ISSN 1831-9424

European Commission

JRC TECHNICAL REPORT

Updated characterisation and normalisation factors for the Environmental Footprint 3.1 method

Andreasi Bassi, S., Biganzoli, F., Ferrara, N., Amadei, A., Valente, A., Sala, S., Ardente, F.

2023

Joint Research Centre

EUR 31414 EN

Contact information
Name: Serenella Sala
Address: Joint Research Centre, Via E. Fermi, 2749, 21027 Ispra (VA) Italy
Email: serenella.sala@ec.europa.eu
Tel.: 0332/786417

EU Science Hub
https://joint-research-centre.ec.europa.eu

JRC130796

EUR 31414 EN

PDF ISBN 978-92-76-99069-7 ISSN 1831-9424 doi:10.2760/798894 KJ-NA-31-414-EN-N

Luxembourg: Publications Office of the European Union, 2023

How to cite this report: Andreasi Bassi S., Biganzoli F., Ferrara N., Amadei A., Valente A., Sala S., Ardente F., *Updated characterisation and normalisation factors for the Environmental Footprint 3.1 method*. Publications Office of the European Union, Luxembourg, 2023, doi:10.2760/798894, JRC130796.

Contents

Abstract

In 2021, the European Commission adopted a revised Recommendation on the use of Environmental Footprint (EF) methods to measure and communicate the life cycle environmental performance of products and organisations. In 2022, a joint effort between the European Commission and the EF Technical Advisory Board and its expert groups (as the Agriculture Working Group and the Data Working Group) resulted in an update of the EF life cycle impact assessment (from EF3.0 to EF3.1), where new characterisation factors for six impact categories and new normalisation factors for eight impact categories were tested and validated. This report describes the EF3.1 update, clarifies the differences between the EF3.0 and the EF3.1, and explains which changes mainly drove the variation of results in case of the EF representative products and of the official EF datasets. The update of the characterisation factors was major (i.e., involving the CFs derivation/calculation rules) in the case of Climate change, Human toxicity, non-cancer, and Ecotoxicity, freshwater, while it only included minor adjustments for other three impact categories (Acidification, Photochemical ozone formation, and Human toxicity, cancer). The change in the normalisation factors was due both to the update of the characterisation factors and to the correction of the global inventory of very few substances. Finally, the EF3.1 results of 2752 EF official datasets and 49 EF representative products were compared to the EF3.0 results.

Acknowledgements

This report is a deliverable of the Administrative Arrangement "Technical support for the Environmental Footprint and the Life Cycle Data Network (EF4)" signed between DG Environment and JRC Ispra (Directorate D). We thank Mattia Damiani, Marc-Andree Wolf, Alexis Laurent, Vincent Colomb, and Jozef Pacyna for the interesting discussions. We would also like to thank the members of the AWG (Agricultural Working Group) and DWG (Data Working Group) of the EF Technical Advisory Board for the received feedback.

Authors

Susanna Andreasi Bassi

Fabrizio Biganzoli

Nicola Ferrara

Andrea Amadei

Antonio Valente

Serenella Sala

Fulvio Ardente

1 Introduction

The Environmental Product Environmental Footprint (PEF) and Organisation Environmental Footprint (OEF) are the life cycle assessment based methodologies recommended by the European Commission[1] to quantify the environmental impacts of products (goods or services) and organisations over their life cycle. The overarching purpose of PEF and OEF is to enable companies to reduce the environmental impacts of goods, services and organisations taking into account supply chain activities (from extraction of raw materials, through production and use to final waste management). This purpose is achieved through the provision of detailed requirements for modelling the environmental impacts of the flows of material/energy and the emissions and waste streams associated with a product or an organisation throughout the life cycle.

The Environmental Footprint (EF) methods, i.e., the PEF and OEF, are regularly updated by the European Commission, aiming at having a good balance between providing a stable methodology and adopting the most updated scientific development. The EF development and EF updates are the result of a collaboration between the European Commission and the Technical Advisory Board, comprising of experts from different stakeholders groups (e.g., private sector, NGOs). The Technical Advisory Board has two sub-groups, the Data Working Group and the Agricultural Working Group, working on data and agricultural specific challenges, respectively.

In 2022, several reasons brought the Joint Research Centre to work on updating the EF characterisation factors (CFs) and the normalisation factors (NFs):

- In 2021, the IPCC published new CFs for *Climate change* (Forster et al., 2021). Being the IPCC the most important international organisation for *Climate change*, several stakeholders highlighted the need to update this impact category to avoid calculating outdated results.
- The EF Agricultural Working Group[2] highlighted several issues related to the three EF toxicity impact categories and elaborated some short-term and long-term actions (see section 3.4 for more information on the group outcomes). The European Commission decided to implement firstly the short-term solutions of the most relevant issues, while continuing working on the remaining challenges.
- The update of the CFs lead to a re-calculation of the NFs. Furthermore, few misalignments between the CFs used in the impact categories and the CFs used to calculate the NFs were found and needed to be corrected.
- Several flows having the same name or synonyms were found in the EF flow list. The EC decided not to change the EF flow list, but worked on assigning the same CF to all the synonyms and duplicates in all the impact categories.

JRC presented the updated CFs and NFs to the Technical Advisory Board, explained the reasons for each change, and showed the consequences of such changes both on the representative products[3] and on the official EF datasets. These meetings lead to an intense exchange between JRC and the various stakeholders of the Environmental Footprint expert groups and resulted in the EF3.1 CFs and NFs being validated by the Technical Advisory Board and published on the eplca website[4] as EF3.1 life cycle impact assessment (LCIA).

This report summarises the EF3.1 LCIA and presents its main differences with the previous version EF3.0. Section 2 presents the EF LCIA and the underlying methods of all the impact categories. Section 3 describes the implementation of the six impact categories affected by the update: *Climate change* (CC), *Photochemical ozone formation, human health* (POF), *Acidification* (AC), *Human toxicity, cancer* (HTOX_c), *Human toxicity, non-cancer* (HTOX_nc), and *Ecotoxicity, freshwater* (ECOTOX). The detailed description of the remaining 10 impact categories can be found in Fazio et al. (2018). Section 4 illustrates the revision of the NFs both from Crenna et al. (2019) to EF3.0 and from EF3.0 to EF3.1. Section 5 compares the EF3.1 and EF3.0 LCIA results of 2752 official datasets on the nodes of the EF database and 49 representative products (RPs). The updated CFs, NFs, and the global inventory can be found on the EF webpages[5]. Finally, Annex I reports all the duplicates, the synonyms (i.e., same substance with different names), and the false synonyms (i.e., same name but different CAS or IEC number

[1] European Commission, 2021, Recommendation 2021/2279 (link)

[2] EF Agricultural Working Group 2020-2021. Milestone 1: Pesticides and toxicity indicators. Draft September 2022

[3] In the context of the EF, a representative product (RP) is developed in each product environmental footprint category rules. The RP can be either a real product sold in the EU market or a virtual (non-existing) product calculated based on average European market sales-weighted characteristics for all existing technologies/materials covered by the product category or sub-category (EC, 2021). All the representative products can be found in the EF Representative product node (https://eplca.jrc.ec.europa.eu/EF-node/).

[4] https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml

[5] The characterisation factors can be downloaded from https://eplca.jrc.ec.europa.eu/permalink/EF3_1/EF-LCIAMethod_CF(EF-v3.1).xlsx and the normalisation factors from https://eplca.jrc.ec.europa.eu/permalink/EF3_1/Normalisation_Weighting_Factors_EF_3.1.xlsx.

having distinguishable toxicological properties) currently found in the EF flow list. A correction of the EF flow list is foreseen in the future.

2 Summary of the EF3.1 LCIA

Figure 1 shows the EF LCIA. The inputs and outputs from the life cycle inventory are aggregated in 16 midpoint characterised impact categories. These impact categories are then normalised (i.e., the results are divided by the overall inventory of a reference unit, e.g., the entire world, to convert the characterised impact categories in relative shares of the impacts of the analysed system) and weighted (i.e., each impact category is multiplied by a weighting factor to reflect their perceived relative importance). The weighted impact categories can then be summed to obtain the EF single overall score. The number and the name of the impact categories is the same in EF3.0 and EF3.1.

Table 1 shows the EF3.1 midpoint impact categories, their indicator, unit and the underlying LCIA method. This report only describes the adaptation of the underlying method to the EF of the six impact categories affected by a change in their CFs, details on the remaining 10 impact categories can be found in Fazio et al. (2018).

Figure 1. EF3.1 life cycle impact assessment method.

Source: JRC analysis.

Table 1. EF3.1 midpoint impact categories with their indicator, unit, and underlying life cycle impact assessment (LCIA) method. *updated in the EF3.1 and described in this report. The adaptation of all the other 10 impact categories can be found in Fazio et al. (2018).

Impact category	Indicator	Unit	Underlying LCIA method
*Climate change**	Radiative forcing as Global Warming Potential (GWP100)	kg $CO_{2\ eq}$	Bern model - Global warming potential (GWP) over a 100-year time horizon based on IPCC 2021 (Forster et al., 2021).
Ozone depletion	Ozone Depletion Potential (ODP)	kg CFC-11_{eq}	EDIP model based on the ODPs of the World Meteorological Organisation (WMO) over an infinite time horizon (WMO 2014 + integrations)
*Human toxicity, cancer**	Comparative Toxic Unit for humans (CTUh)	CTUh	Based on USEtox2.1 model (Fantke et al. 2017, Rosenbaum et al. 2008), as in Saouter et al. (2018)
*Human toxicity, non-cancer**	Comparative Toxic Unit for humans (CTUh)	CTUh	Based on USEtox2.1 model (Fantke et al. 2017, Rosenbaum et al. 2008), as in Saouter et al. (2018)
Particulate matter	Human health effects associated with exposure to PM2.5.	Disease incidences	PM model (Fantke et al., 2016 in UNEP 2016)
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) and published in Frischknecht et al. (2000).
Photochemical ozone formation, human health	Tropospheric ozone concentration increase	kg $NMVOC_{eq}$	LOTOS-EUROS model (Van Zelm et al., 2008) as applied in ReCiPe 2008.
*Acidification**	Accumulated Exceedance (AE)	mol $H+_{eq}$	Accumulated Exceedance (Seppälä et al. 2006, Posch et al., 2008)
Eutrophication, terrestrial	Accumulated Exceedance (AE)	mol N_{eq}	Accumulated Exceedance (Seppälä et al. 2006, Posch et al., 2008)
Eutrophication, freshwater	Fraction of nutrients reaching freshwater end compartment (P)	kg P_{eq}	EUTREND model (Struijs et al., 2009) as implemented in ReCiPe 2008.
Eutrophication, marine	Fraction of nutrients reaching marine end compartment (N)	kg N_{eq}	EUTREND model (Struijs et al., 2009) as implemented in ReCiPe 2008
*Ecotoxicity, freshwater**	Comparative Toxic Unit for ecosystems (CTUe)	CTUe	Based on USEtox2.1 model (Fantke et al. 2017, Rosenbaum et al. 2008), adapted as in Saouter et al. (2018)
Land use	Soil quality index	Dimensionless (pt)	Soil quality index based on LANCA model (De Laurentiis et al. 2019) and on the LANCA CF version 2.5 (Horn and Maier, 2018)

Impact category	**Indicator**	**Unit**	**Underlying LCIA method**
Water use	User deprivation potential (deprivation-weighted water consumption)	m^3 world eq. deprived water	Available WAter REmaining (AWARE) model (Boulay et al., 2018; UNEP 2016)
Resource use, minerals and metals	Abiotic resource depletion (ADP ultimate reserves)	kg Sb_{eq}	van Oers et al., 2002 as in CML 2002 method, v.4.8
Resource use, fossil	Abiotic resource depletion – fossil fuels (ADP-fossil)	MJ	van Oers et al., 2002 as in CML 2002 method, v.4.8

Source: JRC analysis.

3 Characterisation factors (CFs)

As described in the introduction, the CFs of six impact categories were updated in the EF3.1. A summary of the changes can be found in Table 2, while a detailed description of the update is found in the following sections: CC in section 3.1, POFP in section 3.2, AC in section 3.3, and the 3 toxicity-related impact categories in section 3.4.

Annex I reports the synonyms and the duplicates to which the same CFs were assigned in the EF3.1, and the false synonyms (i.e., substances having the same name but different CAS and/or EC number, and different CF). In case of false synonyms, the EF user should be very careful in choosing the right flow after having checked the CAS and the EC number.

Table 2. Summary of the changes of the characterisation factors in EF3.1 compared to EF3.0. CC: *Climate change*; POF: *Photochemical ozone formation, human health;* AC: A*cidification;* ECOTOX: *Ecotoxicity, freshwater*; HTOX_c: *Human toxicity, cancer*; and HTOX_nc: *Human toxicity, non-cancer.* *The update of the impact category was major (i.e., involving the CFs derivation/calculation rules). **The update of the impact category was minor (i.e., involving the correction of few errors).

	CC*	**POF****	**AC****	**ECOTOX***	**HTOX_c****	**HTOX_nc***
Updated underlying method.	X					
Harmonization of the calculation principles and data sources for metals.				X		
Revision of the derivation rules for proxies.				X		X
Revision of derivation rules for “water, unspecified”.				X		
Revision of inorganic substances.				X		X
Reduction of the number of sub-impact categories.				X	X	X
Bug fixing, i.e. same CF to synonyms/duplicates.	X	X		X	X	X
Bug fixing, i.e. wrong CFs.			X			
Missing sub-compartments.	X		X			

Source: JRC analysis.

3.1 Climate change

The EF3.1 *Climate change* was updated to be in line with the Sixth Assessment Report (AR6) of the IPCC2021 (Forster et al., 2021), using the values from Table 7.15 page 1,017 for the available substances and Table 7 SM7 for the remaining substances (Smith, 2021)[6], as suggested by the authors of AR6 in a private communication.

[6] The Table 7 SM7 is located at: https://github.com/chrisroadmap/ar6/blob/main/data_output/7sm/metrics_supplement_cleaned.csv

Note that 32 substances had a CF in the AR5 but not in the AR6 because they were considered not important (or irrelevant) by the IPCC2021, meaning that 32 substances were characterised in EF3.0 and not in EF3.1. Furthermore, AR6 included additional substances than AR5, resulting in about 43 substances (excluding synonyms and duplicate) being characterised in EF3.1 but not in EF3.0. Finally, 23 substances in the AR6 could not be mapped to the EF flow list and the EF3.0 CFs given to “carbon monoxide (fossil)”, “carbon monoxide (land use change)”, and “carbon monoxide (biogenic)” were not replicated in EF3.1 to be fully consistent with the AR6. The biogenic carbon modelling was kept the same as in the EF3.0, meaning that the biogenic carbon uptakes and emissions were considered neutral (see Table 3).

Table 3. Carbon modelling in EF3.1 with the *Climate change* characterisation factors (CFs) in EF3.0 and EF3.1.

Flow	**CF in EF3.0**	**CF in EF3.1**
Emission of “Carbon dioxide (biogenic)” to air	0	0
Emission of “Carbon dioxide (fossil)” to air	1	1
Emission of “Carbon dioxide (land use change) ” to air	1	1
Emission of “Methane (biogenic)” to air	34	27
Emission of “Methane (fossil)” to air	36.8	29.8
Emission of “Methane (land use change)” to air	36.8	29.8
Resource “Carbon dioxide (biogenic)” from air	0	0
Resource “Carbon dioxide (fossil)” from air	0	0
Resource “Carbon dioxide (land use change)” from air	-1	-1

Source: JRC analysis.

Second, the sub-impact categories *Climate change-biogenic* and *Climate change-Land use and land use change* were corrected to include all the biogenic flows and the land use change flows, respectively because the two sub-impact categories were missing a few flows in EF3.0.

Third, all the synonyms and duplicates identified during the update and from the feedback from the members of the Data Working Group were given the same CFs (for details see Annex I) and the same CFs were assigned to all the air sub-compartments when missing in EF3.0.

