganic
333-20-0	206-370-1	potassium thiocyanate	Mono-constituent substance	inorganic
10028-18-9	233-071-3	nickel difluoride	Mono-constituent substance	inorganic
1306-19-0	215-146-2	oxocadmium	Mono-constituent substance	inorganic
7783-90-6	232-033-3	silver(i) chloride	Mono-constituent substance	inorganic
10325-94-7	233-710-6	cadmium dinitrate	Mono-constituent substance	inorganic
55172-98-0	259-509-3	barium neodecanoate	UVCB	inorganic
13709-42-7	237-253-3	neodymium trifluoride	Mono-constituent substance	inorganic
34041-09-3	251-807-1	2-ethylhexanoic acid, molybdenum salt/n	Mono-constituent substance	inorganic

7789-41-5	232-164-6	calcium dibromide	Mono-constituent substance	inorganic
14691-80-6	238-735-6	trisodium [hydroxy(oxido)phosphoryl] phosphate	Mono-constituent substance	inorganic
7778-39-4	231-901-9	as(o)(oh)3 arsenic acid or arsoric acid	Mono-constituent substance	inorganic
19035-79-1	242-768-1	potassium hexadecyl hydrogen phosphate	Multi-constituent substance	inorganic
460-19-5	207-306-5	oxalonitrile	Mono-constituent substance	inorganic
12007-89-5	234-521-1	diammonium decaborate	Mono-constituent substance	inorganic
540-72-7	208-754-4	sodium thiocyanate	Mono-constituent substance	inorganic
7758-16-9	231-835-0	sodium acid pyrophosphate	Mono-constituent substance	inorganic
10035-10-6	233-113-0	hydrogen bromide	Mono-constituent substance	inorganic
7775-14-6	231-890-0	disodium dithionite	Mono-constituent substance	inorganic
7772-98-7	231-867-5	disodium thiosulfate	Mono-constituent substance	inorganic
7699-43-6	231-717-9	dichloro(oxo)zirconium	Mono-constituent substance	inorganic
12060-58-1	235-043-6	disamarium trioxide	Mono-constituent substance	inorganic
6303-21-5	228-601-5	phosphinic acid	Mono-constituent substance	inorganic
1304-28-5	215-127-9	barium oxide	Mono-constituent substance	inorganic
7789-82-4	232-192-9	calcium tetraoxomolybdate	Mono-constituent substance	inorganic
7758-88-5	231-841-3	cerium(3+) trifluoride	Mono-constituent substance	inorganic
14484-69-6	238-485-8	potassiumtetrafluoroaluminate	Mono-constituent substance	inorganic
16731-55-8	240-795-3	dipotassium disulphite	Mono-constituent substance	inorganic
1314-96-1	215-249-2	strontium sulphide	Mono-constituent substance	inorganic
814-89-1	212-409-3	cobalt(2+) oxalate	Mono-constituent substance	inorganic
151-50-8	205-792-3	potassium cyanide	Mono-constituent substance	inorganic
7789-80-2	232-191-3	calcium diiodate	Mono-constituent substance	inorganic
7758-02-3	231-830-3	potassium bromide	Mono-constituent substance	inorganic
13827-02-6	237-537-7	potassium trifluorozincate(1-)	Mono-constituent substance	inorganic
1306-23-6	215-147-8	sulfanylidenecadmium	Mono-constituent substance	inorganic
10026-04-7	233-054-0	silicon tetrachloride	Mono-constituent substance	inorganic
15956-58-8	240-085-3	2-ethylhexanoic acid, manganese salt	Mono-constituent substance	inorganic
68551-44-0	271-378-4	fatty acids, c6-19-branched, zinc salts	UVCB	inorganic
11138-49-1	234-391-6	sodium oxido(oxo)alumane	Mono-constituent substance	inorganic
10117-38-1	233-321-1	dipotassium sulfite	Mono-constituent substance	inorganic
10163-15-2	233-433-0	phosphorofluoridic acid disodium salt	Mono-constituent substance	inorganic
10361-82-7	233-797-0	trichlorosamarium	Mono-constituent substance	inorganic
29736-75-2	249-820-2	2,5,7,10,11,14-hexaoxa-1,6-distibabicyclo[4.4.4]tetradecane	Mono-constituent substance	inorganic
1317-39-1	215-270-7	copper (i) oxide	Mono-constituent substance	inorganic
10421-48-4	233-899-5	iron(3+) trinitrate	Mono-constituent substance	inorganic
10108-64-2	233-296-7	cadmium dichloride	Mono-constituent substance	inorganic
7790-98-9	232-235-1	ammonium perchlorate	Mono-constituent substance	inorganic
12036-22-5	234-842-7	tungsten dioxide	Mono-constituent substance	inorganic
31795-24-1	935-877-7	methylsilanetriol, potassium salt	Multi-constituent substance	inorganic
58834-75-6	406-260-5	bis[oxidovanadium(2+)] diphosphate	Mono-constituent substance	inorganic
18868-43-4	242-637-9	molybdenum dioxide	Mono-constituent substance	inorganic
1560-69-6	216-333-1	cobalt(2+) dipropanoate	Mono-constituent substance	inorganic
14177-55-0	238-034-5	reaction mass of molybdenum oxide and nickel oxide	UVCB	inorganic
506-87-6	208-058-0	ammonium carbonate	Mono-constituent substance	inorganic

