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Domestic Footprint of the EU and Member States: methodology and results (2010-2018)

Assessing the environmental domestic impacts of production and consumption activities

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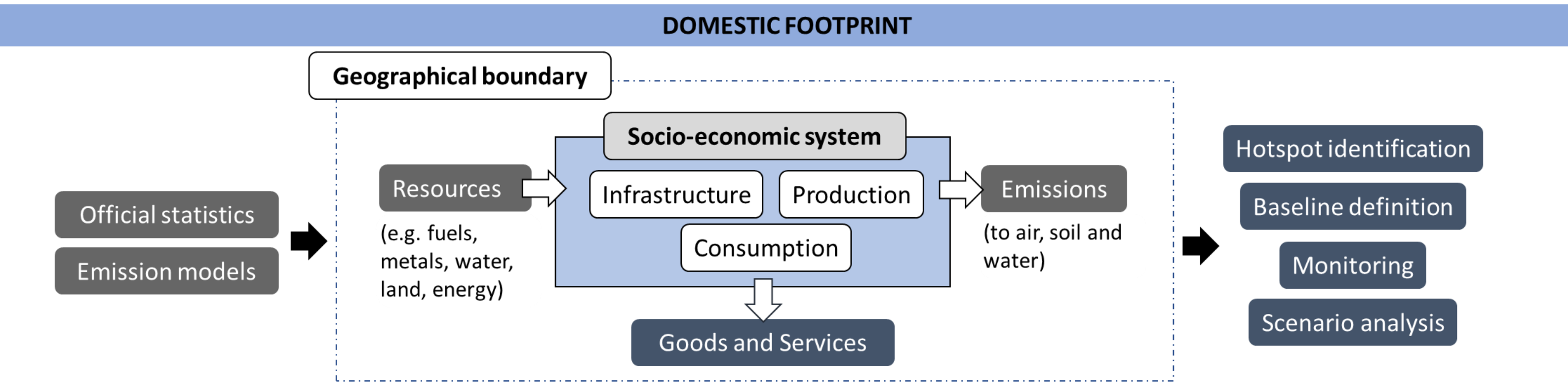
2022



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Contents

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Authors

Esther Sanyé Mengual: technical and scientific development of the report.

Davide Tosches: contribution to chapters 3, 4 and 5; update of Domestic Footprint for the years 2015-2018 and systematic review of Domestic Footprint input data and results.

Serenella Sala: project responsible for the JRC and overall scientific coordinator of the Consumption Footprint project.

Abstract

Towards assessing the environmental domestic impacts of production and consumption activities in the European Union (EU), the Joint Research Centre of the European Commission (EC-JRC) developed the Life Cycle Assessment (LCA)-based Domestic Footprint indicator. The **Domestic Footprint aims at assessing the environmental impacts associated to emissions and resource extraction occurring within a Member State boundary** (or the whole EU boundary) by adopting a production- and territorial-based perspective. Therefore, it accounts for both production and consumption activities taking place within the Member State's domestic territory, e.g., from economic sectors such as industry, agriculture, energy, mining, and services; and also encompass those impacts from households and government's activities (e.g., transport, heating). **It is meant to be used in association with the consumption footprint**, which instead account for the trade-related impacts as well. Both indicators are essential for providing integrated assessment, e.g. in the context of **zero pollution**.

Assessing the Domestic Footprint of individual Member States and the EU allows for identification of environmental hotspots, setting baseline for monitoring of environmental performance progresses and against which testing policy options and scenarios. Domestic footprint focuses exclusively to what is happening within MS boundaries.

The Domestic Footprint builds upon **an extensive and integrated data collection of detailed information of emissions to the environment (air, water and soil) and resource extraction** within the EU and Member State boundaries. This results into a comprehensive inventory of the environmental pressures due to domestic production and consumption. This inventory is then characterized with the Environmental Footprint (EF reference package 3.0), including 16 environmental impact categories which can be presented as individual impacts as well as normalised and weighted into a single score.

This report, building upon previous JRC studies, expands the assessment and details the updated methodological approach for the data collection of the Domestic Footprint indicator for each impact category. The exercise entailed a systematic review of data sources and collected data. Furthermore, the assessment of the **Domestic Footprint at both the EU and Member States level for the period 2000-2018** is presented, including an analysis of the decoupling of environmental impacts from economic growth and the assessment of the domestic footprint against the Planetary Boundaries (PBs).