3.2 Photochemical ozone formation, human health

The EF impact category for *Photochemical ozone formation, human health* is based on Van Zelm et al 2008 as applied in ReCiPe2008, both in EF3.0 and in EF3.1. As described in Fazio et al. (2018), the EF3.0 implemented two main deviations from the original methods kept in the EF 3.1:

- The CF for Volatile Organic Compounds was calculated by weighting the CF of “non-methane volatile organic compounds (generic)” and “methane” with the amount of European emissions in 2004 (i.e., 14 Mt NMVOCs and 47.8 Mt methane based on Vestreng et al. 2006).
- A part for particulate matter, the CFs of substance groups (e.g., metals and pesticides) were not implemented in the EF even if they were provided in ReCiPe2008 for two main reasons. First, it was not considered meaningful to have only one CF for such broad and diverse groups of subtances. Second, the most important compounds from these groups were already assigned a CF as individual substances.

The only change in EF3.1 was to assign the same CF of “HCFC-140” and “dichloromethane” to their synonyms “Methyl chloroform” and “Methylene chloride”, respectively (see Annex I for the complete list of synonyms found in the EF flow list).

3.3 Acidification

The underlying method for acidification in EF3.1, as in EF3.0, is based on Seppälä et al. (2006) and Posch et al (2008).

As described in Fazio et al. (2019), the method was implemented in the EF with the following adaptations:

- The flow "sulfur oxides" (SOx) was given the same CF as "sulfur dioxide" (SO2)
- The CF for NO and SO_3 were derived from the CFs of NO_2 and SO_2 provided in Posch et al. (2008), respectively. The CFs of NO and SO_3 were calculated by applying the conversion factor z/M, where z is the charge of the molecule (NO has the same molecular ions released of NO_2 equal to 1, and SO_3 has the same molecular ions released as SO_2 with a z equal to 2) and M is the molecular weight. The exact conversion factors can be found in Fazio et al. (2008)

Furthermore, country-specific CFs are provided for a number of countries for SO_2, NH_3, and NO_2.

The EF3.1 update only corrected few mistake found in the EF3.0 method. First, the CFs for six flows in the EF3.0 have been corrected (Table 4). Second, the same CFs was assigned to all the air sub-compartments when missing in the EF3.0 (i.e., "sulfur dioxide" to "air, unspecified (long-term)" and "sulfur oxides" to "air, unspecified (long-term)" and to "lower stratosphere and upper troposphere").

Table 4. Corrected characterisation factors (CF) in mol H+ eq/kg for the *Acidification* impact category.

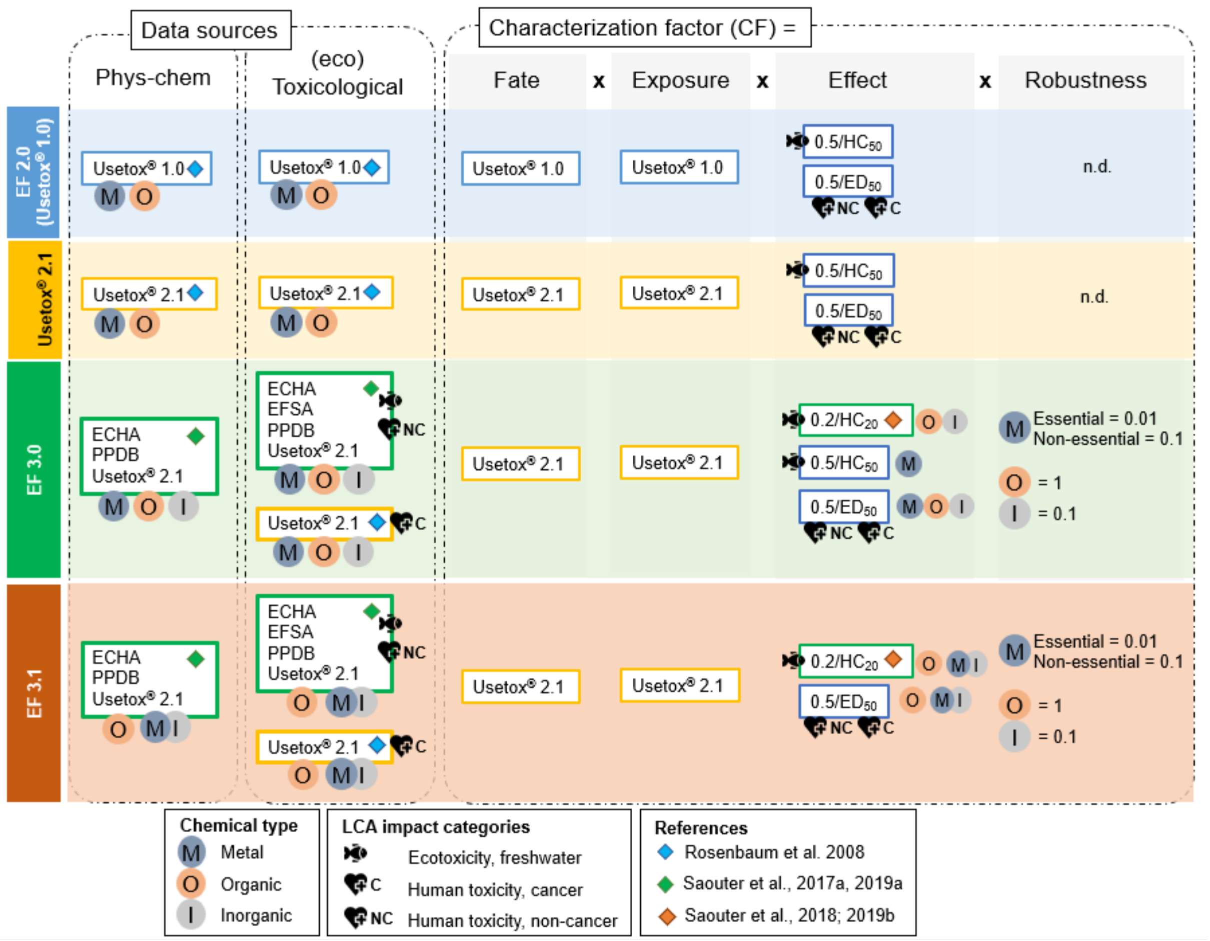
Flow name	Location	Flow class 2	CF in EF3.0	CF in EF3.1
sulfur dioxide	CZ	Emissions to air, unspecified	2118	2.120
sulfur dioxide	CZ	Emissions to lower stratosphere and upper troposphere	2118	2.120
sulfur dioxide	CZ	Emissions to non-urban air or from high stacks	2118	2.120
sulfur dioxide	CZ	Emissions to urban air close to ground	2118	2.120
sulfur dioxide	AL	Emissions to non-urban air or from high stacks	1.310	0.0320
sulfur dioxide	AL	Emissions to urban air close to ground	1.310	0.0320

Source: JRC analysis.

3.4 Toxicity impact categories

The three EF toxicity impact categories are based on the USEtox® factors (v.2.1). Figure 2 illustrates the evolution of the USEtox model and its adaptation to the EF method. It can be read as an illustrated table: each column reports a variable (data sources, fate, exposure, effect and robustness factors) and each row the USEtox model versions (1.0 as adopted in EF 2.0, 2.1, its adaptation for EF3.0 and EF3.1). The colour of the frames of each box brings information on the origin: all pieces of information in boxes with the same colour were introduced in the same version of the model.

Figure 2. Evolution of the toxicity impact categories from EF2.0 to EF3.1.



Source: JRC analysis.

3.4.1 From EF2.0 to EF3.0

The CFs of the 3 toxicity-related impact categories (ECOTOX; HTOX_c; and HTOX_nc) were initially updated in the EF3.0 to address several issues observed during the EF pilot phase. Such update is already extensively described in another JRC report and in other scientific publications (Saouter et al., 2018; Saouter et al., 2019a; Sala et al., 2022), but it mainly focused on three areas:

— In EF3.0 the physico-chemical and eco-/human- toxicity data were mainly retrieved from EU sources (ECHA (EC, 2006), EFSA (Dorne et al., 2017)) to guarantee the reliability of data and to cover chemicals in EU market;

— A new ecotoxicological endpoint was adopted to derive the Effect Factor (EfF) (HC_{20}, i.e., the Hazardous Concentration that kills 20% of species in an exposed ecosystem) for the ECOTOX to align ecotoxicity data used for Life Cycle Assessment and Environmental Risk Assessment purposes (Saouter et al., 2019b). This proposed endpoint found the consensus of the scientific community (Owsianiak et al., 2019);

— Robustness Factors were introduced to mitigate the dominance of metals in the overall toxicity contribution. Moreover, a lower robustness factor was applied to address the essentiality of metals.

After this update, EC-JRC performed some testing on representative products for the EU citizen consumption and received several stakeholders' feedback, as collected mainly during the Agricultural Working Group[7]. Many of the comments focused on the high contribution of metals and of certain inorganics (i.e. sulphur) to the toxicity impact categories, the relevance of the toxicity impact categories on the single overall score, the sub-categorisation in organics, inorganics, and metals, and the lack of pesticides direct exposure. Not all the issues raised by the Agricultural Working Group could be solved in the 3.1 updates but JRC prioritised work on the most

[7] EF Agricultural Working Group 2020-2021. Milestone 1: Pesticides and toxicity indicators. Draft September 2022

relevant issues highlighted in Table 5. Additional future actions may include: revising the essentiality of metals and verifying it is reflected in LCIA results; direct exposure of pesticides and implementation of near-field exposure in the EF method (Fantke et al., 2021).

Table 5. Short-term actions to address high-priority issues. ECOTOX: *Ecotoxicity, freshwater.*

Issue	**Level**	**Action**	**Section in the report**
Calculation principles inconsistency for metals in ECOTOX	CF	Harmonization of the ECOTOX calculation principles and data sources for metals	Section 3.4.2.1
Confusing split between metals and inorganics	CF	Merge metals and inorganics in the same sub-impact category	Section 3.4.2.2
Few non-toxic inorganics driving the impacts	CF	Revision of the CFs for the most contributing inorganic substances	Section 3.4.2.3
Lack of clarity/ transparency with certain elementary flows	CF	Revision of the underlying derivation rules for proxies	Section 3.4.2.4
Lack of clarity/ transparency with certain elementary flows	CF	Revision of the underlying derivation rule for “Emissions to water, unspecified” in ECOTOX	Section 3.4.2.5

Source: JRC analysis.

3.4.2 From EF3.0 to EF3.1

This section describes into detail the changes in the toxicity impact categories in the EF3.1 summarised in Table 5. In addition, all the synonyms and duplicates were given the same CFs (for details see Annex I).

3.4.2.1 Harmonization of the ECOTOX calculation principles and data sources for metals

This action aims at overcoming the inconstancy in calculation principles for the ECOTOX CFs. In EF3.0, the ECOTOX CFs for organic and inorganic chemicals were derived by introducing HC_{20} as an ecotoxicological endpoint (Owsianiak et al., 2019) and input data from EU sources (when available) (Saouter et al., 2018, Sala et al., 2022). As in the EF3.0, the term “EU sources” refer to the ECHA (EC, 2006) and EFSA (Dorne et al., 2017) registry. On the contrary, the CFs for metals were adopted in EF3.0 as published in the USEtox after a long stakeholder consultation (Westh et al., 2015) even if they relied on different underlying endpoints and data sources.

The CFs of metals in EF3.0 and EF3.1 are shown in Table 6. The CFs of metals in EF3.1 were calculated in two different ways depending on whether EU data sources were available. The EF3.1 CFs of the 13 metals (aluminium, cadmium, cobalt, copper, lead, manganese, mercury, molybdenum, nickel, silver, tin, vanadium and zinc) having available EU data sources were calculated using the same endpoint (i.e., the ecotoxicological endpoint HC_{20} from Owsianiak et al., 2019) and EU data sources as the organic and inorganic chemicals. HC_{20} was derived from Species Sensitivity Distribution curves when ecotoxicological data for more than one species were available in EU data sources. On the other hand, the CFs EF3.1 of the metals missing EU sources were calculated by converting the HC_{50} value in USEtox to HC_{20} by applying 0.34 as an extrapolation factor (Saouter et al., 2018). This extrapolation factor causes an around +18% increase in the CF value, as demonstrated in Equations 1 to 4:

$$CF_{HC20} = \frac{0.2}{HC_{20}} \times FF \times XF \qquad (1)$$

$$CF_{HC50} = \frac{0.5}{HC_{50}} \times FF \times XF \quad (2)$$

$$\frac{CF_{HC20}}{CF_{HC50}} = \frac{0.2/HC_{20} \times FF \times XF}{0.5/HC_{50} \times FF \times XF} = \frac{0.2}{0.5} \times \frac{HC_{20}}{HC_{50}} = \frac{0.2}{0.5} \times \frac{HC_{20}}{HC_{20} \times 0.34} = 1.176 \quad (3)$$

$$CF_{HC20} = 1.176 \times CF_{HC50} = CF_{HC50} + 18\%\ CF_{HC50} \quad (4)$$

For some metals, such as aluminium and copper, the increase in CF values resulting from the ecotoxicological endpoint harmonisation was compensated by the adoption of EU data sources. This suggests a potential overestimation of ecotoxicological potential using USEtox input data. As shown in Table 6, aluminium and copper showed the highest ECOTOX CFs in EF3.0. On the contrary, their ECOTOX CFs drop by two and four orders of magnitude in EF3.1, respectively. On the other hand, cadmium, silver and mercury are the most potential impactful metals in EF3.1 while they were ranked as 2nd, 5th and 15th in EF 3.0, respectively.

Finally, the same robustness factors as in Saouter et al. (2018) were applied.

Table 6. Characterisation factors (CFs) of metals in CTUe/kg in EF3.0 and EF3.1 in the *Ecotoxicity, freshwater* impact category. CFs refer to emissions to fresh water. [a] Relative difference calculated as (CF in EF3.1 – CF in EF3.0) / CF EF in 3.0. [b] No ecotoxicological data from EU sources were available and the HC_{20} was derived from the HC_{50} value in USEtox (see equations 1 to 4 for more information). [c] The CF of the element was set equal to the CF of the speciation. [d] The CF of the element was calculated as the average between the two chemical forms.

Flow name	CF EF3.0	CF EF3.1	Relative difference[a]
aluminium / aluminium (iii) [c]	4.09E+05	4.35E+03	-99%
antimony [d]	1.22E+02	1.12E+04	9110%
antimony (iii) [b]	1.22E+02	1.43E+02	18%
antimony (v) [b]	1.90E+04	2.23E+04	18%
arsenic [d]	1.52E+03	3.26E+03	115%
arsenic (iii) [b]	1.52E+03	1.79E+03	18%
arsenic (v) [b]	4.03E+03	4.74E+03	18%
barium / barium (ii) [c]	3.14E+03	3.70E+03	18%
beryllium / beryllium (ii) [b,c]	1.38E+03	1.63E+03	18%
cadmium / cadmium (ii) [c]	2.29E+05	6.74E+05	195%
cesium / cesium (i) [b,c]	3.80E+03	4.47E+03	18%
chromium (iii)	8.09E+02	9.52E+02	18%
chromium (vi) / chromium [b,c]	1.04E+03	1.23E+04	1080%

Flow name	CF EF3.0	CF EF3.1	Relative difference[a]
cobalt / cobalt (ii) [c]	1.23E+04	5.53E+03	-55%
copper / copper (ii)	9.92E+04	4.65E+01	-100%
iron [d]	1.34E+02	2.11E+03	1474%
iron (ii) [b]	1.34E+02	1.58E+02	18%
iron (iii) [b]	3.45E+03	4.06E+03	18%
lead / lead (ii) [c]	6.89E+01	6.83E+01	-1%
manganese / manganese (ii) [c]	1.64E+02	5.17E+01	-68%
mercury / mercury (ii) [c]	2.21E+03	3.32E+04	1401%
molybdenum / molybdenum (vi) [c]	2.95E+00	9.84E-01	-67%
nickel / nickel (ii) [c]	2.98E+04	2.70E+04	-9%
selenium / selenium (iv) [b,c]	7.32E+01	8.61E+01	18%
silver / silver (i) [c]	1.94E+04	1.77E+05	813%
strontium / strontium (ii) [b,c]	1.54E+04	1.81E+04	17%
thallium / thallium (i) [b,c]	3.53E+03	4.15E+03	17%
tin / tin (ii) [c]	2.98E+02	5.13E+02	72%
vanadium / vanadium (v) [c]	1.13E+03	4.78E+03	323%
zinc / zinc (ii) [c]	1.33E+03	1.66E+03	25%

Source: JRC analysis.