27253-29-8	248-370-4	neodecanoic acid, zinc salt	UVCB	inorganic
1345-04-6	215-713-4	tricyclo[3.3.1.1~3,7~]tetrastibathiane	Mono-constituent substance	inorganic
13780-39-7	237-430-5	oxotitanium dihydrochloride	Mono-constituent substance	inorganic
22205-45-4	244-842-9	copper(i) sulphide	Mono-constituent substance	inorganic
13822-56-5	237-511-5	3-trimethoxysilylpropan-1-amine	Mono-constituent substance	inorganic
1327-53-3	215-481-4	arsenic trioxide	Mono-constituent substance	inorganic
7758-01-2	231-829-8	potassium bromate	Mono-constituent substance	inorganic
21041-95-2	244-168-5	cadmium dihydroxide	Mono-constituent substance	inorganic
12069-32-8	235-111-5	boron carbide	Mono-constituent substance	inorganic
10101-50-5	233-251-1	sodium permanganate	Mono-constituent substance	inorganic
12036-21-4	234-841-1	vanadium dioxide	Mono-constituent substance	inorganic
13768-11-1	237-380-4	hydroxy(trioxo)rhenium	Mono-constituent substance	inorganic
98903-75-4	308-876-9	vanadium, oxalate complexes	Mono-constituent substance	inorganic
68309-95-5	269-682-7	diammonium bis[carbonato-o]dihydroxyzirconate	Mono-constituent substance	inorganic
16853-85-3	240-877-9	lithium tetrahydridoaluminate/n	Mono-constituent substance	inorganic
1317-40-4	215-271-2	copper(ii) sulphide	Mono-constituent substance	inorganic
7790-86-5	232-227-8	cerium(3+) trichloride	Mono-constituent substance	inorganic
39455-80-6	254-463-0	ammonium sodium vanadium oxide	Mono-constituent substance	inorganic
13463-40-6	236-670-8	pentacarbonyliron	Mono-constituent substance	inorganic
533-96-0	208-580-9	trisodium hydrogendicarbonate	Mono-constituent substance	inorganic
136-53-8	205-251-1	zinc bis(2-ethylhexanoate)	Mono-constituent substance	inorganic
7580-67-8	231-484-3	lithium hydride	Mono-constituent substance	inorganic
298-14-6	206-059-0	potassium hydrogen carbonate	Mono-constituent substance	inorganic
61789-51-3	263-064-0	cobalt(2+) bis[3-(3-ethylcyclopentyl)propanoate]	UVCB	inorganic
7783-96-2	232-038-0	silver(1+) iodide	Mono-constituent substance	inorganic
546-67-8	208-908-0	lead(4+) tetraacetate	Mono-constituent substance	inorganic
7803-55-6	232-261-3	ammonium trioxovanadate	Mono-constituent substance	inorganic
7722-64-7	231-760-3	potassium oxido(trioxo)manganese	Mono-constituent substance	inorganic
26628-22-8	247-852-1	sodium azide	Mono-constituent substance	inorganic
7803-49-8	232-259-2	hydroxylamine	Mono-constituent substance	inorganic
11138-47-9	234-390-0	sodium perborate	Mono-constituent substance	inorganic
7789-06-2	232-142-6	strontium chromate	Mono-constituent substance	inorganic
7789-23-3	232-151-5	potassium fluoride	Mono-constituent substance	inorganic
3811-04-9	223-289-7	potassium chlorate	Mono-constituent substance	inorganic
21109-95-5	244-214-4	barium sulfide	Mono-constituent substance	inorganic
1762-95-4	217-175-6	ammonium thiocyanate	Mono-constituent substance	inorganic
75-71-8	200-893-9	cfc-12	Mono-constituent substance	inorganic
14507-19-8	238-510-2	lanthanum trihydroxide	Mono-constituent substance	inorganic
13746-89-9	237-324-9	zirconium tetranitrate	Mono-constituent substance	inorganic
1303-00-0	215-114-8	gallium arsenide	Mono-constituent substance	inorganic
10026-11-6	233-058-2	zirconium tetrachloride	Mono-constituent substance	inorganic
7790-62-7	232-216-8	dipotassium disulphate	Mono-constituent substance	inorganic
7601-89-0	231-511-9	sodium perchlorate	Mono-constituent substance	inorganic
547-67-1	208-933-7	nickel(2+) oxalate	Mono-constituent substance	inorganic
10038-98-9	233-116-7	germanium(4+) tetrachloride	Mono-constituent substance	inorganic