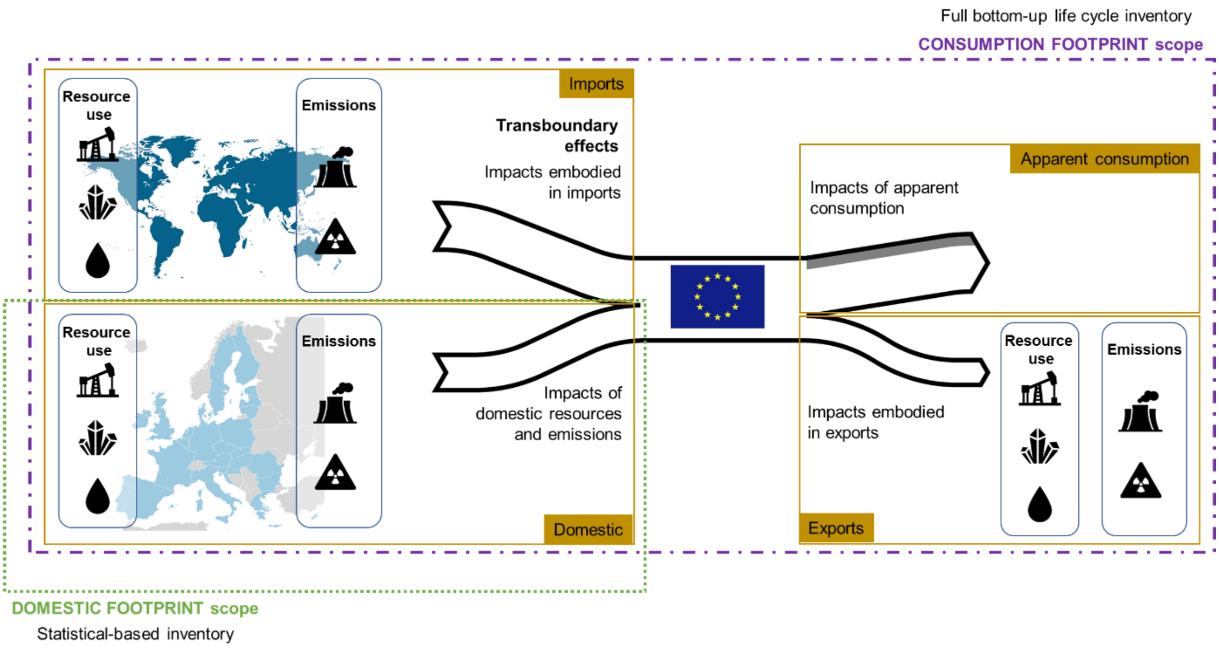
The EU Domestic Footprint showed a steady decrease for the period 2000-2018, confirming an absolute decoupling of domestic environmental impacts from economic growth. Most of the impact categories also showed absolute decoupling for this period, barring mineral resource use and land use which increased along time although at a slower pace than the Gross Domestic Product (GDP), leading to relative decoupling. Considering an absolute sustainability perspective, **the EU Domestic Footprint transgresses the PBs on climate change and particulate matter (being both in the high-risk area), and the PB regarding fossil resources (being in the uncertainty area).** Member States showed a different contribution to the EU Domestic Footprint and to the different impact categories. The role of individual countries and their differences in impact per capita depended on the level of economic growth, the technological context (e.g., energy technologies and electricity market) and the availability of natural resources. Three impact categories contributed the most to the EU Domestic Footprint single score: climate change, particulate matter and human toxicity, non-cancer. An analysis at the elementary flow level (i.e. environmental pressures) unveiled that: i.) several impact indicators are driven by a few environmental pressures (i.e., resources used, or substances emitted to the environment), ii.) some environmental pressures contribute to diverse environmental impacts (such as NOx contributing to acidification, eutrophication marine, particulate matter), and iii.) some environmental pressures are resulting from the same anthropic activities (e.g., agricultural production, combustion of fossil fuels).

1 Introduction

Towards assessing the environmental impacts of domestic production and consumption activities, the Joint Research Centre of the European Commission (EC-JRC) developed the Life Cycle Assessment (LCA)-based Domestic Footprint indicator. The goal of this indicator is to monitor the environmental impacts of EU and Member States domestic activities along time and the efforts of EU Member States to their domestic environmental impacts from economic growth. Furthermore, the environmental impacts of domestic activities can be assessed against the Planetary Boundaries (PBs) towards identifying the current situation in relation to the ecological limits of our planet.

This indicator was developed together with the Consumption Footprint indicator. Figure 1 details the differences in scope and methodological approach of the Domestic Footprint and Consumption Footprint indicators. On one hand, the coverage of the Domestic Footprint indicator is limited to domestic activities taking place within the EU, while the Consumption Footprint assesses also the impact associated to the trade flows (imports and exports) to evaluate the apparent consumption. On the other hand, the Domestic Footprint compiles an inventory of statistical data, whereas the Consumption Footprint is a full bottom-up life cycle inventory based on the model of representative products.

Figure 1: Scope and methodological approach of the Domestic Footprint and Consumption Footprint indicators.



The Domestic Footprint aims at assessing the environmental impacts associated to emissions and resource extraction occurring within a Member State boundary (or the whole EU boundary) by adopting a production- and territorial-based perspective. Assessing the environmental impacts of domestic activities can support the monitoring of policy implementation and their effect on the territory (Sanyé-Mengual et al., 2019). An overview of the indicator and the policy uses is provided in Chapter 2.