3.4.2.2 Merge metals and inorganics in the same sub-impact category

In EF3.0, chemicals were divided into three sub-impact categories (organics, inorganics, and metals) to capture the different uncertainty associated with metals and inorganics compared to organics, and the different ecotoxicological endpoints used for metals. Since the same ecotoxicological endpoint is used for metals and organics in the EF3.1 (section 3.4.2.1), the sub-impact categories of the toxicity impact categories were reduced from three to two (organics and inorganics including metals). As recommended in Saouter et al. (2018), interpretation of the toxicity results at the characterisation level should be done separately for each sub-category (i.e., organics and inorganics).

3.4.2.3 Revision of the CFs for the most contributing inorganic substances.

The toxicity impact categories in EF3.0 caused the toxicity results being driven by a few inorganic substances whose ecotoxicological data and experimental conditions were further investigated in the EF3.1. For example, carbon monoxide and chlorine are very toxic gases to humans at concentrations unlikely to be reached in standard environmental conditions, meaning that the ecotoxicological data for these chemicals are therefore suitable for Environmental Risk Assessment, which is site and time specific, but not for Life Cycle Assessment studies, which aim to evaluate steady state condition. Table 7 summarises the changes adopted in EF3.1, their rationale, and their references. The review of the inorganic substances was performed only for the most contributing substances, due to the considerable number of characterised chemicals.

Table 7. Changes and rationale for the inorganics' updates, per substance and impact category. HTOX_nc: *Human toxicity, non-cancer*; ECOTOX: *Ecotoxicity, freshwater*

Impact category	**Flow name**	**Change in EF3.1**	**Rationale**	**References**
HTOX_nc	Sulfur, Chloride	CF = 0 (all compartments)	Deemed non-toxic in literature	(US EPA, 1991; EFSA, 2008; WHO, 1996)
HTOX_nc	Chlorine	CF = 0 (all compartments)	Unlikely to reach toxic concentration in standard environmental conditions	(ATSDR, 2010)
HTOX_nc	Carbon monoxide	CF = 0 (all compartments, except "air, indoor")	Toxic concentration only in closed environment	(US EPA, 2021)
ECOTOX	Sulfur, Calcium, Bentonite	CF = 0 (all compartments)	No evidence of its toxicity was found in the literature.	(US EPA, 1991; EFSA, 2008; ECHA, 2022; Sprague & Logan, 1979)

Source: JRC analysis.

3.4.2.4 Revision of the underlying derivation rules for proxies.

Proxies are generally used in EF methods to assign CFs to either uncharacterised elementary flows or generic groups of substances (e.g. "fungicides, unspecified").

In EF3.0, proxies were used to characterise 34 chemicals or groups of chemicals in HTOX_nc and ECOTOX (Saouter et al., 2018; Sala et al., 2022).

The derivation rules for proxies were revised in EF3.1 to account for the most recent data available and to enhance their transparency (Table 8).

Table 8. Changes in proxy derivation rules and rationales used in Ecotoxicty, freshwater and Human toxicity, non-cancer in EF3.0 and EF3.1. *2019 was chosen as the reference year because it has the largest data availability.

Flow name	**EF3.0 derivation rule**	**EF3.1 derivation rule**	**Rationale**
Fungicides, unspecified	Median CF of fungicides available	2019* sales-based weighted average CF of fungicides available.	New sales data available. More robust proxy
Herbicides, unspecified	Median CF of herbicides available	2019* sales-based weighted average CF of herbicides available.	New sales data available. More robust proxy
Insecticides, unspecified	Median CF of insecticides available	2019* sales-based weighted average CF of insecticides available.	New sales data available. More robust proxy
Chlorate	Median CF of inorganic chlorides available	Median CF of potassium chlorate and sodium chlorate	Different chemical species
Hydrogen arsenide	CF of Arsenic	CF of Arsenic	

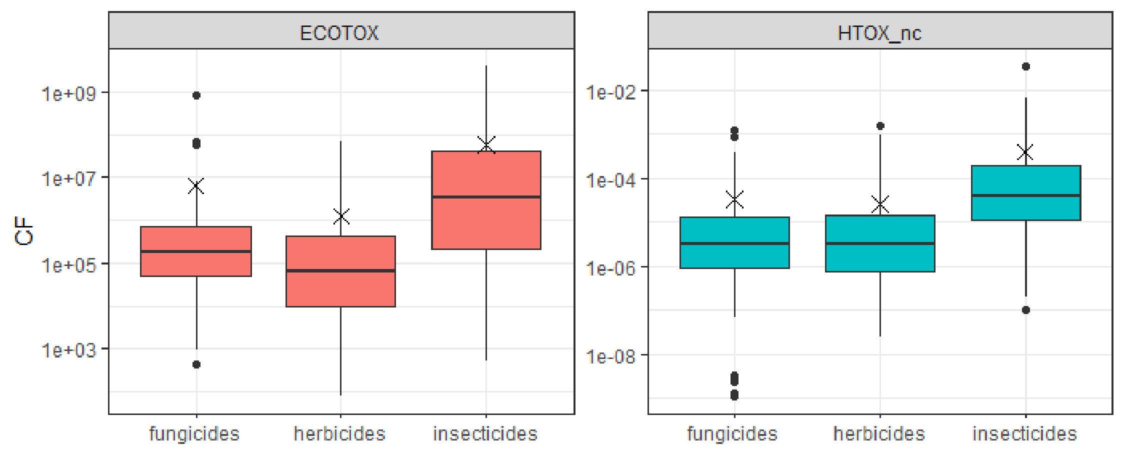
Flow name	EF3.0 derivation rule	EF3.1 derivation rule	Rationale
Lead dioxide	CF of Lead	CF of Lead	Updated ECOTOX CFs for metals
Tin oxide	CF of Tin	CF of Tin	

Source: JRC analysis.

The adoption of sales-based data resulted in more conservative CFs for “fungicides, unspecified”, “herbicides, unspecified”, and “insecticides, unspecified”. Figure 3 illustrates the distribution of CFs for available pesticides in the EF method. In the box plots, the coloured boxes represent all CFs within the 1st and 3rd quartiles. The bold black horizontal line represents the median CFs in the distribution (equivalent to the EF3.0 CFs, according to the proxy rule in Table 8). The cross represents the EF3.1 CFs.

With this revised rule, the EF3.1 CFs for unspecified categories of pesticides are always above the 3rd quartile of pesticides available in the method (being above the upper limit of the coloured box). EF3.1 CFs ensure a better alignment with very toxic and widely used pesticides. This alignment avoids the presence of an alternative pick in the EF method that could lead to greenwashing of LCIA results. For instance, CFs for “insecticides, unspecified” and “chlorpyrifos” present the same order of magnitude in EF3.1, whereas there was a difference of around two orders of magnitude in EF3.0 CFs.

Figure 3. Distribution of CFs for pesticides available in the EF method. Crosses indicate the EF3.1 CFs for unspecified fungicides, herbicides and insecticides. Emissions to freshwater. ECOTOX: *Ecotoxicity, freshwater*; HTOC_nc: *Human toxicity, non-cancer*



Source: JRC analysis.

3.4.2.5 Revision of the underlying derivation rule for “Emissions to water, unspecified” in ECOTOX

In the EF3.0 the CFs for the ECOTOX impact category were calculated as an average between “Emissions to fresh water” and “Emissions to sea water” (Saouter et al., 2018; Sala et al., 2022) that caused the “Emissions to water, unspecified” to be around half of “Emissions to fresh water” due to the much lower fate factor in the sea water. In EF3.1 instead, the CFs of “Emissions to fresh water” were assigned to “Emissions to water, unspecified” to prevent alternative-picking options that could halve LCIA results of waterborne emissions.

4 Normalisation factors (NFs)

The NF of the impact category *i* is calculated as the sum of the products between the inventory I of the flow *j* and the CF of the flow *j* for that impact category *i*:

$$NF_i = \sum_{j=1}^{x} I_j * CF_{i,j}$$

This means that the NFs can change both due to an update of the CFs and if the global inventory is modified.

The NFs of the EF3.0 were calculated on the basis of the inventory published in Crenna et al. (2019) with few modifications. For clarity, section 4.1 describes changes initially implemented between the NFs in Crenna et al. (2019) and in EF3.0, and section 4.2 the more recent changes in EF3.1.

4.1 From Crenna et al. (2019) to the EF3.0

Table 9 shows the detailed differences between the inventory published in Crenna et al. (2019) and the inventory used to calculate the NFs in the EF.0.

On top of the differences detailed in Table 9, an additional correction was performed regarding "Non-methane volatile organic compounds" (NMVOCs) to prioritise the information at the level of single substances. The nomenclature NMVOCs includes a variety of different substances divided in subgroups (such as, "acids, "alkanols", "ketones", etc.). The original inventory in Crenna et al. (2019) contained the emission flows of single NMVOCs (e.g., toluene, propane, acetylene) and the aggregated inventory flow comprising all NMVOCs substances. To improve the granularity and the precision of the inventory, only the specific single flows were characterised in the updated version. Given that not all the single substances that fall under the NMVOCs nomenclature were present in the inventory, several specific rows of NMVOCs subgroups were added to the inventory (i.e., "other alkanals (aldehyedes)", "other alk(adi)enes", "other NMVOCs", "acids (alkanoic)", "alkanols", "alkanones (ketones)"). To estimate an inventory flow to each of these subgroups a three-stepped approach was followed:

1. The list of substances included in each of the subgroups and the total emission flow for each subgroup was derived based on EDGAR data (EC-JRC, 2021).
2. The list of substances derived from EDGAR for each substance type was then compared to the substances (belonging to the same type) as already available in the inventory provided by Crenna et al. (2019) and the total inventory flow for the identified substances in the inventory provided by Crenna et al. (2019) was calculated.
3. The inventory flow associated with each subgroup was calculated as the difference between the total emission flow for that subgroup (as indicated in EDGAR) and the total inventory flow of the subgroup substances available in the inventory of Crenna et al. (2019) as summarised by Equation (5).

$$\boldsymbol{Inventory\_flow_i = Total\_emissions\_EDGAR_i - \sum Inventory\_flows\_Crenna_i} \qquad (5)$$

Where:

- *i*=subgroup
- Inventory_flow$_i$= Inventory flow associated to a specific subgroup;
- Total_emissions_EDGAR$_i$ = Total emissions associated to the substances listed within a specific subgroup (derived from EDGAR);
- Σ Inventory_flow$_i$ = Total inventory flows associated to the substances listed within a specific subgroup, of which an inventory value was available in Crenna et al. (2019).

Table 9. List of changes in the global inventory used to calculate the normalisation factors (NFs) between Crenna et al. (2019) and EF3.0. *Reference year: 2010. HTOX_nc: *Human toxicity, non-cancer*; ECOTOX: *Ecotoxicity, freshwater*; LUC: land use change; NMVOC: non-methane volatile organic compounds.

Substance and Compartment	**Global inventory* [kg]**		**Comment**
	Crenna (2019)	**EF3.0**	
Hcfc-22 to air	Double inventory: 1.00E+08 3.66E+08	3.66E+08	Crenna et al. (2019) had a duplicate inventory for "Hcfc-22" with two different values: 1.00E+08 kg (from the EU27 data in Sala et al. (2015) scaled with a factor of 14.12 based on Cucurachi et al. 2014) and 3.66E+08 kg from Fraser et al. (2014). In EF3.0, the value from Fraser et al. (2014) was selected.
Biogenic methane to air	Double inventory: 1.31E+11 2.05 E+11	1.31E+11	Crenna et al. (2019) calculated the NFs in different impact categories using different values for the inventory of biogenic methane, while the same inventories were used in all the impact categories in EF3.0.
Phosphorus to water	7.13E+09	9.35E+09	The value in Crenna et al. (2019) was calculated as the sum of the emissions from agriculture and wastewater treatment plants from Bouwman et al. (2013). The value was updated in EF3.0 as the sum of the emissions from agriculture and wastewater treatment plants based on Bouwman et al. (2013), Scherer & Pfister (2015) and FAOSTAT (2018).
Phosphorus to soil	1.88E+10 1.58E+10 3.33E+09	Manure 1.88E+10 Fertilizer 1.58E+10	Crenna et al. (2019) published three values for the inventory of phosphorus: - "manure, applied (p component)" -> 1.88E+10 kg (derived from Bouwman et al., 2013) *Freshwater eutrophication*; - "fertilizer applied (p component)" -> 1.58E+10 kg (derived from Bouwman et al., 2013) in *Freshwater eutrophication*; - "phosphorous total" -> 3.33E+09 kg (derived from EU27 data indicated in Sala et al. (2015) considering an upscaling factor equal to 14.12 from Cucurachi et al. 2014) in HTOX_nc and ECOTOX. In the EF3.0, the same inventory was used for all the impact categories.

Substance and Compartment	**Global inventory* [kg]**		**Comment**
	Crenna (2019)	**EF3.0**	
Toluene to air	6.59E+09	7.76E+09	The inventory was updated on the basis of EDGAR voc14 (EC-JRC, 2021).
Formaldehyde to air	5.52E+09	4.22E+09	The inventory was updated on the basis of EDGAR voc21 (EC-JRC, 2021).
Xylene (all isomers) to air	Double inventory: 7.80E+08 1.82E+08	7.20E+09	Crenna et al. (2019) had a double inventory for "zxylene (all isomers)" with different values both derived from the EU27 data indicated in Sala et al. (2015) scaled with a factor of 14.12 from Cucurachi et al. 2014). In EF3.0, one value was kept and it was updated based on EDGAR voc15 (EC-JRC, 2021).
Propane to air	4.71E+09	5.99E+09	The inventory was updated based on EDGAR voc3 (EC-JRC, 2021).
Chloromethane / Methyl Chloride to air	"Methyle Chloride": 4.10E+09 "Chloromethane": 5.79E+09	"Chloromethane": 5.79E+09	Crenna et al. (2019) had two different values for "Methyl Chloride" (4.10E+09 kg from Fahey & Hegglin (2011)) and "Chloromethane" (5.79E+09 kg from EDGAR (EC-JRC, 2021)) for different impact categories even if they are synonyms. The inventory for "Chloromethane" was chosen in the EF3.0 for all the impact categories.
HFC-134a / HFC 134a to air	1.81E+08	1.81E+08	The same substance was repeated twice ("HFC-134a" and "HFC 134a") in Crenna (2019). Only "HFC-134a" was kept in EF3.0 for all the impact categories.
HFC-152a / HFC 152a to air	3.45E+07	3.45E+07	The same substance was repeated twice ("HFC-152a" and "HFC 152a") in Crenna (2019). Only "HFC-134a" was kept in EF3.0 for all the impact categories.
Chlordane to water	Missing	5.93E+03	The value for this substance was retrievable from the supplementary materials provided by Crenna et al. (2019), but it was not included in the final inventory proposed by the authors, therefore it was added to the inventory.