1336-21-6	215-647-6	ammonium hydroxide	Mono-constituent substance	inorganic
10025-73-7	233-038-3	chromium(3+) trichloride	Mono-constituent substance	inorganic
1317-60-8	215-275-4	hematite	UVCB	inorganic
462-34-0	207-325-9	oxolane;trifluoroborane	Mono-constituent substance	inorganic
2950-43-8	220-971-6	(aminooxy)(hydroxy)sulfane dioxide	Mono-constituent substance	inorganic
10544-72-6	234-126-4	dinitrogen tetraoxide	Mono-constituent substance	inorganic
618-36-0	210-545-8	1-phenylethanamine	Mono-constituent substance	inorganic
20427-58-1	243-814-3	zinc dihydroxide	Mono-constituent substance	inorganic
7727-18-6	231-780-2	vanadium trichloride oxide	Mono-constituent substance	inorganic
1317-80-2	215-282-2	rutile (tio2)	Mono-constituent substance	inorganic
7789-17-5	232-145-2	cesium iodide	Mono-constituent substance	inorganic
12003-63-3	234-432-8	potassium oxido(oxo)alumane	Mono-constituent substance	inorganic
1306-25-8	215-149-9	telluroxocadmium	Mono-constituent substance	inorganic
7785-23-1	232-076-8	silver(1+) bromide	Mono-constituent substance	inorganic
3982-91-0	223-622-6	phosphorothioic trichloride	Mono-constituent substance	inorganic
13709-38-1	237-252-8	lanthanum trifluoride	Mono-constituent substance	inorganic
919-31-3	213-050-5	3-(triethoxysilyl)propanenitrile	Mono-constituent substance	inorganic
10217-34-2	425-050-4	2-(3,4-epoxycyclohexyl)ethyltriethoxy silane	Mono-constituent substance	inorganic
7783-66-6	232-019-7	iodine pentafluoride	Mono-constituent substance	inorganic
7789-21-1	232-149-4	fluorosulfuric acid	Mono-constituent substance	inorganic
353-42-4	206-532-1	dimethyloxonio(trifluoro)boranuide	Mono-constituent substance	inorganic
2699-79-8	220-281-5	sulphuryl difluoride	Mono-constituent substance	inorganic
1314-84-7	215-244-5	trizinc diphosphide	Mono-constituent substance	inorganic
20859-73-8	244-088-0	aluminium phosphide	Mono-constituent substance	inorganic
12003-51-9	234-430-7	sodium aluminium silicate(1:1:1)	UVCB	inorganic
7785-88-8	232-090-4	phosphoric acid, aluminium sodium salt	UVCB	inorganic
1302-78-9	215-108-5	bentonite	UVCB	inorganic
7778-18-9	231-900-3	gypsum	Mono-constituent substance	inorganic
7705-08-0	231-729-4	iron (iii) chloride	Mono-constituent substance	inorganic
1309-37-1	215-168-2	iron(iii)oxide	Mono-constituent substance	inorganic
7784-30-7	232-056-9	[phosphato(3-)-kappa~3~o,o',o'']aluminum	Mono-constituent substance	inorganic
12012-35-0	234-576-1	trichromium dicarbide	Mono-constituent substance	inorganic
12036-37-2	405-290-6	zinc stannate	Mono-constituent substance	inorganic
1317-37-9	215-268-6	iron (ii) sulfide	Mono-constituent substance	inorganic
1313-96-8	215-213-6	niobium(v) oxide	Mono-constituent substance	inorganic
13845-36-8	237-574-9	pentapotassium triphosphate	Mono-constituent substance	inorganic
7783-54-2	232-007-1	nitrogen trifluoride	Mono-constituent substance	inorganic
7778-74-7	231-912-9	potassium perchlorate	Mono-constituent substance	inorganic
1345-25-1	215-721-8	iron oxide	Mono-constituent substance	inorganic
12060-59-2	235-044-1	strontium titanium trioxide	Mono-constituent substance	inorganic
12055-23-1	235-013-2	hafnium dioxide	Mono-constituent substance	inorganic