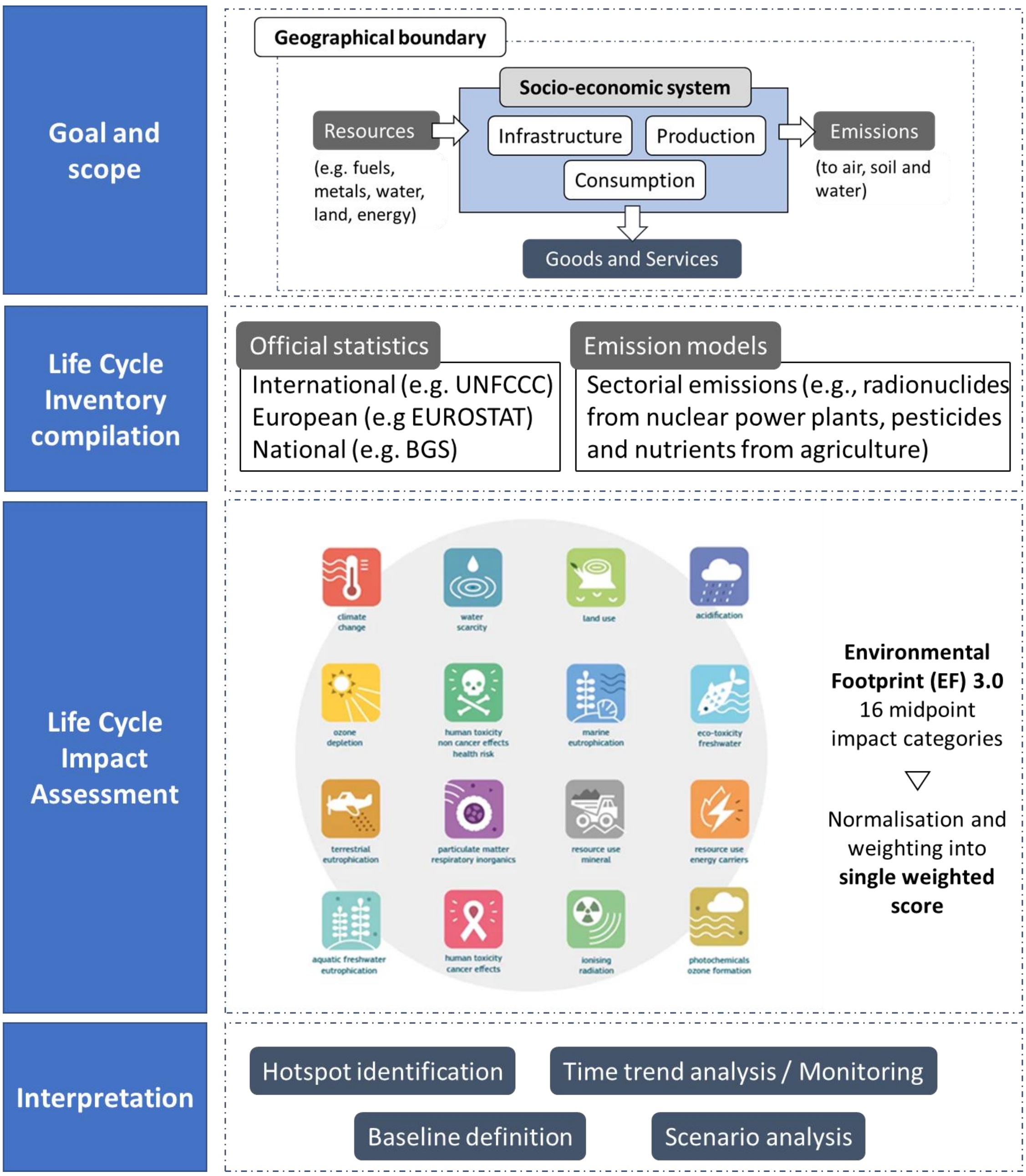
The Domestic Footprint builds upon an extensive data collection of detailed information on resource extraction and emissions to the environment in the EU territory (Chapter 3). This report details the methodological approach for the data collection in the Domestic Footprint for each impact category (Chapter 4). The methodology elaborates on previous JRC works on the Domestic Footprint of the EU and Member States. Sala et al. (2014, 2015) evaluated the EU-27 Domestic Footprint for the period 1990-2010. Sala et al. (2019) assessed the EU-28 Domestic Footprint for the period 2000-2014, including an update for 2011-2014 and the inclusion of Croatia. The present document further extended the data compilation for the period 2015-2018 towards assessing the Domestic Footprint of EU-28[1] and individual Member States for the timeframe 2000-2018 (Chapter 5), which included a systematic review of compiled data.

[1] The assessment has been performed for EU-28, i.e. including United Kingdom, as the timeframe evaluated is 2000-2018.

2 The Domestic Footprint

The Domestic Footprint aims at assessing the environmental impacts associated to emissions and resource extraction occurring within a Member State boundary (or the whole EU boundary) by adopting a production- and territorial-based perspective (Figure 1). Therefore, it accounts for both production and consumption activities taking place within the Member State's domestic territory, e.g., from economic sectors such as industry, agriculture, energy, mining, and services; and also encompasses those impacts from households and government's activities (e.g., transport, heating). The geographical scope of the Domestic Footprint is both the EU and Member States level. The present assessment covers the period 2000-2018.

Figure 2: Overview of the Domestic Footprint: goal and scope, Life Cycle Inventory (LCI) compilation, Life Cycle Impact Assessment (LCIA), and Interpretation.



The Domestic Footprint is a comprehensive collection of data on resource use (e.g., minerals and metals, energy carriers, land use, water use) and emissions to air (e.g., greenhouse gases, particulate matter), water (e.g., nitrogen, phosphorous) and soil (e.g., heavy metals, pesticides) taking place in the territory complemented by emission estimates based on modelling. This collection results in a Life Cycle Inventory (LCI) and includes an exhaustive list of environmental pressures resulting from domestic activities.