Substance and Compartment	**Global inventory* [kg]**		**Comment**
	Crenna (2019)	**EF3.0**	
Other alkanals (aldehyedes) to air	-	7.95E+09	Added on the basis of EDGAR NMVOCs substances' categorization and total emissions amount (Janssens-Maenhout, et al., 2017), compared with substances categorized as "alkanals (aldehyedes)" already included in the inventory by Crenna et al. (2019).
Other alk(adi)enes to air	-	5.31E+09	Added on the basis of EDGAR NMVOCs substances' categorization and total emissions amount (Janssens-Maenhout, et al., 2017), compared with substances categorized as "alk(adi)enes" already included in the inventory flows in by Crenna et al. (2019).
Other NMVOCs to air	-	5.65E+09	Added on the basis of EDGAR NMVOCs substances' categorization and total emissions amount (Janssens-Maenhout, et al., 2017), considering all remaining (i.e., not included in the other sub-groups) NMVOCs not present in the inventory by Crenna et al. (2019).
Acids (alkanoic) to air	-	8.07E+09	Added on the basis of EDGAR NMVOCs substances' categorization and total emissions amount (Janssens-Maenhout, et al., 2017, compared with substances categorized as "acids (alkanoic)" already included in the inventory flows in by Crenna et al. (2019).
Alkanols to air	-	7.02E+08	Added on the basis of EDGAR NMVOCs substances' categorization and total emissions amount (Janssens-Maenhout, et al., 2017), compared with substances categorized as "alkanols" already included in the inventory flows in by Crenna et al. (2019).
Alkanones (ketones) to air	-	6.08E+09	Added on the basis of EDGAR NMVOCs substances' categorization and total emissions amount (Janssens-Maenhout, et al., 2017) compared with substances categorized as "alkanones (ketones)" already included in the inventory flows in by Crenna et al. (2019).

Source: JRC analysis.

4.2 From EF3.0 to EF3.1

Table 10 shows the changes of the NFs in EF3.1 compared to EF3.0. The suggested changes are due to:

- The change of the CFs in the EF3.1 for some impact categories (see section 3).
- The harmonization between the CFs used in the toxicity impact assessment methods and the CFs used to calculate the corresponding NFs. In particular, 174 substances of the global inventory did not have a corresponding flow in EF and are characterised using the EF "unspecified" flows (namely, "Insecticide, unspecified"; "Herbicide, unspecified"; "Fungicide, unspecified") in the EF3.1.
- The global inventory of Methyl bromide was corrected and the same value was used for all the impact categories. Crenna et al. (2019) had different values for "Methyl bromide" (1.80E+07 kg from Fraser et al. (2011)) and "Bromomethane" to air (1.57E+07 kg based on Leclerc and Laurent (2018) for different impact categories even if they are synonyms. The inventory for "Methyl bromide" was chosen in EF3.1.
- An error in the global inventory of the emissions to air of propane was corrected from 5.99E+03 kg in EF3.0 to 5.99E+09 kg in EF3.1 based on EDGAR 4.3.2 (EC JRC, 2021).
- The CFs of a few substances used to calculate the NFs of *Particulate matter* and *Resource use, minerals and metals* have been corrected, causing a small reduction of the factors (0.003% and 0.03%, respectively).

Table 10. Comparison of normalisation factors (NFs) in EF3.0 and EF3.1 and their relative difference (reference year: 2010; population: 6,895,889,018 persons). The relative difference is calculated as (NFs in EF3.1 – NF in EF3.0)/(NFs in EF3.0). CF: characterisation factor.

Impact category	**EF3.0 NFs**	**EF3.1 NFs**	**Relative difference**	**What caused the change between EF3.1 and EF3.0**
Climate change [kg CO_2 eq./person]	8.10E+03	7.55E+03	-6.7%	Mainly due to the lower CF of "methane" to air and because the CF of "carbon monoxide" to air was set to 0 (section 3.1).
Ozone depletion [kg CFC-11 eq./person]	5.36E-02	5.23E-02	-2.4%	Due to the inventory of "Bromomethane" to air was deleted since it was a duplicate of "Methyl bromide" in EF3.0 (section 4.2)
Human toxicity, cancer [CTUh/person]	1.69E-05	1.73E-05	2.1%	Due to the addition of the CF of "carbon tetrachloride" to air since it is a synonym of "CFC-10" that already had a CF (Annex I).
Human toxicity, non-cancer [CTUh /person]	2.30E-04	1.29E-04	-44%	Mainly due to the CF of "carbon monoxide" to air was set equal to 0 (section 3.4.2.3).
Particulate matter [disease incidences/person]	5.95E-04	5.95E-04	0.0034%	Correction of an error in EF3.0 where the emissions of "particles (PM2.5)" to lower stratosphere and upper troposphere were assigned the wrong CF instead of the CF equal to 0.
Ionising radiation, human health [kBq U235 eq./person]	4.22E+03	4.22E+03	0%	
Photochemical ozone formation, human health [kg NMVOC eq./person]	4.06E+01	4.09E+01	0.63%	Due to the correction of the CF for "propane" to air (section 4.2)
Acidification [mol H^+ eq./person]	5.56E+01	5.56E+01	0%	
Eutrophication, terrestrial [mol N eq./person]	1.77E+02	1.77E+02	0%	
Eutrophication, freshwater [kg P eq./person]	1.61E+00	1.61E+00	0%	
Eutrophication, marine [kg N eq./person]	1.95E+01	1.95E+01	0%	

Impact category	EF3.0 NFs	EF3.1 NFs	Relative difference	What caused the change between EF3.1 and EF3.0
Ecotoxicity, freshwater [CTUe/person]	4.27E+04	5.67E+04	33%	Mainly due to the CF of "chlorides, unspecified" and "chlorpyrifos" to unspecified water increased
Land use [pt/person]	8.19E+05	8.19E+05	0%	
Water use [m^3 water eq. of deprived water/person]	1.15E+04	1.15E+04	0%	
Resource use, minerals and metals [kg Sb eq./person]	6.36E-02	6.36E-02	-0.028%	Due to the different approximations of the CFs. The EF3.1 used exactly the CF published in the impact category.
Resource use, fossils [MJ/person]	6.50E+04	6.50E+04	0%	

Source: JRC analysis.

5 Comparing LCIA results in EF3.0 and EF3.1

5.1 Datasets in the official nodes of the EF database

At the time of the release of the official EF3.1 reference package, 2752 datasets were delivered to the EC in the official nodes of the EF database. These datasets were downloaded from the Blonk, Ecoinvent and Sphera nodes[8], organised in 5 categories and 31 sub-categories (Table 11), and then tested to analyse the difference of the LCIA results when applying the CFs and NFs from the EF3.0 and from the EF3.1.

For a correct interpretation of the results, note that:

— The relative difference presented in the below sections is calculated as (EF3.1 LCIA result – EF3.0 LCIA result) / (EF3.0 LCIA result).

— The sign of the relative difference (positive and negative) depends both if the EF3.1 LCIA is higher or lower than in EF3.0 and also on the signs of the LCIA EF3.1 and EF3.0.

Table 11. Categories and sub-categories of the 2752 official datasets of the EF database available at the time of the release of the official EF3.1 reference package.

Category	Sub-category	No of datasets
End-of-life treatment	Incineration	430
	Landfilling	16
	Material recycling	71
	Other end-of-life services	2
	Waste water treatment	5
Energy carriers and technologies	Crude oil-based fuels	132
	Electricity	412
	Energetic raw materials	10
	Hard coal-based fuels	11
	Heat and steam	18
	Lignite based fuels	0
	Renewable fuels	12
Materials production	Agricultural production means	857
	Food and renewable raw materials	10
	Glass and ceramics	134
	Inorganic chemicals	2
	Metals and semimetals	171
	Organic chemicals	1

[8] https://eplca.jrc.ec.europa.eu/LCDN/contactListEF.xhtml

Category	Sub-category	No of datasets
	Other materials	51
	Paper and cardboards	55
	Plastics	4
	Water	64
	Wood	21
Systems	Construction	49
	Electrics and electronics	83
	Packaging	8
	Unspecific parts	1
Transport services	Transport - Air	1
	Transport - Rail	3
	Transport - Road	61
	Transport - Water	4

Source: JRC analysis.

5.1.1 Characterised results

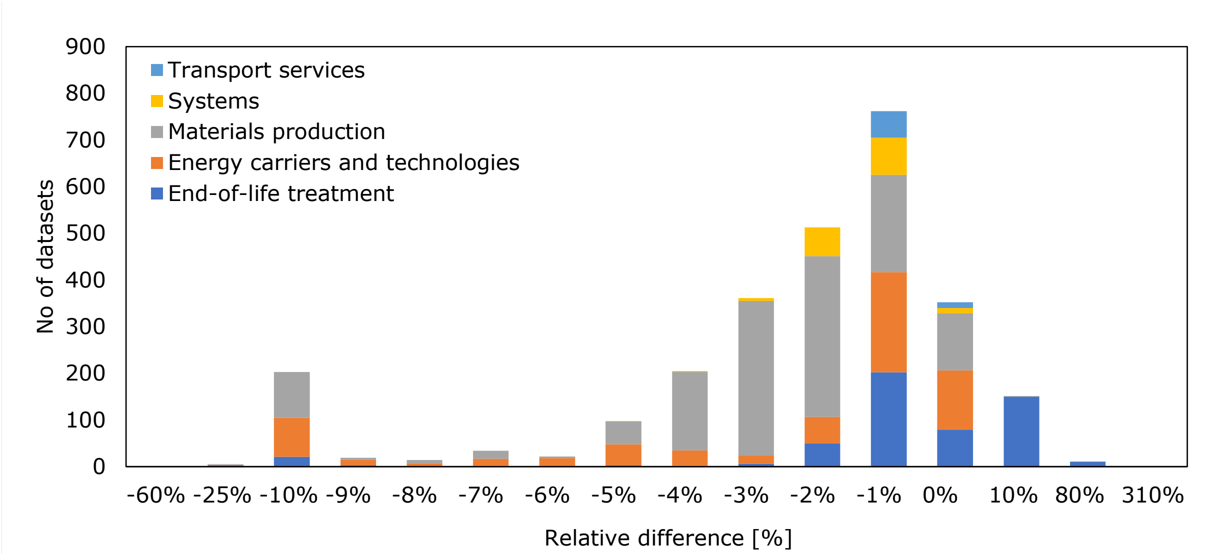
5.1.1.1 Climate change

The CC EF3.1 results are on average 2.9% lower than EF3.0 (with the median equal to 2.2%) and the number of datasets decreasing less than 5% and 10% is 83% and 94%. respectively. Figure 4 and Figure 9 in Annex II show the relative difference per product category and per sub-product category.

Due to the lower CF of methane in the EF3.1, the datasets that are the most affected by the updated CFs are the ones that have a high contribution of methane to the overall CC. In fact, the datasets that decrease by more than 10% are mainly from the sub-categories “Agricultural production means” (e.g., production of cow milk, rice, sheep, beef cattle), “Electricity production” (from biogas), “Incineration”, “Landfilling” (of wood, paper, textile and food waste) and “Waste water treatment”. The maximum reduction of CC (-58%) is observed in “waste incineration of processed wood” in Spain.

On the other hand, only 6% of the studied datasets increases their CC impact (and only 0.4% of more than 10%) and they are mainly waste incineration processes in different geographical areas. Finally, the largest increase (302%) is found in “waste incineration of polyurethane” in Denmark.

Figure 4. Relative difference of the *Climate change* results of the 2752 analysed datasets from the EF database per product category using the EF3.0 and EF3.1 characterisation factors. The relative difference is calculated as (LCIA in EF3.1 – LCIA in EF3.0) / LCIA in EF3.0.



Source: JRC analysis.

5.1.1.2 Photochemical ozone formation, human health

No dataset was affected by the update of the CFs of *Photochemical ozone formation, human health*.

5.1.1.3 Acidification

Only 5 datasets (Table 12) are affected by the few updated CFs (related to the missing sub-compartments) described in section 3. They all increase by around 8% compared to EF3.0 due to the addition of CFs for the flows “sulfur dioxide” and “sulphur oxide” to “air, unspecified (long-term)” and to “lower stratosphere and upper troposphere” in EF3.1. No dataset was affected by the correction of the regionalised CFs of sulfur dioxide.

Table 12. Datasets affected by the updated of the *Acidification* CFs. The relative difference is calculated as (LCIA in EF3.1 – LCIA in EF3.0) / LCIA in EF3.0.

Dataset	**Location**	**Relative Difference**
“container glass, flint colour”	eu+efta+uk	8.2%
“container glass, virgin”	eu+efta+uk	8.9%
“container glass, amber colour”	eu+efta+uk	8.4%
“container glass, unspecified colour”	eu+efta+uk	8.2%
“container glass, green colour”	eu+efta+uk	7.8%

Source: JRC analysis.

5.1.1.4 Human Toxicity, cancer

Only 13 datasets were affected by the update of the CFs of HT_c: 10 increased by less than 1.5%, 2 datasets increased by around 12% (“benzo[thia]diazole-compounds” and “bipyridylium-compounds”) and 1 by around 33% (“acetamide-anillide-compounds”). Such increases were due to the addition of a CF for the emissions of “Carbon tetrachloride” to air because it was found to be a synonym of the already characterised “CFC-10” (Annex I).

5.1.1.5 Human Toxicity, non-cancer

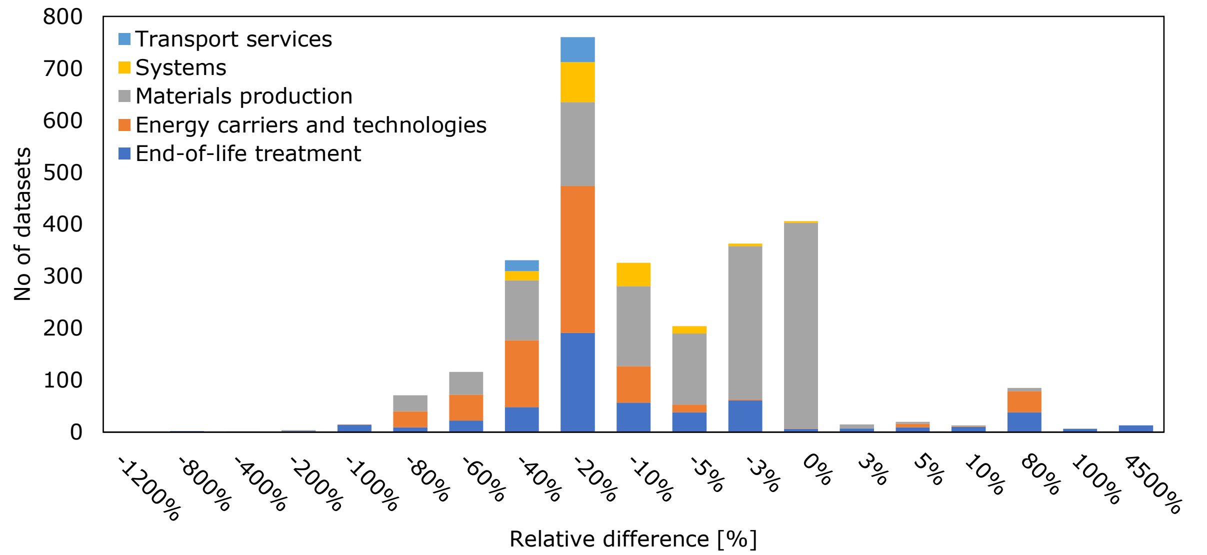
The HTOX_nc shows an average variation from the EF3.0 LCIA equal to 20% (with the median equal to 18%) and 94% of the analysed datasets have a lower result in the EF3.1 (**Figure 5** and **Figure 10** in Annex II).

The sub-categories that have the largest reduction are "Incineration", "Electricity" (from nuclear) and some organic and inorganic chemicals production (as acetamide-anillide-compounds and triphenyl phosphate) and the dataset having the largest reduction (-1,174%) is "waste incineration of non-ferro metals, aluminium, less than 50μm" in SK.

On the other hand, the largest increase (+4,438%) is observed in "waste incineration of processed wood" in ES and the few datasets having a higher result are mainly related to "Incineration" and energy production from biogas (both electricity and thermal energy).

Both increases and decreases are mainly due to the changed CF of chlorine in freshwater and carbon monoxide to air in EF3.1. The results increase or decrease depending if the emissions of chlorine and carbon monoxide are direct emissions or avoided emissions (e.g., energy avoided due to the waste generation).