Metals (facto 0.1)

CAS.Number	EC.Number	Flow name	Final.com.type	Final.origin
7429-90-5	231-072-3	aluminium	Mono-constituent substance	element
22537-23-1		aluminium (iii)	Mono-constituent substance	element in usetox
7440-36-0	231-146-5	antimony	Mono-constituent substance	element
23713-48-6		antimony (iii)	Mono-constituent substance	element in usetox
22537-51-5		antimony (v)	Mono-constituent substance	element in usetox
7440-38-2		arsenic	Mono-constituent substance	element
22541-54-4		arsenic (iii)	Mono-constituent substance	element in usetox
17428-41-0		arsenic (v)	Mono-constituent substance	element in usetox
7440-39-3		barium	Mono-constituent substance	element
22541-12-4		barium (ii)	Mono-constituent substance	element in usetox
7440-41-7		beryllium	Mono-constituent substance	element
22537-20-8		beryllium (ii)	Mono-constituent substance	element in usetox
7440-69-9	231-177-4	bismuth	Mono-constituent substance	element
7440-42-8	231-151-2	boron	Mono-constituent substance	element
7440-43-9	231-152-8	cadmium	Mono-constituent substance	element
22537-48-0		cadmium (ii)	Mono-constituent substance	element in usetox
7440-70-2	231-179-5	calcium	Mono-constituent substance	element
7440-45-1	231-154-9	cerium	Mono-constituent substance	element
7440-46-2		cesium	Mono-constituent substance	element
18459-37-5		cesium (i)	Mono-constituent substance	element in usetox
16065-83-1		chromium (iii)	Mono-constituent substance	element in usetox
7440-48-4	231-158-0	cobalt	Mono-constituent substance	element
22541-53-3		cobalt (ii)	Mono-constituent substance	element in usetox
7440-58-6	231-166-4	hafnium	Mono-constituent substance	element
7439-91-0	231-099-0	lanthanum	Mono-constituent substance	element
7439-92-1	231-100-4	lead	Mono-constituent substance	element
14280-50-3		lead (ii)	Mono-constituent substance	element in usetox
7439-93-2	231-102-5	lithium	Mono-constituent substance	element
7439-97-6	231-106-7	mercury	Mono-constituent substance	element
14302-87-5		mercury (ii)	Mono-constituent substance	element in usetox
7440-02-0	231-111-4	nickel	Mono-constituent substance	element
14701-22-5		nickel (ii)	Mono-constituent substance	element in usetox
7440-15-5	231-124-5	rhenium(2+)	Mono-constituent substance	element
7440-21-3	231-130-8	silicon	Mono-constituent substance	element
7440-22-4	231-131-3	silver	Mono-constituent substance	element
14701-21-4		silver (i)	Mono-constituent substance	element in usetox
7440-24-6		strontium	Mono-constituent substance	element
22537-39-9		strontium (ii)	Mono-constituent substance	element in usetox
7704-34-9	231-722-6	sulfur	Mono-constituent substance	element
13494-80-9	236-813-4	tellurium	Mono-constituent substance	element
7440-28-0		thallium	Mono-constituent substance	element
22537-56-0		thallium (i)	Mono-constituent substance	element in usetox
7440-31-5	231-141-8	tin	Mono-constituent substance	element