Environmental pressures are then translated into environmental impacts through the implementation of the Environmental Footprint 3.0 (EF reference package 3.0) method (EC-JRC, 2018; Fazio et al., 2018) in the Life Cycle Impact Assessment (LCIA) stage. The EF 3.0 method includes 16 impact categories (Table 1), which can be normalized and weighted for their aggregation into a single weighted score. Normalization Factors (NFs) correspond to the EF global NFs[2] (adapted from Crenna et al., 2019), while Weighting Factors (WFs) of the EF weighting set (Sala et al., 2018) are employed in this study. Finally, the assessment against PBs as absolute ecological thresholds (Rockström et al., 2009; Steffen et al., 2015) is performed by employing the LCIA-based PBs developed for the EF 3.0 framework (Sala et al., 2020).

Assessing the Domestic Footprint of individual Member States and the EU allows for several analysis that can support policies, such as:

- Monitoring: yearly updates of the indicator allow tracking the evolution of impacts associated with changes in production and consumption patterns within Member States boundaries. This may be strategic for monitoring e.g.,:
    - how much the EU is decoupling environmental impacts from economic growth,
    - the benefits of transition towards circular economy,
    - the ability of the EU to remain within planetary boundaries
    - as well as progress related to the UN Sustainable Development Goals (SDGs) (especially SDG12 on responsible consumption and production) (UN, 2015).
- Identification of environmental hotspots: identification of most contributing pressures (emissions or resources) to the environmental impacts e.g. towards reaching environmental targets. This can be performed at multiple levels:
    - elementary flows (resource use, emissions to the environment) to a specific environmental impact,
    - identifying the environmental impacts beyond the planetary boundaries requiring more urgent action.
- Setting a baseline for monitoring and against which testing policy options and scenarios: the Domestic Footprint sets a baseline for monitoring purposes of domestic impacts or for assessing scenarios based on, e.g., modelling exercises, such as expected effect of circular economy on resources use and climate change emissions.

In this context, this indicator can support current EU policy ambitions, such as sustainable food production (Farm to Fork Strategy[3]), biodiversity conservation (EU Biodiversity Strategy for 2030[4]), circular economy (Circular Economy Action Plan[5]), and zero pollution (Chemical Strategy for Sustainability[6], Zero Pollution Action Plan[7]). Specifically in support to the latter, the Domestic footprint represents an integrated indicator (and platform) embracing a number of emissions to air, soil, and water, resulting from a multiplicity of sources. The 16 impact categories indicates the potential environmental impacts occurring as result of all the accounted emissions.

[2] Updated normalization factors are available in: https://eplca.jrc.ec.europa.eu/EFtransition.html
[3] A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system. COM/2020/381 final.
[4] Biodiversity Strategy for 2030: Bringing nature back into our lives. COM/2020/380 final.
[5] A new Circular Economy Action Plan: For a cleaner and more competitive Europe. COM/2020/98 final.
[6] Chemicals Strategy for Sustainability: Towards a Toxic-Free Environment. COM/2020/667 final.
[7] Pathway to a Healthy Planet for All. EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil' COM/2021/400

Table 1: Summary of the impact categories used in EF3.0: abbreviation, unit, underpinning impact assessment model, global normalisation factor (NF), weighting factor (WF) and the current level of regionalisation of the impacts

Impact category	**Abbreviation**	**Unit**	**Impact assessment model**	**Global NF**	**WF**	**Regionalisation level**
Climate change	CC	kg CO_2 eq	Intergovernmental Panel on Climate Change (IPCC, 2013)	5.58E+13	21.06	Global
Ozone depletion	ODP	kg CFC-11 eq	World Meteorological Organisation (WMO, 2014)	3.70E+08	6.31	Global
Human toxicity, cancer	HTOX_c	CTUh	Based on USEtox2.1 model (Fantke et al., 2017), adapted as in Saouter et al. (2018)	1.91E+05 (a)	2.13	Global
Human toxicity, non-cancer[8]	HTOX_nc	CTUh	Based on USEtox2.1 model (Fantke et al., 2017), adapted as in Saouter et al. (2018)	1.74E+07 (a)	1.84	Global
Particulate matter	PM	disease incidences	Fantke et al. (2016); UNEP (2016)	4.11E+06	8.96	Global
Ionising radiation	IR	kBq U^{235} eq.	Frischknecht et al (2000) (as developed by Dreicer et al., 1995)	2.91E+13 (a)	5.01	Global
Photochemical ozone formation	POF	kg NMVOC eq.	Van Zelm et al. (2008), as applied in ReCiPe 2008 (Goedkoop et al., 2013)	2.82E+11	4.78	Global
Acidification	AC	mol H^+ eq	Seppälä et al. (2006); Posch et al. (2008) (Goedkoop et al., 2013)	3.83E+11	6.20	Country
Eutrophication, terrestrial	TEU	mol N eq	Seppälä et al. (2006); Posch et al. (2008) (Goedkoop et al., 2013)	1.22E+12	3.71	Country
Eutrophication, freshwater	FEU	kg P eq	Struijs et al. (2009) as applied in ReCiPe 2008 (Goedkoop et al., 2013)	1.11E+10	2.80	Global
Eutrophication, marine	MEU	kg N eq	Struijs et al. (2009) as applied in ReCiPe 2008 (Goedkoop et al., 2013)	1.35E+11	2.96	Global
Land use	LU	pt	Soil quality index based on an updated LANCA model (De Laurentiis et al., 2019) and on the LANCA CF version 2.5 (Horn and Meier, 2018)	5.65E+15	7.94	Country
Ecotoxicity freshwater	ECOTOX	CTUe	Based on USEtox2.1 model (Fantke et al., 2017), adapted as in Saouter et al. (2018)	8.51E+14 (a)	1.92	Global
Water use	WU	m^3 water eq	Boulay et al. (2018); UNEP (2016)	7.91E+13	8.51	Country
Resource use, fossil	FRD	MJ	van Oers et al. (2002)	4.48E+14	8.32	Global
Resource use, minerals and metals	MRD	kg Sb eq	van Oers et al. (2002)	4.39E+08	7.55	Global