Figure 5. Relative difference of the HTOX_nc (*Human toxicity, non-cancer)* results of the 2752 analysed datasets from the EF database per product category using the EF3.0 and EF3.1 characterisation factors. The relative difference is calculated as (LCIA in EF3.1 – LCIA in EF3.0) / LCIA in EF3.0.



Source: JRC analysis.

5.1.1.6 Ecotoxicity, freshwater

The average variation of ECOTOX between EF3.1 and EF3.0 is 10% (with the median equal to -0.4%), 70% of the datasets increase or decrease between 0 and 50% and 98% between 0 and 100%.

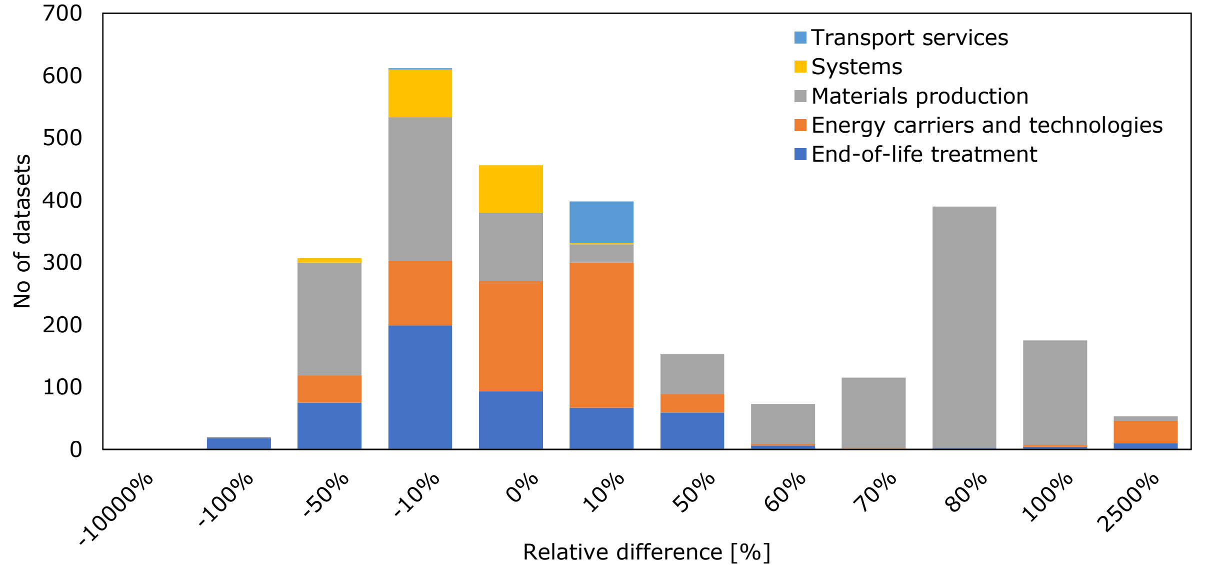
The sub-categories that are mostly affected by the CFs update are "Waste incineration", "Electricity production", "Energetic raw materials", "Agricultural production means", "inorganic and organic chemicals", "Metals and semimetals", "Paper and cardboard" and "wood" production (Figure 6 and Figure 11 in Annex II show the results per category and sub-category, respectively).

The highest increase (almost 2,500%) is observed in "landfill of untreated wood" in EU+EFTA+UK and in many datasets concerning lignite (i.e. production of lignite and energy from lignite). In these cases, the increase is mainly caused by the different CFs for the emissions of aluminium and iron to freshwater (either directly emitted or avoided). For example, in the case of "landfill of untreated wood" in EU+EFTA+UK, the emissions of "aluminium" to air contributed to 45% of the ECOTOX result in EF3.0 and to only 1% in EF3.1 and this causes the considerable observed change.

Furthermore, the majority of the datasets of the sub-category "Agricultural production means" show a relevant increase in the result (85% of this category has an increase above 50% compared to EF3.0) especially due to the different rational behind the emissions to unspecified water (see section 3.4.2.5) and secondly to the different CFs for heavy metals (see section 3.4.2.1).

On the other hand, a large decrease in the results is observed in several datasets modelling incineration of hazardous waste, paint, and PVC (especially due to the different CFs of aluminium and iron with the largest reduction in “waste incineration of PVC” in HU (- 8,000%) followed by the production of chemicals as hexyl salicylate production (GLO), copper sulfate (EU+28+3), copper cathode (EU+28+3), potassium sulphate production (EU+EFTA+UK) (especially due to the CF of sulphur set to 0 and the lower CF for Aluminium). A part for processes involving chemicals, also “coconut, dehusked” and “coconut husk” in PH have a decrease of around 1,400%. For example, the ECOTOX 3.0 of “coconut, dehusked” in PH was caused 52% by the emissions of copper (ii) to agricultural soil while in EF3.1 the same emissions were responsible of only to 0.03% (due to the CF that changed from 9.92E+04 in EF3.0 to 9.92E+04 in EF3.1) and the emissions of “iron” to freshwater caused 44% of the total ECOTOX compared to the 2% in EF3.0 (since the CF changed from 1.34E+02 in EF3.0 to 2.11E+03 in EF3.1).

Figure 6. Relative difference of the *Ecotoxicity, freshwater* results of the 2752 analysed datasets from the EF database per product category using the EF3.0 and EF3.1 characterisation factors. The majority of sub-categories having a very high or very low relative difference are related to “Agricultural production means” (in the category “Material production), electricity production from lignite (in the category “Energy carrier and technologies”), and “Incineration” (in the category “end-of-life treatment”). The relative difference is calculated as (LCIA in EF3.1 – LCIA in EF3.0) / LCIA in EF3.0.



Source: JRC analysis.

5.1.2 Single overall score

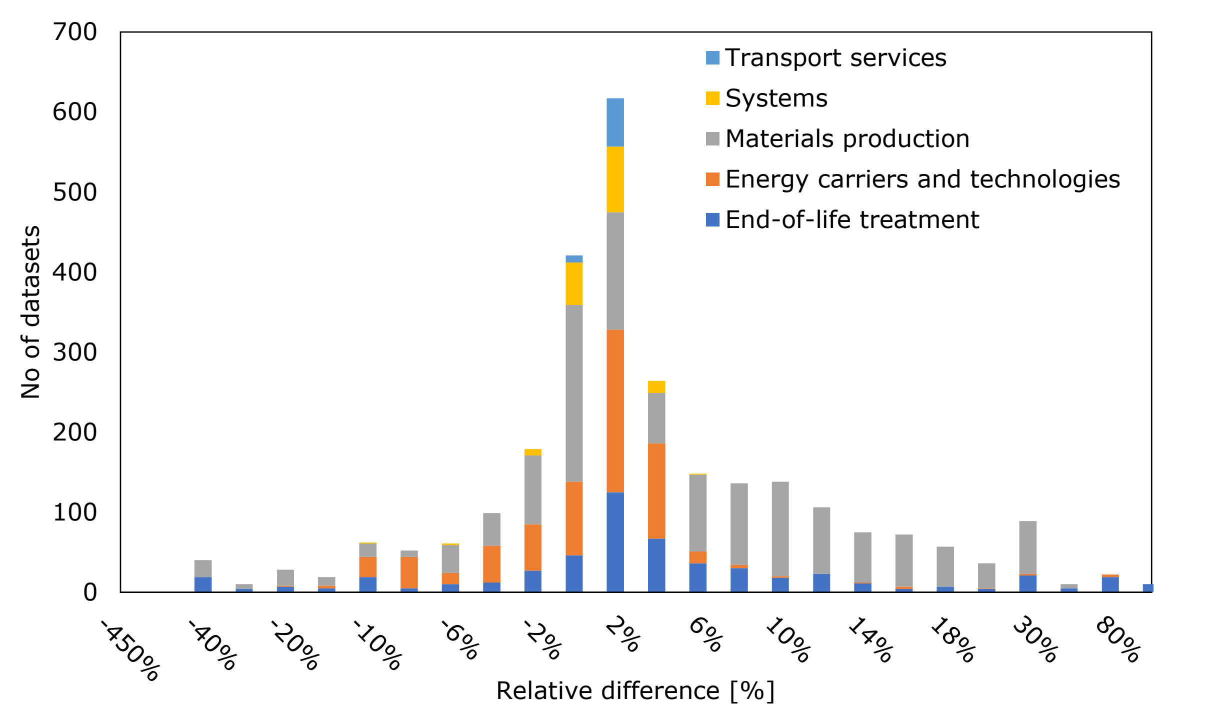
The same approach was used to calculate the occurrences of the differences in the weighted results, calculated accordingly to the new NFs proposed with the 3.1 updates (Section 4.2).

The trend is an average increase of 2% (with the median equal to 1%), where the single overall score increases in 67% of the studied datasets and decreases in 33%. The breakdown of the relative difference per category (Figure 7) and sub-category (Figure 12) shows that the sub-categories that have the highest increase are “Incineration”, “lignite based fuels”, and “Agricultural production means”, with the highest increase in “waste incineration of processed wood” in SK.

On the other hand, the largest decrease is seen in the sub-category “Incineration” (e.g. the highest decrease is in “waste incineration of pe”, -412%), organic and inorganic chemicals, “waste water treatment”, and “Paper and cardboard”.

As already observed in other impact categories, the sub-category “Incineration” has the largest variation of results (between around -400% and 600%), followed by “Agricultural production means”, and in fact, the grey and light blue bars are spread along the whole bins.

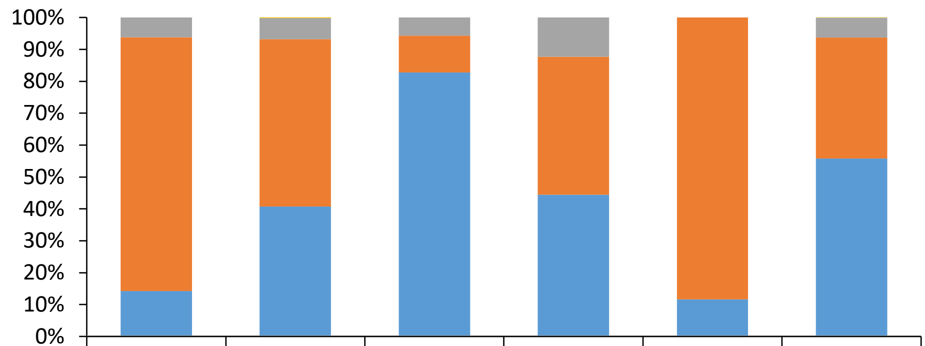
Figure 7. Relative difference of the single overall score results of the 2752 analysed datasets from the EF database per product category using the EF3.0 and EF3.1 characterisation factors. The relative difference is calculated as (LCIA in EF3.1 – LCIA in EF3.0) / LCIA in EF3.0.



Source: JRC analysis.

Figure 8 shows the impact categories contributing the most to the variation of the single overall score, meaning the category showing the higher difference in terms of weighted results. The impact category that most determines the change is ECOTOX, followed by CC even if the weighting factor of CC is several times higher.

Figure 8. Top contributing impact category to the variation of the single overall score due to the update of characterisation and normalisation factors.



	End-of-life treatment	Energy carriers and technologies	Materials production	Systems	Transport services	TOTAL
human toxicity, cancer	0	1	0	0	0	1
human toxicity, non-cancer	33	42	77	20	0	172
climate change	425	331	156	70	61	1043
ecotoxicity, freshwater	76	257	1122	72	8	1535

Source: JRC analysis.

The last step of the analysis was to identify in which cases the most relevant impact categories were different when looking at the EF3.0 single overall score compared to the EF3.1 single overall score (Table 13). The 1st, 2nd, and 3rd impact categories changed in 171, 280, and 358 datasets corresponding to 6%, 10%, and 13% of the analysed datasets.

CC becomes the most relevant impact category in 81 datasets (mainly related to the production of "Paper and cardboards" and inorganic and organic chemicals and "Incineration") at the expense of ECOTOX, and *Resource use, fossils* and stops being the most relevant category 45 datasets (mainly "Agricultural production means") to the advantage of ECOTOX.

Table 13. Number of datasets in the official nodes that have a specific impact category in the first 5 impact categories contributing to the singe score. Highlighted in green when the number increased in EF3.1 compared to EF3.0, highlighted in red when the number decreased.

	EF3.0					EF3.1				
	1st	2nd	3rd	4th	5th	1st	2nd	3rd	4th	5th
Climate change	1212	818	428	149	73	1248	829	387	161	161
Ozone depletion	4	0	0	1	0	4	0	1	0	0
Human toxicity, cancer	17	44	53	20	17	16	42	57	21	21
Human toxicity, non-cancer	7	3	26	26	45	8	7	60	42	42
Particulate matter	59	201	698	594	671	61	196	724	608	608
Ionising radiation, human health	0	32	42	45	59	0	32	43	57	57
Photochemical ozone formation, human health	1	19	107	159	364	1	20	114	155	155
Acidification	26	63	181	609	579	26	63	187	621	621
Eutrophication, terrestrial	0	0	32	144	144	0	0	29	152	152
Eutrophication, freshwater	7	6	9	10	16	9	7	7	8	8
Eutrophication marine	25	95	203	198	156	18	87	213	201	201
Land use	167	153	250	88	91	152	165	245	93	93
Ecotoxicity, freshwater	533	276	284	185	223	541	221	219	113	113
Water use	125	114	192	204	163	121	116	218	204	204
Resource use, fossils	451	900	207	237	96	429	938	206	223	223
Resource use, minerals and metals	118	28	40	83	55	118	29	42	93	93

Source: JRC analysis.

5.2 Representative products

We compared the LCIA results of 49 representative products (RPs) when using CFs and NFs in EF3.0 and EF3.1.

The most relevant observed changes can be summarised as follows:

— Single overall score: The single overall score decreases in 27 RPs and increases in 22 RPs with a variation lower than 2% in 40 RPs out of 49. The largest reduction can be seen in “still wine” (15%) and “still wine packaged in glass bottle” (15%), while the largest increase is in “animal feed for food-producing animals” (13%). Table 14 shows the single overall score calculated using the EF3.0 set and the EF3.1 and their relative difference.

— Most relevant impact categories for the single overall score. Table 14 also shows the first 5 impact categories that contribute the most to the single overall score in EF3.0 and EF3.1 and their variation (i.e., cells highlighted in light red). In particular, ECOTOX was among the three most relevant impact categories in 18 RPs and 16 RPs using the EF3.0 and EF3.1, respectively, and it was among the first five most relevant impact categories in 29 RPs using the EF3.0 and only in 21 with the EF3.1. However, even in the RPs where ECOTOX remains the most relevant impact category (“animal feed for food-producing animals”, “beer”, “dry cat food”, “dry dog food”, and the 5 RPs covering t-shirts), its contribution to the single overall score decreases. For example, in the 5 RPs covering t-shirts ECOTOX causes between 39% and 41% of the single overall score using the EF3.0 and between 30% and 31% with the EF3.1. On the other hand, the HTOX_nc was among the first five most relevant impact categories in 5 RPs with EF3.0 whereas in 12 with EF3.1.

— Characterised impacts:

- *Climate Change*: A reduction of the characterised results is observed for all the RPs. For the majority of RPs, the reduction is lower than 5%. However, a larger reduction is seen in “butterfat product from cow milk” (12%), “cheese from cow milk” (12%), “dried why product from cow milk” (11%), “exterior trim and cladding paints for wood” (21%) “fermented cow milk product” (8%), “indoor wall paint” (6%), “indoor wood paint (8%), “liquid cow milk” (10%), “outdoor mineral wall paint” (6%), “thermal insulation of a building element, pitched roof application” (13%) and all the RPs relative to finished leather (7-8%), especially due to the lower CF of methane and nitrous oxide in EF3.1 compared to EF3.0 (Section 3.1).

- *Photochemical ozone formation, human health*. No meaningful change in the characterised results is observed in any RP.

- *Acidification*. No meaningful change in the characterised results is observed in any RP.