22541-90-8		tin (ii)	Mono-constituent substance	element in usetox
7440-32-6	231-142-3	titanium	Mono-constituent substance	element
7440-33-7	231-143-9	tungsten	Mono-constituent substance	element
7440-62-2	231-171-1	vanadium	Mono-constituent substance	element
15121-26-3		vanadium (v)	Mono-constituent substance	element in usetox
7440-67-7	231-176-9	zirconium	Mono-constituent substance	element

Essential Metals (factor 0.01)

CAS.Number	EC.Number	Flow name	Final.com.type	Final.origin
7440-47-3	231-157-5	chromium	Mono-constituent substance	element
18540-29-9		chromium (vi)	Mono-constituent substance	element in usetox
7440-50-8	231-159-6	copper	Mono-constituent substance	element
15158-11-9		copper (ii)	Mono-constituent substance	element in usetox
7439-89-6		iron	Mono-constituent substance	element
15438-31-0		iron (ii)	Mono-constituent substance	element in usetox
20074-52-6		iron (iii)	Mono-constituent substance	element in usetox
7439-95-4	231-104-6	magnesium	Mono-constituent substance	element
7439-96-5	231-105-1	manganese	Mono-constituent substance	element
16397-91-4		manganese (ii)	Mono-constituent substance	element in usetox
7439-98-7	231-107-2	molybdenum	Mono-constituent substance	element
16065-87-5		molybdenum (vi)	Mono-constituent substance	element in usetox
7782-49-2	231-957-4	selenium	Mono-constituent substance	element
22541-55-5		selenium (iv)	Mono-constituent substance	element in usetox
7440-66-6	231-175-3	zinc	Mono-constituent substance	element
23713-49-7		zinc (ii)	Mono-constituent substance	element in usetox

GETTING IN TOUCH WITH THE EU

In person

All over the European Union there are hundreds of Europe Direct information centres. You can find the address of the centre nearest you at: http://europea.eu/contact

On the phone or by email

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

- by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),

- at the following standard number: +32 22999696, or

- by electronic mail via: http://europa.eu/contact

FINDING INFORMATION ABOUT THE EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website at: http://europa.eu

EU publications

You can download or order free and priced EU publications from EU Bookshop at: http://bookshop.europa.eu. Multiple copies of free publications may be obtained by contacting Europe Direct or your local information centre (see http://europa.eu/contact).

KJ-NA-29600-EN-N

JRC Mission

As the science and knowledge service of the European Commission, the Joint Research Centre's mission is to support EU policies with independent evidence throughout the whole policy cycle.

EU Science Hub
ec.europa.eu/jrc

@EU_ScienceHub

EU Science Hub - Joint Research Centre

Joint Research Centre

EU Science Hub

Publications Office

doi:10.2760/002447

ISBN 978-92-79-98584-3