(a) The NFs from Crenna et al. (2019) have been revised and updated for these impact categories. Further refinements are ongoing to ensure the best alignment with the UN life cycle initiative working group of GLAM on normalisation. Updates will be available at https://eplca.jrc.ec.europa.eu/EFtransition.html

[8] The list of elementary flows of the EF 3.0 reference package was edited for this impact category by excluding the CF provided for carbon monoxide, as will be in the forthcoming version of the method.

3 Overview of data sources

The inventory of resources domestic extraction[9] and emissions to the environment of the Domestic Footprint gathers data from different sources: mainly official statistics, emissions reports, and emission models. Data sources include international, European and national organizations, such as the United Nations Convention on Climate Change (UNFCCC), Eurostat or the British Geological Survey (BGS). A complete overview of the data sources is reported in Table 2, by impact category and substance group.

A hierarchical approach is applied to the selection of the dataset to be used for building the domestic inventory when different sources were available for the same data, following the guidance on data selection proposed by Sala et al. (2015). In decreasing importance, data have been selected as follows:

1. Officially reported data provided by EU and international bodies (Eurostat, FAO, OECD, BGS), based on agreed models, methods and standards, with documented metadata and periodical quality checks. Datasets already used in EU monitoring and policy making (e.g. IPCC, EEA based on EMEP, Eurostat, E-PRTR) and providing consistent time-series were preferred;

2. Activity-based estimations, derived as "activity data * emission factor". Activity data were taken from officially reported data, emission factors were based on scientific literature, grey literature (e.g. sectorial reports), and available life cycle inventories (LCIs);

3. Statistical proxies (time, flows) when the correlation is statistically significant. When possible, consistency rules are applied (e.g. the sum of the estimated relative shares must sum-up to 1);

4. Speculative assumption(s). Assumptions are based on reasonable correlation and/or cause-effect models, not statistically tested. Very often this strategy is used for filling-in punctual data gaps (e.g. figure available for 2009 and not for 2010, without evident underlying trend).

Table 2: List of data sources by impact category and substance group.

Impact category	**Substance groups**	**Data sources**
Climate Change (CC)	Greenhouse gases (GHGs) both from direct emissions and those associated to LULUCF (land use, land-use change and forestry); Perfluorinated compounds (PFCs); Hydrofluorocarbons (HFCs); Sulfur hexafluoride (SF_6)	- UNFCCC (2020)
	CFCs; Hydrochlorofluorocarbons (HCFCs)	- Linear extrapolation based on 2000-2010, from Sala et al. (2014)
Ozone Depletion (ODP)	CFCs; HCFCs	- Linear extrapolation based on 2000-2010, from Sala et al. (2014) -EDGAR (EC-JRC&PBL, 2011)
Human toxicity cancer (HTOX_c), Human toxicity, non-cancer (HTOX_nc) and Ecotoxicity freshwater (ECOTOX)	Air emissions: Heavy metals (HMs) Organics non-NMVOC (non-methane volatile organic compounds), dioxins, Polycyclic-aromatic hydrocarbons (PAHs), Hexachlorobenzene (HCB), etc. Releases to water: Industrial releases of HMs + organics Urban wastewater treatment plants (HMs + organics) Releases to soil: Industrial releases (HMs, Persistent Organic Pollutants (POPs) Sewage sludge (containing organics and metals) Manure Pesticides: Active ingredients (AI) breakdown (i.e., disaggregated into EU countries and major types of crops) combined with dosage statistics. Pharmaceuticals: emissions to water estimated from national sales.	Based on Leclerc et al. (2019), which was relying on the following sources: - E-PRTR (2020) - Waterbase (EEA, 2020) - FAOSTAT (2020) - Kuczyński et al. (2005) - Hamscher et al. (2005) - EC (2010b) - Eurostat (2007) - Substance-specific literature
Particulate matter (PM)	NO_x; NH_3; SO_2; PM_{10}; $PM_{2.5}$; CO	- EMEP/CEIP (2020)

[9] Resource extraction refers to the extraction of abiotic resources (i.e., fossils, minerals and metals) without considering any import. For land use and water use impact categories, domestic extraction is considered as use of the resource.