- *Human toxicity, cancer*. The only characterised result that increases more than 1% is “thermal insulation of a building element, flat roof application” (2%) due to the additional CF assigned to “carbon tetrachloride” (that was given a CF since it is a synonym of “CFC-10")

- *Human toxicity, non-cancer*. The characterised result decreases in almost the totality of the RPs. A reduction higher than 50% is found in “outdoor mineral wall paint” (50%), “steel sheet (appliance)” (59%), and “steel sheet (building)” (59%). Almost the totality of the changes is due to the updated CFs of chloride, chlorine, and carbon monoxide that are set to 0 in the EF3.1 (more details are in Section 3.4.2.3).

- *Ecotoxicity, freshwater*. The characterised result increased in 15 RPs (mainly agricultural RPs) and decreased in 34 RPs. The decreased results are mainly driven by the lowered CF of aluminium, calcium, cadmium, copper, and sulfur (see Section 3.4.2.1). The increased results are mainly driven by the increased CFs of all the emissions to unspecified water, especially regarding chlorpyrifos, phorate, lambda-cyhalothrin, and bifenthrin.

Table 14. Single overall score of the 49 representative products using the characterisation normalisation factors EF3.0 and EF3.1. The relative difference is calculated as (single overall score EF3.1 – single overall score EF3.0) / (single overall score EF3.0). Highlighted in red are the relevant impact categories that changed from EF3.0 to EF3.1.

Representative products	**Single overall score**			**Most relevant impact categories**									
	EF3.0	**EF3.1**	**Rel.Diff.**	**EF3.0**					**EF3.1**				
				1st	2nd	3rd	4th	5th	1st	2nd	3rd	4th	5th
aluminium sheet (appliance)	2.2E-03	2.3E-03	1.0%	CC	FRD	PM	AC	IR	CC	FRD	PM	AC	IR
aluminium sheet (building)	1.6E-03	1.6E-03	1.0%	CC	FRD	PM	AC	IR	CC	FRD	PM	AC	IR
animal feed for food-producing animals	2.1E-01	2.3E-01	12.8%	ECOTOX	CC	WU	PM	MEU	ECOTOX	CC	WU	PM	MEU
beer	9.4.E-03	9.9.E-03	5.9%	ECOTOX	CC	FRD	PM	WU	ECOTOX	CC	FRD	PM	WU
butterfat product from cow milk	4.0.E-05	4.2.E-05	4.7%	CC	PM	AC	TEU	HTOX_nc	CC	HTOX_nc	PM	AC	TEU
cheese from cow milk	1.0.E-05	1.1.E-05	4.6%	CC	PM	AC	TEU	HTOX_nc	CC	HTOX_nc	PM	AC	TEU
copper sheet (building)	2.6.E-02	2.7.E-02	0.7%	MRD	PM	CC	HTOX_nc	WU	MRD	PM	CC	HTOX_nc	WU
cpt li-ion (1kwh)	1.1.E-04	1.1.E-04	0.6%	MRD	CC	FRD	PM	AC	MRD	CC	FRD	PM	AC
dried whey product from cow milk	8.9.E-01	9.2.E-01	4.3%	CC	PM	AC	TEU	HTOX_nc	CC	HTOX_nc	PM	AC	TEU
dry cat food	2.0.E-05	2.0.E-05	2.1%	ECOTOX	CC	WU	FRD	PM	ECOTOX	CC	WU	FRD	PM
dry dog food	7.1.E-05	7.2.E-05	1.5%	ECOTOX	WU	CC	PM	FRD	ECOTOX	CC	WU	PM	FRD
e-mobility li-ion (1kwh)	4.6.E-05	4.6.E-05	0.5%	CC	FRD	MRD	PM	ECOTOX	CC	FRD	MRD	PM	IR
exterior trim and cladding paints for wood	6.3.E-04	5.8.E-04	-8%	CC	FRD	POF	ECOTOX	AC	CC	FRD	POF	ECOTOX	AC

Representative products	Single overall score			Most relevant impact categories									
	EF3.0	EF3.1	Rel.Diff.	EF3.0					EF3.1				
fermented cow milk product	1.7.E-05	1.8.E-05	4.1%	CC	FRD	PM	ECOTOX	AC	CC	FRD	ECOTOX	PM	HTOX_nc
finished leather for automotive and upholstery	5.5.E-03	5.6.E-03	1.9%	CC	ECOTOX	PM	AC	TEU	CC	ECOTOX	PM	AC	TEU
finished leather for footwear & leather goods	5.0.E-03	5.1.E-03	1.5%	CC	ECOTOX	PM	AC	FRD	CC	ECOTOX	PM	AC	FRD
finished leather for garments & gloves	3.1.E-03	3.1.E-03	-1%	CC	PM	AC	FRD	TEU	CC	PM	AC	FRD	TEU
finished sole leather	9.8.E-03	1.0.E-02	2.2%	CC	ECOTOX	PM	AC	FRD	CC	ECOTOX	PM	AC	FRD
hot and cold water supply plastic piping systems mix to the building	2.2.E-02	2.2.E-02	0.3%	CC	FRD	PM	MRD	ECOTOX	CC	FRD	PM	MRD	AC
household heavy duty liquid laundry detergents (hdlld) for machine wash - aggregated dataset	4.5.E-05	4.2.E-05	-7%	CC	FRD	ECOTOX	PM	AC	CC	FRD	ECOTOX	PM	AC
ict li-ion (1kwh)	7.2.E-05	7.2.E-05	0%	MRD	CC	FRD	PM	AC	MRD	CC	FRD	PM	AC
ict nimh (1kwh)	1.4.E-04	1.4.E-04	0%	MRD	CC	PM	AC	FRD	MRD	CC	PM	AC	FRD
indoor wall paint	3.7.E-04	3.6.E-04	-3%	CC	FRD	PM	ECOTOX	AC	CC	FRD	PM	AC	ECOTOX
indoor wood paint	3.1.E-04	3.0.E-04	-4%	CC	FRD	PM	AC	ECOTOX	CC	FRD	PM	AC	POF
it storage subsystem	4.4.E-03	4.4.E-03	0.0%	CC	FRD	MRD	PM	IR	CC	FRD	MRD	PM	IR
lead sheet (building)	5.3.E-03	5.6.E-03	4.1%	MRD	CC	PM	HTOX_nc	FRD	MRD	HTOX_nc	CC	PM	FRD
liquid cow milk, unsweetened, unflavoured	1.4.E-04	1.4.E-04	4.0%	CC	PM	AC	TEU	FRD	CC	PM	HTOX_nc	AC	TEU

Representative products	Single overall score			Most relevant impact categories									
	EF3.0	EF3.1	Rel.Diff.	EF3.0					EF3.1				
outdoor mineral wall paint	3.3.E-04	3.2.E-04	-3%	CC	FRD	PM	AC	ECOTOX	CC	FRD	PM	AC	ECOTOX
packed water in PET bottle one-way (1500 ml capacity)	3.1.E-06	3.1.E-06	-1%	MRD	CC	FRD	ECOTOX	WU	MRD	CC	FRD	WU	PM
packed water in HOD PC refillable (5 gallons capacity)	1.3.E-06	1.3.E-06	0%	CC	FRD	WU	ECOTOX	AC	CC	FRD	WU	AC	PM
packed water in glass bottle refillable (1000 ml capacity)	2.0.E-06	2.0.E-06	-1%	CC	FRD	AC	ECOTOX	MRD	CC	FRD	AC	MRD	PM
pasta	3.9.E-04	3.9.E-04	-1%	CC	AC	PM	FRD	TEU	CC	AC	PM	FRD	TEU
sparkling wine	2.3.E-04	2.0.E-04	-12%	CC	ECOTOX	FRD	WU	MRD	CC	FRD	WU	MRD	PM
steel sheet (appliance)	1.3.E-03	1.3.E-03	-1%	CC	MRD	HTOX_c	FRD	PM	CC	MRD	HTOX_c	FRD	PM
steel sheet (building)	2.2.E-03	2.1.E-03	-1%	CC	MRD	HTOX_c	FRD	PM	CC	MRD	HTOX_c	FRD	PM
still wine	1.9.E-04	1.6.E-04	-15%	ECOTOX	CC	FRD	MRD	PM	CC	FRD	MRD	PM	AC
still wine packaged in glass bottle	2.0.E-04	1.7.E-04	-15%	CC	ECOTOX	FRD	MRD	PM	CC	FRD	MRD	PM	ECOTOX
thermal insulation of a building element, flat roof application	2.3.E-03	2.2.E-03	-4%	CC	FRD	PM	ECOTOX	POF	CC	FRD	PM	POF	ECOTOX
thermal insulation of a building element, pitched roof application with massive timber rafters	1.1.E-03	1.0.E-03	-5%	CC	PM	LU	FRD	MRD	CC	PM	LU	FRD	MRD
tshirt for baby	8.9.E-04	8.4.E-04	-5%	ECOTOX	HTOX_c	CC	PM	FRD	ECOTOX	HTOX_nc	CC	HT_c	PM
tshirt for children 8 to 14 years	1.3.E-03	1.2.E-03	-5%	ECOTOX	CC	HTOX_c	PM	FRD	ECOTOX	CC	HTOX_nc	HT_c	PM

Representative products	Single overall score			Most relevant impact categories									
	EF3.0	EF3.1	Rel.Diff.	EF3.0					EF3.1				
tshirt for children age 2-7 years	1.0.E-03	9.5.E-04	-5%	ECOTOX	CC	HTOX_c	PM	FRD	ECOTOX	CC	HTOX_nc	HT_c	PM
tshirt for man	1.6.E-03	1.5.E-03	-5%	ECOTOX	CC	HTOX_c	PM	FRD	ECOTOX	HTOX_nc	CC	HT_c	PM
tshirt for woman	1.5.E-03	1.4.E-03	-5%	ECOTOX	CC	HTOX_c	PM	FRD	ECOTOX	HTOX_nc	CC	HT_c	PM
uninterruptible power supply 1.5-5kva	2.8.E-03	2.8.E-03	-0.1%	CC	MRD	FRD	PM	IR	CC	MRD	FRD	PM	IR
uninterruptible power supply 10.1-200kva	2.2.E-03	2.2.E-03	-0.1%	MRD	CC	FRD	PM	IR	MRD	CC	FRD	PM	IR
uninterruptible power supply 5.1-10 kva	2.3.E-03	2.3.E-03	-0.1%	MRD	CC	FRD	PM	IR	MRD	CC	FRD	PM	IR
wet cat food	4.3.E-05	4.4.E-05	0.5%	CC	FRD	ECOTOX	PM	WU	CC	FRD	ECOTOX	PM	WU
wet dog food	1.4.E-04	1.4.E-04	0.6%	CC	FRD	ECOTOX	PM	WU	CC	FRD	ECOTOX	PM	WU

Source: JRC analysis.

6 Conclusions

The Environmental Product Environmental Footprint (PEF) and Organisation Environmental Footprint (OEF) are methods to quantify the environmental impacts over the life cycle of a product and of an organisation. The PEF and OEF are regularly updated by the European Commission, aiming at having a good balance between stability and following the most recent scientific development.

In 2022, several reasons lead the EC to work on an update of the characterisation factors (CFs) and normalisation factors (NFs) and the new EF3.1 was published in July 2022 in the eplca website[9]. The results were validated by the EF Technical advisory Board.

The EF3.1 update of the CFs of the 6 impact categories can be summarised as following:

- *Climate change* (major update): the method was updated in line with the Sixth Assessment Report (AR6) of the IPCC (Forster et al., 2021), the sub-impact categories were completed, and synonyms and duplicates were assigned the same CF when missing.
- *Photochemical ozone formation, human health* (minor update): synonyms and duplicates were assigned the same CF when missing.
- *Acidification* (minor update): the CFs of 6 regionalised flows were corrected and a CF was assigned to all the missing sub-compartments.
- *Human toxicity, cancer* (minor update): metals and inorganics were merged in the same sub-impact category; and synonyms and duplicates were assigned the same CF when missing.
- *Human toxicity, non-cancer* (major update): metals and inorganics were merged in the same sub-impact category; the CF of sulphur, chloride, chlorine, and carbon monoxide (excluding emissions to indoor air) was set to 0; the derivation rules of proxy (e.g. fungicides, insecticides) were revised; and synonyms and duplicates were assigned the same CF when missing.
- *Ecotoxicity, freshwater* (major update): the calculation principles of the CFs of metals was harmonised with organics and inorganics; metals and inorganics were merged in the same sub-impact category; the CF of sulphur, calcium, and bentonite was set to 0; the derivation rules of proxy (e.g. fungicides, insecticides) were revised; the "Emissions to water, unspecified" were given the same CF as "Emissions to fresh water" (instead than average between freshwater and ocean as in the EF3.0); and synonyms and duplicates were assigned the same CF when missing.

The change in the NFs was due both to the update of the CFs (described above) and to the correction of the global inventory of few substances. In summary, the NFs that changed the most in EF3.1 compared to EF3.0 were *Human toxicity, non-cancer* (-44%), *Ecotoxicity, freshwater* (+33%), and *Climate change* (-6.7%).

Moreover, 2752 datasets in the official nodes of the EF database and 49 representative products were tested when using the EF3.1 characterisation and normalisation factors compared to EF3.0. When analysing the 2752 datasets, in average the EF single overall score showed an increase of around 2% compared to EF3.0 (increasing in 67% of the studied datasets and decreasing in 33%), and the largest changes were observed in the processing involving waste incineration. More in detail, the LCIA result of Climate change, Ecotoxicity, freshwater, Human toxicity, non-cancer were in average 2.9% lower, (median +2.2%), 10% higher (median -0.4%), and 20% higher (median +18%), respectively. No major effects were observed in Acidificatoin and Photochemical ozone formation.

Finally, the LCIA in the EF is expected to continuously develop and update. Medium to long-term developments may include a possible alignment of the EF methods with future versions of USETox and recommendations from the GLAM (Global Life Cycle Impact Assessment Method) when consensus will be reached in the scientific community. Additional future research needs were also highlighted in the Agricultural Working Group (Milestone 1)[10].

[9] https://eplca.jrc.ec.europa.eu/LCDN/developerEF.xhtml

[10] Some recommendations and discussion points at the AWG regarded: the review of CFs of pesticides (when used in the field and in greenhouses); introducing a "plant" compartment in the life cycle inventory and impact assessment of products; defining modelling rules for ionic forms of metals emissions; including degradation products (i.e. metabolites when important toxicity products are emitted; developing terrestrial ecotoxicity indicator.

References

ATSDR (Agency for Toxic Substances and Disease Registry), Toxicological profile of chlorine, chapter 2: relevance to public health, 2010, available at: https://www.atsdr.cdc.gov/ToxProfiles/tp172-c2.pdf Accessed September 2021.

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., 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,* Vol. 23, 2018, pp. 368-378, DOI: http://dx.doi.org/10.1007/s11367-017-1333-8

Bouwman, L., K.K. Goldewijk, K.W. Van Der Hoek, A.H.W. Beusen, D.P. Van Vuuren, J. Willems, M.C. Rufino, and E. Stehfest, 'Erratum: Exploring Global Changes in Nitrogen and Phosphorus Cycles in Agriculture Induced by Livestock Production over the 1900-2050 Period, Proceedings of the National Academy of Sciences of the United States of America, Vol. 110, No. 52, 2013, p. 21196, DOI: https://doi.org/10.1073/pnas.101287810.

Crenna, E., M. Secchi, L. Benini, and S. Sala, 'Global Environmental Impacts: Data Sources and Methodological Choices for Calculating Normalisation Factors for LCA', *Int J Life Cycle Assess,* Vol. 24, 2019, pp. 1851–1877. DOI: https://doi.org/10.1007/s11367-019-01604-y

Cucurachi, S., S. Sala, A. Laurent, and R. Heijungs, 'Building and Characterizing Regional and Global Emission Inventories of Toxic Pollutants', *Environmental Science and Technology*, Vol. 48, No. 10, 2014, pp. 5674–5682.

De Laurentiis, V., Secchi, M., Bos, U., Horn, R., Laurent, A. and Sala, S., Soil quality index: Exploring options for a comprehensive assessment of land use impacts in LCA, *Journal of cleaner production*, 215, 2019, pp. 63-74.

Dorne, JL, Richardson, J, Kass, G, Georgiadis, N, Monguidi, M, Pasinato, L, Cappe, S, Verhagen, H and Robinson, T, 2017. Editorial: OpenFoodTox: EFSA's open source toxicological database on chemical hazards in food and feed. *EFSA Journal,* Vol. 1, Issue 1/ e15011, 2017. DOI: doi.org/10.2903/j.efsa.2017.e15011.

Dreicer, M., Tort, V., Manen, P., 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, 1995.

EC (European Commission), 'Regulation (EC) No 1907/2006 of the European Parliament and of the Council of 18 December 2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH)', *Off J Eur Union,* L 369:1–15, 2006.

EC-JRC, *Global speciated NMVOC Emissions: EDGAR v4.3.2_VOC_spec (January 2017)*, 2021, available at: https://edgar.jrc.ec.europa.eu/overview.php?v=432_VOC_spec, accessed January 2023.

ECHA, Calcium registration dossier, 2022. https://echa.europa.eu/it/registration-dossier/-/registered-dossier/15400/6/2/1, accessed March 2022.

EFSA (European Food Safety Authority), Conclusion on pesticide peer review regarding the risk assessment of the active substance sulfur. EFSA Scientific Report 221, Vol. 7, Issue 4, 2008, pp. 1-70, DOI: https://doi.org/10.2903/j.efsa.2009.221r.

Fahey D.W., Hegglin M.L., *Twenty questions and answers about the ozone layer: 2010 update, in scientific assessment of ozone depletion: 2010, global ozone research and monitoring project*, report no. 52, 2011, pp 516, WMO, Geneva, Switzerland.

Fantke, P., Evans, J., Hodas, N., Apte, J., Jantunen, M., Jolliet, O., McKone, T.E., 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, 2016, pp. 76-99 (available at: www.lifecycleinitiative.org/applying-lca/lcia-cf/, accessed January 2023).

Fantke, P., Chiu, W.A., Aylward, L. et al. Exposure and toxicity characterisation of chemical emissions and chemicals in products: global recommendations and implementation in USEtox. *Int J Life Cycle Assess,* Vol. 26, 2021, pp. 899–915. DOI: https://doi.org/10.1007/s11367-021-01889-y.

FAOSTAT, Crop - production quantity, 2018, Available at: http://www.fao.org/faostat/en/#data/QC. Accessed September 2022.

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.

Fraser, P., Krummel, P., Dunse, B., Steele, P., Derek, N. and Allison, C. 'DSEWPaC research projects 2010–11'. Centre for Australian Weather and Climate Research, Aspendale, Australia, 2011, pp. 34.

Fraser, P., B. Dunse, P. Krummel, P. Steele, and N. Derek, 'Australian & Global Emissions of Ozone Depleting Substances', 2014, pp. 29.

Frischknecht, R., Braunschweig, A., Hofstetter P., Suter P., Modelling human health effects of radioactive releases in Life Cycle Impact Assessment, *Environmental Impact Assessment Review*, Vol. 20, No. 2, 2000, pp. 159-189.

Forster, P., T. Storelvmo, K. Armour, W. Collins, J. L. Dufresne, D. Frame, D. J. Lunt, T. Mauritsen, M. D. Palmer, M. Watanabe, M. Wild, H. Zhang, 2021, The Earth's Energy Budget, Climate Feedbacks, and Climate Sensitivity. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change [Masson-Delmotte, V., P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu and B. Zhou (eds.)]. Cambridge University Press. In Press. - https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter_07.pdf

Horn, R., Maier, S., LANCA® - Characterization Factors for Life Cycle Impact Assessment, Version 2.5, 2018, Available at: http://publica.fraunhofer.de/documents/N-379310.html, accessed January 2023.

Janssens-Maenhout, Greet; Crippa, Monica; Guizzardi, Diego; Muntean, Marilena; Schaaf, Edwin, Emissions Database for Global Atmospheric Research, version v4.2 FT2012 (time-series). 2014. European Commission, Joint Research Centre (JRC) [Dataset], URL: http://data.europa.eu/89h/jrc-edgar-jrc-edgar_v4-2_ft2010_timeseries, accessed January 2023.

Leclerc, A. S. C., Laurant, A., Personal communication, 2018.

Owsianiak M, Fantke P, Posthuma L, Saouter E, Vijver MG, Backhaus T, Schlekat T, Hauschild MZ., *Global Guidance for Life Cycle Impact Assessment Indicators Volume 2. Chapter 7 Ecotoxicity*, 2019. Downloaded from: https://www.lifecycleinitiative.org/training-resources/global-guidance-for-life-cycle-impact-assessment-indicators-volume-2/.

Posch, M., Seppälä, J., Hettelingh, J.P., Johansson, M., Margni M., Jolliet, O., 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,* Vol. 13, 2008, pp.477–486

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. and 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.

Sala, S., L. Benini, L. Mancini, and R. Pant, 'Integrated Assessment of Environmental Impact of Europe in 2010: Data Sources and Extrapolation Strategies for Calculating Normalisation Factors', *Int J Life Cycle Assess*, Vol. 20, 2015, pp. 1568–1585. DOI: https://doi.org/10.1007/s11367-015-0958-8.

Sala, S., Biganzoli, F., Mengual, E.S., Saouter, E., Toxicity impacts in the environmental footprint method: calculation principles. *Int J Life Cycle Assess,* Vol. 27, 2022, pp. 587–602. DOI: https://doi.org/10.1007/s11367-022-02033-0

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

Saouter E, Biganzoli F, Pant R, Sala S, Versteeg D., Using REACH for the EU Environmental Footprint: Building a Usable Ecotoxicity Database, Part I. *Integr Environ Assess Manag,* Vol. 15, Issue 5, 2019a, pp. 783–795. DOI: https://doi.org/10.1002/ieam.4168.

Saouter E, Wolff D, Biganzoli F, Versteeg D., Comparing Options for Deriving Chemical Ecotoxicity Hazard Values for the European Union Environmental Footprint, Part II. *Integr Environ Assess Manag,* Vol. 15, Issue 5, 2019b, pp. 796-807, DOI: https://doi.org/10.1002/ieam.4169.

Scherer, L., and S. Pfister, 'Modelling Spatially Explicit Impacts from Phosphorus Emissions in Agriculture', *Int J Life Cycle Assess*, Vol. 20, No. 6, 2015, pp. 785–795.

Seppälä, J., Posch, M., Johansson, M., Hettelingh, J.P., Country-dependent Characterisation Factors for Acidification and Terrestrial Eutrophication Based on Accumulated Exceedance as an Impact Category Indicator, *International Journal of Life Cycle Assessment,* Vol. 11, Issue 6, 2006, pp. 403-416.

Smith, C., Nicholls, Z. R. J., Armour, K., Collins, W., Forster, P., Meinshausen, M., Palmer, M.D., Watanabe, M., 7. SM Chapter 7: The Earth's energy budget, climate feedbacks, and climate sensitivity - Supplementary Material, 2021,
https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter_07_Supplementary_Material.pdf

Sprague JB, Logan WJ, Separate and joint toxicity to rainbow trout of substances used in drilling fluids for oil exploration, *Environmental Pollution*, Volume 19, Issue 4, 1979, pp. 269-281, ISSN 0013-9327, DOI: https://doi.org/10.1016/0013-9327(79)90119-8.

Struijs, J., Beusen, A., van Jaarsveld, H. and Huijbregts, M.A.J., Aquatic Eutrophication, Chapter 6, 2009, 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*, 2009 UNEP: UNEP-SETAC Life Cycle Initiative (2016) – Global Guidance for Life Cycle Impact Assessment Indicators. Volume 1.

UNEP: UNEP-SETAC Life Cycle Initiative, *Global Guidance for Life Cycle Impact Assessment Indicators*. Vol. 1, 2016.

US EPA (United States Environmental Protection Agency), Sulfur Registration Eligibility Fact Sheet. US EPA archive document, 1991, available at: https://archive.epa.gov/pesticides/reregistration/web/pdf/0031fact.pdf. Accessed September 2022.

US EPA (United States Environmental Protection Agency), Basic Information about Carbon Monoxide (CO) Outdoor Air Pollution, 2021. https://www.epa.gov/co-pollution/basic-information-about-carbon-monoxide-co-outdoor-air-pollution. Accessed September 2022.

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

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., European characterization factors for human health damage of PM10 and ozone in life cycle impact assessment. *Atmospheric Environment,* Vol. 42, 2008, pp: 441-453.

Vestreng et al., 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, 2006.

Westh TB, Hauschild MZ, Birkved M, Jørgensen MS, Rosenbaum RK, Fantke P., The USEtox story: a survey of model developer visions and user requirements. *Int J Life Cycle Assess,* Vol. 20, 2015, pp. 299–310. DOI: https://doi.org/10.1007/s11367-014-0829-8.

WHO (World Health Organization), Guidelines for drinking-water quality, Health criteria and other supporting information, 2nd ed., Vol. 2, 1996.

World Meteorological Organisation (WMO), Scientific Assessment of Ozone Depletion: 2014, Global Ozone Research and Monitoring Project Report No. 55, Geneva, Switzerland, 2014

List of abbreviations and definitions

AC	Acidification
AR	Assessment Report
CC	Climate Change
CF	Characterisation factor
EC	European Commission
ECOTOX	Ecotoxicity, freshwater
EF	Environmental Footprint
EfF	Effect Factor
EU	European Union
GLAM	Global Life Cycle Impact Assessment Method
HTOX_c	Human toxicity, cancer
HTOX_nc	Human toxicity, non-cancer
LCIA	Life cycle impact assessment
NF	Normalisation factor
NMVOCs	Non-methane volatile organic compounds
PEF	Product Environmental Footprint
POF	Photochemical ozone formation
OEF	Organisation Environmental Footprint
RP	Representative product

List of figures

List of tables

Annex A

Annex I – Synonyms, duplicate and false synonyms.

Table 15 and Table 16 show the synonyms and the duplicates given the same CF in the EF 3.1 update. Source: JRC analysis.

Table 17 shows the false synonyms that were not given the same CF.

Table 15. List of synonyms flows in the EF flow list that were given the same CF in all the impact categories.

Synonym 1	**Synonym 2**
(2z)-1,1,1,4,4,4-hexafluorobut-2-ene	(Z)-HFC-1336
1,1,1,2,2,4,5,5,5-nonafluoro-4-(trifluoromethyl)-3-pentanone	perfluoro-2-methyl-3-pentanone
1,1,2-trifluoro-2-(trifluoromethoxy)ethene	HFE-216
1,1-difluoroethene	HFC-1132a
alpha-cypermethrin	α-cyano-3-phenoxybenzyl [1r-[1α(s*),3α]]-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylate
Carbon tetrachloride	CFC-10
Curium alpha	curium
Decanoic acid, ester with 1,2,3-propanetriol octanoate	Glycerol octanoate decanoate
Dichloromethane	Methylene chloride
d-menthol	Menthol
FC-14	1,6-hexanediyl-bis(2-(2-(1-ethylpentyl)-3-oxazolidinyl)ethyl)carbamate
fluoroethylene	HFC-1141
HCFC-140	Methyl chloroform
HFC-116	PFC-116
HFC-1234yf	PFC-14
HFE-236ea2	1,1,2-Trifluoro-2-(trifluoromethoxy)-ethane
HFC-1234yf	polyhaloalkene
Mecoprop-p	(R)-2-(4-chloro-2-methylphenoxy)propionic acid
Methyl bromide	Halon-1001
PFC-1114	tetrafluoroethylene
PFC-1216	1,1,2,3,3,3-hexafluoroprop-1-ene

PFC-14	FC-14
tin, dioctylbis(2,4-pentanedionato-κo2,κo4)-	tin, dibutylbis(2,4-pentanedionato-ko2,ko4)-

Source: JRC analysis.

Table 16. List of flows that have duplicates in the EF database. The same CF was assigned to all the duplicate.

Flow
3,3,4,4,5,5,6,6,6-nonafluorohex-1-ene
Acrylate, ion
Borate
carbon dioxide (fossil)
carcass meal
Curium alpha
Dichromate
diethyl ether
Dissolved solids
Hydrocarbons, aliphatic, alkanes, unspecified
Hydrocarbons, aliphatic, unsaturated
Lactic acid
methyl 2-hydroxypropanoate
Methylene chloride
municipal solid waste deposition
Nitrogen, organic bound
Noble gases, radioactive, unspecified
Paraffins
particles (> PM10)
Phosphorus
Plutonium-alpha
Radioactive species, alpha emitters
Radioactive species, from fission and activation
Radioactive species, Nuclides, unspecified

Radioactive tailings
Silicon
Silicon
Technetium-99m
Tellurium-123m
tridemorph
Uranium alpha
Yttrium-90
zinc slag (unspecified)

Source: JRC analysis.

Table 17. List of false synonyms (synonyms that have the same name but different CAS and/or EC number) and reason why they were not given the same CF.

Flow	CAS/EC number (1)	CAS/EC number (2)	Reason why they should have different CF
1,3-benzenediamine	541-69-5	108-45-2	In the eCHA website they have different toxicological properties so we consider them different substances.
1,6-hexanediyl-bis(2-(2-(1-ethylpentyl)-3-oxazolidinyl)ethyl)carbamate	925-259-5	411-700-4	In the eCHA website they have different toxicological properties so we consider them different substances.
1-pentene	25377-72-4	109-67-1	In the eCHA website they have different toxicological properties so we consider them different substances.
2,4-dihydroxy-n-(3-hydroxypropyl)-3,3-dimethylbutanamide	81-13-0	16485-10-2	In the eCHA website they have different toxicological properties so we consider them different substances.
3,6-dimethyl-1,4-dioxane-2,5-dione	4511-42-6	95-96-5	In the eCHA website they have different toxicological properties so we consider them different substances.
bis(2-ethylhexyl) but-2-enedioate	141-02-6	142-16-5	In the eCHA website they have different toxicological properties so we consider them different substances.
butene		9003-29-6	There is a duplicate in the sub-compartment "air-indoor". However, this is an error of nomenclature because the correct name for the flow with CAS 9003-29-6 is "butene, homopolymer (products derived from butene)". We added the same CF as "butene, homopolymer (products derived from