Ionising radiation (IR)	Emissions of radionuclides: - to air and water from electricity generation from nuclear sources, - to air and water from nuclear spent-fuel reprocessing - to air from crude oil in the energy mix supply - to air from combustion of coal - to air and water from end of life of gypsum - to seawater from non-nuclear activities	- UNSCEAR (2016); PRIS (2020); - RADD (2020); UNSCEAR (2016) - EF dataset (EC-JRC, 2017); Eurostat(2020a) - Eurostat(2020b) - Eurostat (2020c) - OSPAR (2020)
Photochemical ozone formation (POF)	NMVOC as aggregated; NO_X, CH_4; CO	- EMEP/CEIP (2020)
	NMVOC breakdown	- Laurent & Hauschild (2014)
Acidification (AC)	NO_x; SO_2; NH_3	- EMEP/CEIP (2020)
Eutrophication, Terrestrial (TEU)	NO_x; NH_3	- EMEP/CEIP (2020)
Eutrophication, freshwater (FEU)	Phosphorous (total) to soil and water, from agriculture	- Eurostat (2020d) for phosphorous input and output data; UNFCCC (2020) for nitrogen input; FAOSTAT (2020) for cultivated cereal surfaces - Bouwman et al. (2009) 10% loss of phosphorous to water as global average
	Phosphorous (total) to soil and water, from sewages	- Van Drecht et al (2009): Removal efficiency of phosphorous - RPA (2006): Use of laundry and dishwater detergents and Fraction of Phosphorous-free laundry detergent - Eurostat (2020e): Share of people connected to wastewater treatment plants (WWTPs)
Eutrophication, marine (MEU)	NO_x; NH_3	- EMEP/CEIP (2020)
	Nitrogen (total) to water, from agriculture	- UNFCCC (2020): Nitrogen total input data, losses to water and to air, synthetic fertilizers manure - Nitrogen output based on ratios (by country, by year) between Input and Output by Eurostat (2020d), multiplied to Inputs from UNFCCC (2020)
	Nitrogen (total) to soil and water, from sewages	- FAOSTAT (2020): Protein intake - Van Drecht et al. (2009): Removal efficiency of Nitrogen - Eurostat (2020e): Share of people connected to WWTP
Land use (LU)	“Land occupation” and “land transformation”: forest, cropland, grassland, settlements, wetlands, unspecified	- UNFCCC (2020)
Water use (WU)	Gross freshwater abstraction & Gross water consumption	- Eurostat (2020f) - WaterGAP: (Müller Schmied et al., 2014)
Resource use	Minerals and metals (MRD)	-BGS (2020); USGS (2020); WMD (2020) Euromines (2020)
	Fossils (FRD)	- Eurostat (2020g)

4 Detailed methodology per impact category

This section details the data collection method for all the elementary flows considered in the Domestic Footprint, by each impact category of the EF 3.0 method. In the LCA domain, the term "**elementary flow**" is used to identify each of the environmental pressures of a LCI, which include both resource extraction and emissions to the environment.

4.1 Climate Change (CC)

For the Climate Change (CC) impact category, data on emissions to air of substances with global warming potential were collected (Table 3). The included substances were carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), nitrogen trifluoride (NF_3), sulphur hexafluoride (SF_6) and perfluorinated compounds (PFCs). Data were collected from the annual National Inventory Submissions of the United Nations Framework Convention on Climate Change (UNFCCC) (2020), which is provided at country level.

Regarding CO_2, CH_4 and N_2O, emissions were retrieved considering the differentiation by emission source (i.e., fossil, biogenic and land transformation emissions), in alignment to the level of detail in the EF 3.0 impact assessment model (IPCC, 2013). Data elaborations were required for the emissions of NF_3, SF_6 and PFCs. These substances were reported in UNFCC data as kg CO_2 equivalent and were converted to mass (kg of substance) based on the characterisation factor (CF) reported by IPCC (2013), according to the elaboration described in Sala et al. (2014)[10].

The inventory value of these substances for a given country and year (Inventory value$_{i,c,y}$) was calculated as follows (Equation 1):

$$Inventory\ value_{i,c,y}(kg\ susbtance_i) = \frac{UNFCCC_{i,c,y}(kg\ CO_2 eq.)}{CF_i\left(\frac{kg\ CO_2 eq.}{kg\ susbtance_i}\right)} \quad \text{[Eq. 1]}$$

With regard to substances with both global warming and ozone depletion potential (i.e., HCFC and CFCs), data compilation is detailed in section 4.2. Other minor substances with global warming potential (e.g. chlorinated compounds as dichloromethane) come from inventory of toxicity.

The final inventory covers 22 substances out of 212 for which a CF is available in EF 3.0. In the case of PFCs, data were collected although no CF is currently available in EF 3.0. Emissions compiled for the climate change category were reported as "emissions to air, unspecified".

Table 3: Substances, data source, data elaboration requirements and presence of a corresponding CF in the EF 3.0 method for climate change retrieved from UNFCCC.