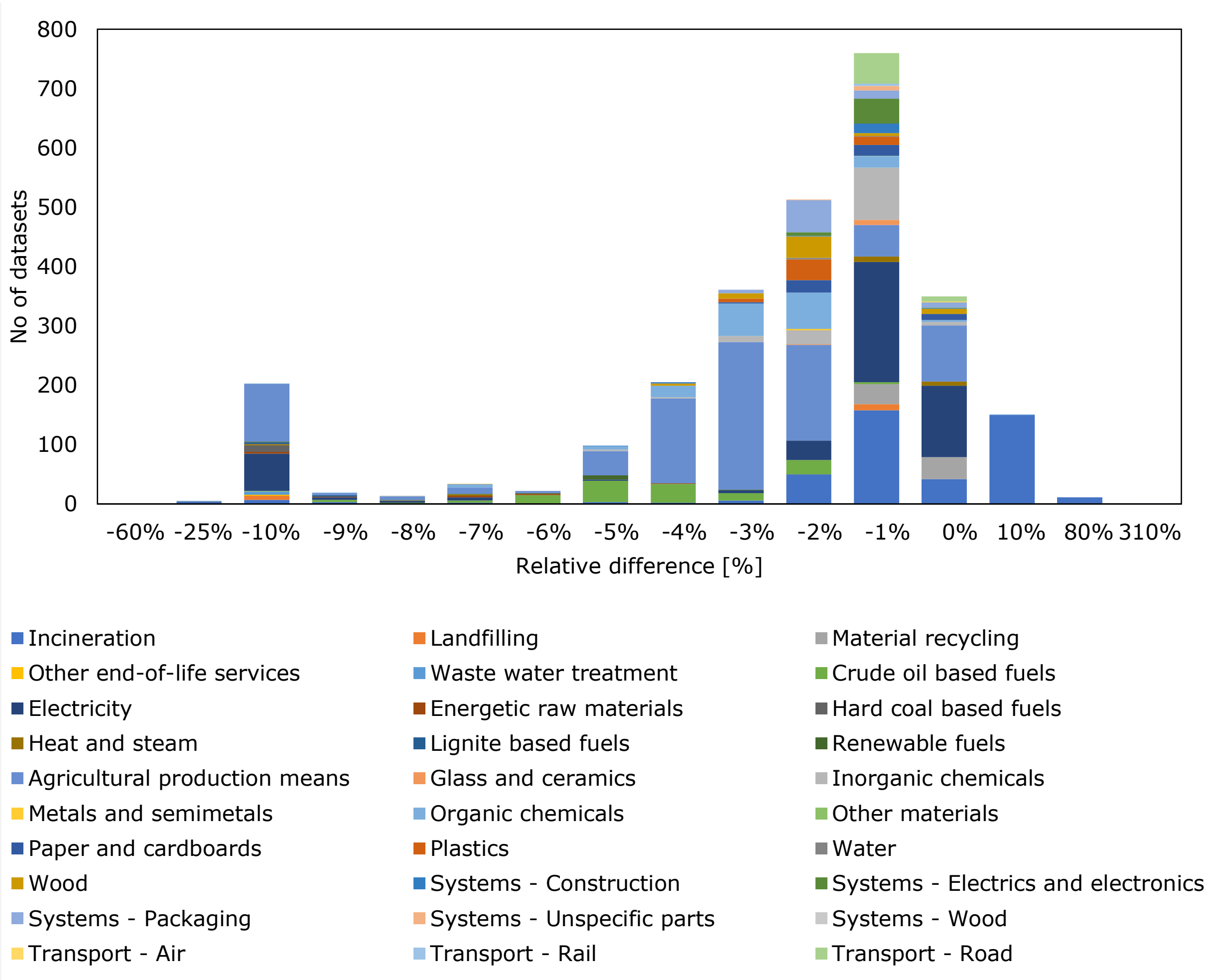
			butene)" to the "butene" having a CAS equal to 9003-29-6.
calcium dihydrogen phosphate	7758-23-8	7757-93-9	In the eCHA website they have different toxicological properties so we consider them different substances.
kresoxim methyl	604-351-6	417-880-0	There are two flows having the same CAS but different EC numbers. "417-880-0" is the active principle.
turpentine	232-350-7	932-349-8	In the eCHA website they have different toxicological properties so we consider them different substances.

Source: JRC analysis.

Annex II - EF3.1 versus EF3.0 per sub-categories.

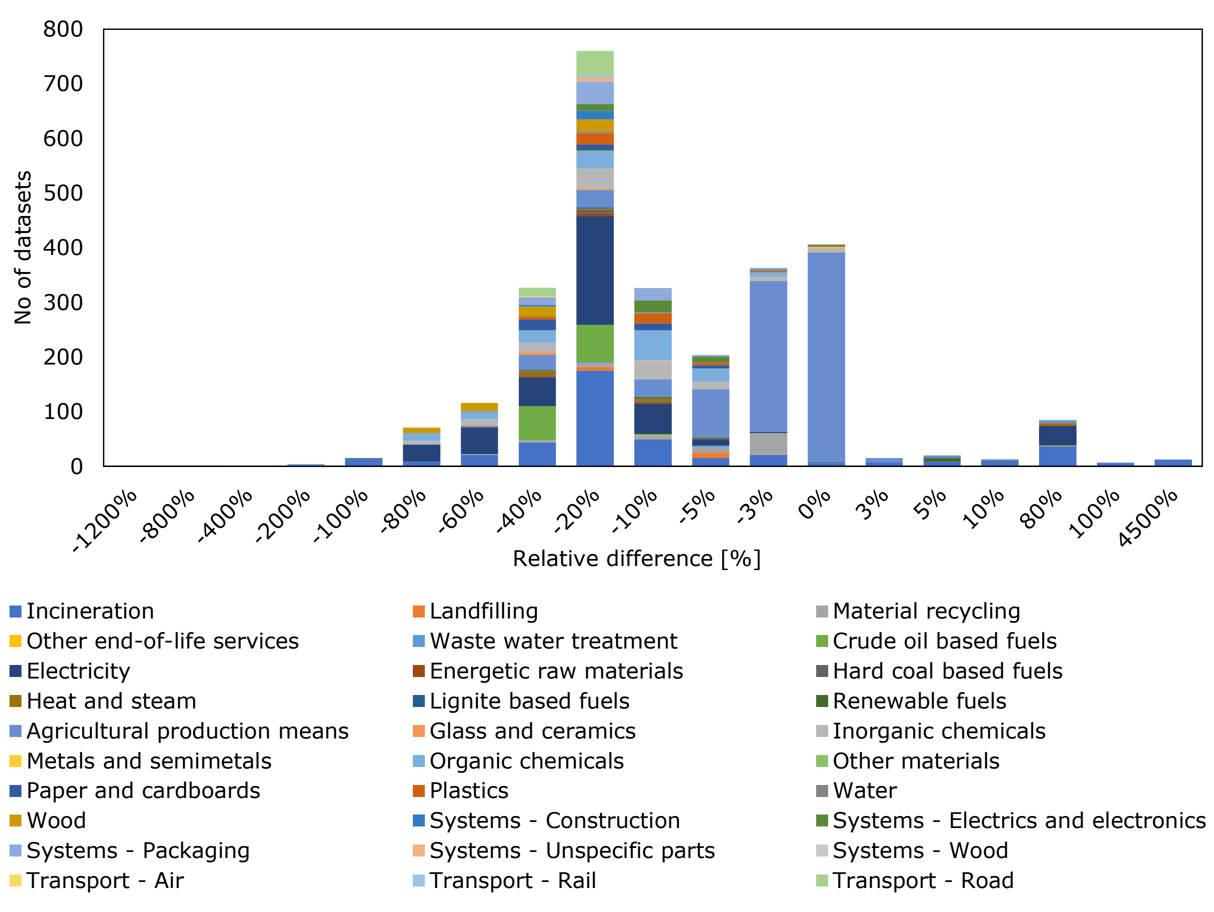
Figure 9, Figure 11, Figure 10, and Figure 12 illustrate how the LCIA results change from EF3.0 to EF3.1 per product sub-categories (described in Table 11) in *Climate Change*, *Human toxicity, non-cancer*, *Ecotoxicity, freshwater*, and in the single overall score.

Figure 9. Relative difference of the *Climate Change* results of the 2752 analysed datasets from the EF database per product sub-category using the EF3.0 and EF3.1 characterisation factors. The relative difference is calculated as (LCIA in EF3.1 – LCIA in EF3.0) / LCIA in EF3.0.



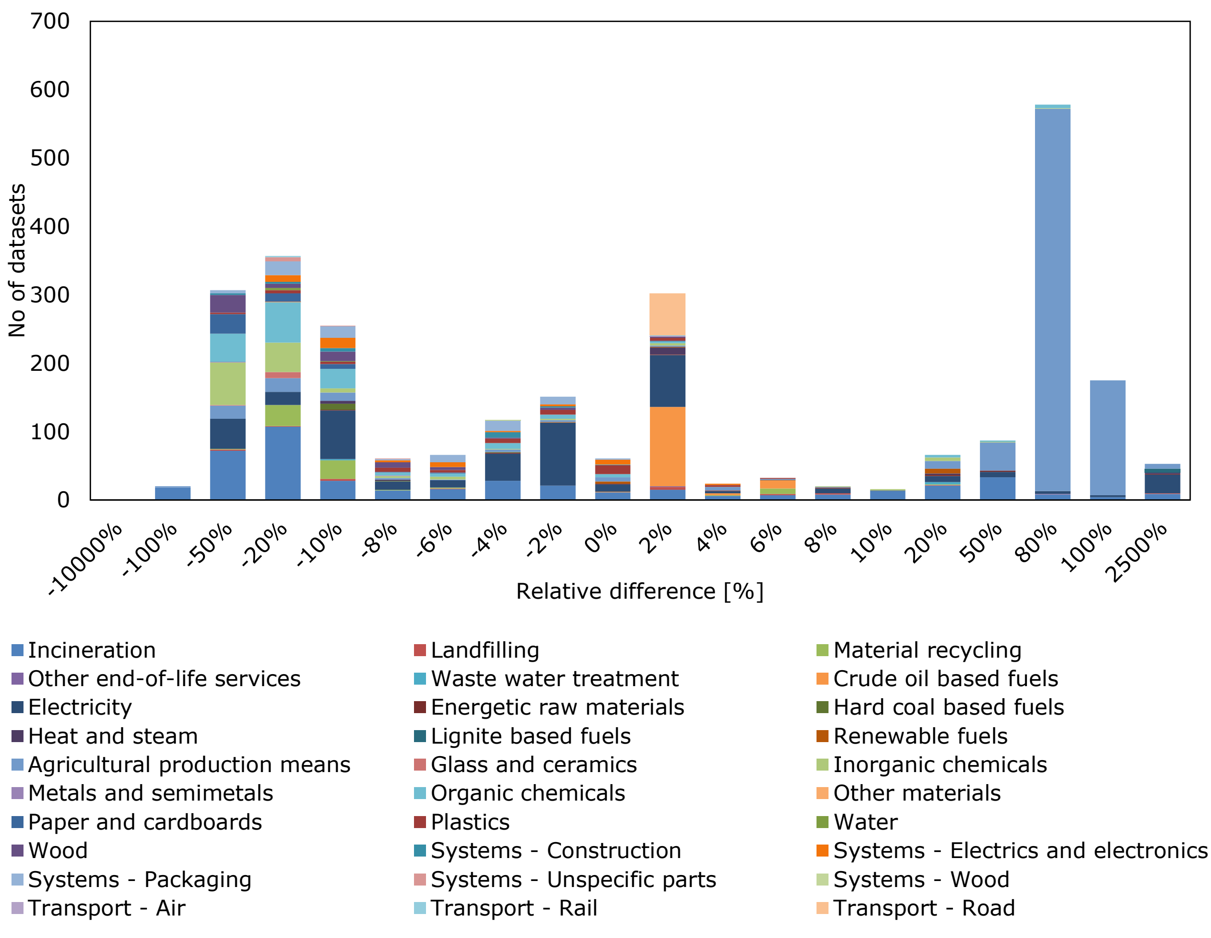
Source: JRC analysis.

Figure 10. Relative difference of the *Human toxicity, non-cancer* results of the 2752 analysed datasets from the EF database per product sub-category using the EF3.0 and EF3.1 characterisation factors. The relative difference is calculated as (LCIA in EF3.1 – LCIA in EF3.0) / LCIA in EF3.0.



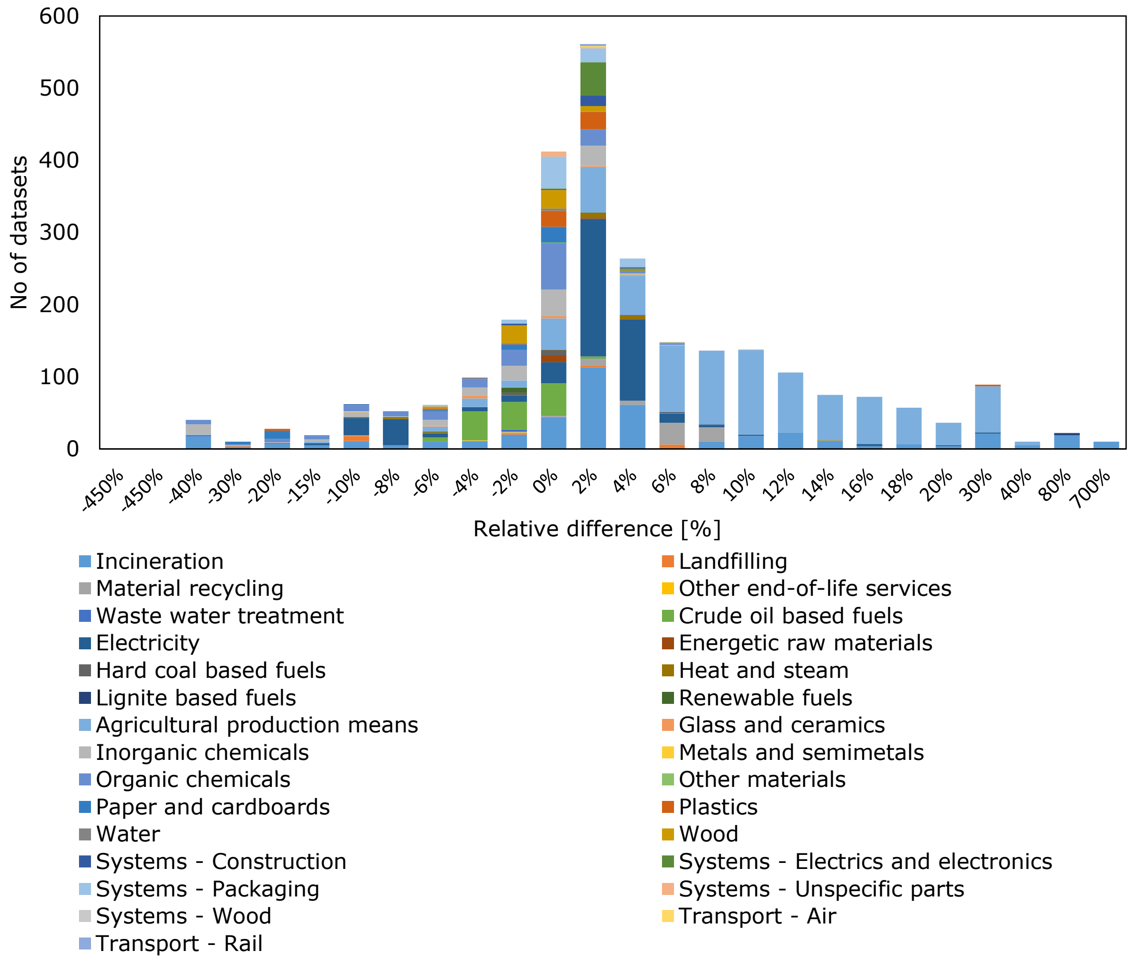
Source: JRC analysis.

Figure 11. Relative difference of the *Ecotoxicity, freshwater* results of the 2752 analysed datasets from the EF database per product sub-category using the EF3.0 and EF3.1 characterisation factors. The relative difference is calculated as (LCIA in EF3.1 – LCIA in EF3.0) / LCIA in EF3.0.



Source: JRC analysis.

Figure 12. Relative difference of the single overall score results of the 2752 analysed datasets from the EF database per product sub-category using the EF3.0 and EF3.1 characterisation factors. The relative difference is calculated as (LCIA in EF3.1 – LCIA in EF3.0) / LCIA in EF.



Source: JRC analysis.

GETTING IN TOUCH WITH THE EU

In person

All over the European Union there are hundreds of Europe Direct centres. You can find the address of the centre nearest you online (european-union.europa.eu/contact-eu/meet-us_en).

On the phone or in writing

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,

— via the following form: european-union.europa.eu/contact-eu/write-us_en.

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 (european-union.europa.eu).

EU publications

You can view or order EU publications at op.europa.eu/en/publications. Multiple copies of free publications can be obtained by contacting Europe Direct or your local documentation centre (european-union.europa.eu/contact-eu/meet-us_en).

EU law and related documents

For access to legal information from the EU, including all EU law since 1951 in all the official language versions, go to EUR-Lex (eur-lex.europa.eu).

Open data from the EU

The portal data.europa.eu provides access to open datasets from the EU institutions, bodies and agencies.

The European Commission's science and knowledge service

Joint Research Centre

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
joint-research-centre.ec.europa.eu

@EU_ScienceHub

EU Science Hub - Joint Research Centre

EU Science, Research and Innovation

EU Science Hub

EU Science

Publications Office of the European Union