Substance	**Source**	**Data elaboration**	**CF in the EF3.0**
Carbon Dioxide (CO_2)	UNFCCC	No elaboration performed	Yes. Fossil, biogenic and land use
Methane (CH_4)	UNFCCC	No elaboration performed	Yes. Fossil, biogenic and land use
Nitrous Oxide (N_2O)	UNFCCC	No elaboration performed	Yes.
Nitrogen Trifluoride (NF_3)	UNFCCC	Converted in kg of NF_3 from kg CO_2 equivalent (CF = 17200)	Yes
Sulphur Hexafluoride (SF_6)	UNFCCC	Converted in kg of SF_6 from kg CO_2 equivalent (CF = 22800)	Yes
Perfluorinated compounds (PFCs)	UNFCCC	Converted in kg of PFCs from kg CO_2 equivalent (CF = 7610)	No

4.2 Ozone Depletion (ODP)

For the Ozone Depletion (ODP) impact category, data on emission to air of substances with ozone depleting potential were collected (Table 4). The inventory included emissions of chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs). Data were retrieved from the Emissions Database for Global Atmospheric Research (EDGAR) v4.2 (EC-JRC & PBL, 2011) for years 2000-2010.

[10] Note that the CF of SF_6 was updated in this study, according to IPCC (2013).

Since data were not available from 2011, linear extrapolation was implemented to fill data gaps for years 2011-2018. Note that when the linear regression leads to negative values, gaps were filled with zeros. For CFC-11 and CFC-12, some countries had incomplete time series for 2000-2010 and was impossible to perform a meaningful linear extrapolation to fill data gaps after these years (i.e., 2011-2018). In these cases, missing values were filled with 0, in alignment with previous assessments (Sala et al., 2019). The countries with incomplete time series were the following:

- for CFC-11 and CFC-12: Czech Republic, Hungary, Lithuania, Luxembourg, Poland and Romania.
- for CFC-12: Germany, Denmark, Estonia Greece, Malta and Sweden.

Data were limited to 2000-2010 also for HCFC-141b and HCFC-142b. In this case, time series of all countries were complete, and no data gap filling was required in the original time series. Linear extrapolation was implemented for the following years (i.e., 2011-2018). Since the trend showed high variability for some countries, no extrapolation was performed and the last available value was used as a proxy, consistently with the procedure used in the previous assessment (Sala et al., 2019). The countries for which a proxy was used were:

- for HFCF-141b: Belgium, Denmark, Finland, France, Luxembourg, Sweden, United Kingdom.
- for HFCF-142b: Austria, Belgium, Denmark, Germany, Greece, Spain, Finland, France, Ireland, Italy, Luxembourg, Malta, Netherlands, Portugal, Sweden, United Kingdom.

The final inventory includes 4 substances out of 25 covered in the EF 3.0 impact assessment model (WMO, 2014). Emissions compiled for the ODP category are reported as emissions to air, unspecified.

Table 4: Substances, data sources, and elaboration requirements and presence of a corresponding CF in the EF 3.0 method for Ozone Depletion.

Substance	**Source**	**Data elaboration**	**CF in the EF3.0**
CFC-11	EDGAR	Data available for 2000-2010, with gaps filled with 0. Linear extrapolation for 2011-2018 with 0 for negative values.	Yes
CFC-12	EDGAR	Data available for 2000-2010, with gaps filled with 0. Linear extrapolation for 2011-2018 with 0 for negative values.	Yes
HFCC-141b	EDGAR	Linear extrapolation from 2000-2011. Last year used as a proxy when extrapolation was impossible.	Yes
HFCC-142b	EDGAR	Linear extrapolation from 2000-2011. Last year used as a proxy when extrapolation was impossible.	Yes

4.3 Human toxicity, cancer (HTOX_c); human toxicity, non-cancer (HTOX_nc); and freshwater ecotoxicity (ECOTOX)

The impact categories addressing both human toxicity and ecotoxicity include a large number of emissions of chemicals to the environment (air, water, and soil). Since toxic emissions originate from different type of human activities, several sources were used for the creation of the inventories of toxicity-related impact categories. The inventory included emissions from the following sources:

- Emissions from industrial activity
- Emissions from household activity
- Emissions from manure
- Emissions from sewage sludge
- Emissions due to pesticides use
- Emissions due to pharmaceuticals use

Inventories for all Member States were built using the procedure described in Leclerc et al. (2019), which have been summarized in the following sections.

The overall inventory included 537 substances, which are detailed in Annex 1 (Table A-2 and Table A-3), 437 of them have a CF in EF3.0 (which includes a total of 6603 substances with CF) (Saouter et al., 2018). A list of substance groups, environmental compartment and data source by emission source is provided in Table 5.

Table 5: Emission source, type of substances, environmental compartments and data sources considered for elementary flows regarding toxicity impact categories. Calculations are detailed in the next sections.

Emission source	**Substance groups**	**Environmental compartment**	**Data source**
Industrial activity	Chlorinated organic substances, Pesticides, other gases, Heavy metals (HMs)	Air, water, and soil	E-PRTR (2020)
Household activity	HMs, organic substances	Water	EEA (2020)
Manure	HMs, veterinary drugs	Soil	Kuczyński et al. (2005)
Sewage sludge	HMs	Soil	Calculation based on Eurostat (2020j), EC (2010b)
Pesticides use	Pesticide	Air, water and soil	Calculation based on Eurostat (2007 2020k)
Pharmaceuticals use	Pharmaceuticals	Water	Calculation based on multiple sources

4.3.1 Emissions from industrial activity

For emissions deriving from industrial activities, data were retrieved from the European Pollutant Release and Transfer Register (E-PRTR) database (2020). The database reports the emissions into air, water, and soil of companies subject to the Industrial Emission Directive (EC, 2010a). The reported emissions in the E-PRTR database were collected by country, year and economic sector according to the NACE classification (Statistical classification of economic activities in the European Community). Several data gaps were found both in terms of time and country coverage.

As a result, a data gap filling process was followed (Figure 3) in two cases:

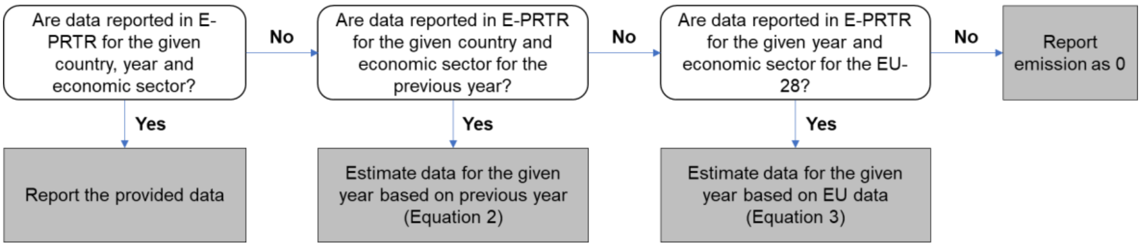
- Case 1: Missing data for specific years for a given country with available data for previous year. When data were reported for the previous year and for the same sector of the data gap, this value was used to estimate the emission based on the proportional variation of the annual economic output of the sector (Equation 2). Economic output data by sector were retrieved from Eurostat (2020h).

$$Emission\ from\ economic\ sector\ A_{i,c,y} = Emission\ from\ economic\ sector\ A_{i,c,(y-1)} * \frac{Economic\ output\ A_{i,c,(y)}}{Economic\ output\ A_{i,c,(y-1)}} \quad \text{[Eq. 2]}$$

- Case 2: Missing data for specific years for a given country without available data for previous year. When no emissions were declared for a given economic sector in the previous year, the EU average value for the year was used to estimate the emission based on the proportional economic output of the sector in the EU and in the considered Member State (Equation 3). Economic output data by sector were retrieved from Eurostat (2020h).

$$Emissions\ from\ economic\ sector\ A_{i,c,y} = Emission\ from\ economic\ sector\ A_{i,EU28,y} * \frac{Economic\ output\ A_{i,c,y}}{Economic\ output\ A_{i,EU28,y}} \quad \text{[Eq.3]}$$

Figure 3: Data gap filling process for industrial emissions.



4.3.2 Emissions from household activity

Household activity can lead to emissions of toxic substances to water, which can be released after wastewater treatment (WWT) to the environment. Data on these emissions were collected from the E-PRTR database. However, emissions from household activity can also occur due to untreated urban wastewater, unconnected dwellings to WWT, and run-off and storm overflows. E-PRTR data were therefore complemented with these emissions with data from the Waterbase (EEA 2020), an EEA database which collects information on point and diffuse emissions to water. In both databases, data correspond to NACE sector E (Water supply, sewage, waste management and remediation activities).

Waterbase data showed data gaps that were filled by defining emission profiles based on country data for other years. In these cases, this estimation assumed population and waste water treatment technology as main emission drivers. The emission of a substance for a given country and year ($emission_{i,cy}$) was calculated based on these parameters (Equation 4):

$$emission_{i,c,y} = emission_{i,c,y-1} * \frac{population_{c,y} * D_{X,c,y}}{population_{c,y-1} * D_{X,c,y-1}} \qquad [Eq.4]$$

Data on population and share of population connected to different WWTP situations (D_X in Equation 4) were retrieved respectively from Eurostat (2020i) and Eurostat (2020e). The emission of each substance depends on the origin of the wastewater discharge, according to Waterbase. For this purpose, different proxies of share of population with different WWTP situations were employed in the estimation (D_x):

- the share of population connected to sewage but without treatment was used as proxy for discharges of untreated urban wastewater
- the share of population not connected to sewage was used as proxy for emissions from unconnected dwellings
- the share of urban population was used as proxy for pollutant emissions due to storm overflow and urban run-off

4.3.3 Emissions from manure

The use of manure in agriculture involves the release of substances into soil. The emissions of HMs can be calculated based on the HM content of different types of manure and the annual use of manure by country. The emission of a specific HM for a given country and year ($HM\ emission_{i,c,y}$) was calculated as follows (Equation 5):

$$HM\ emission_{i,c,y}(kg\ HM) = \sum_{n=1}^{n=10} Manure\ use_{c,y,n}(kg\ manure_n) * HM\ content\ \left(\frac{kg\ HM_i}{kg\ manure_n}\right) \qquad [Eq.5]$$

Emissions of 8 HMs per mass of manure (kg) were taken from Leclerc and Laurent (2017) for 10 groups of livestock and manure management. The amount of manure used per country was taken from FAOSTAT (2020) for 14 types of animals for each Member State. These 14 types were aggregated into 7 groups of livestock. For 3 of them was possible to further separate the amount of manure according to management system with data provided by Kuczyński et al. (2005). The country-specific shares of livestock manure being managed as solid or liquid slurry were retrieved from a survey conducted on 17 Member States. The geometric mean of the 17 available Member States was assumed as representative value for the remaining countries. A summary of the manure management system and livestock considered is shown in Table 6.

Following the same methodology, additional emissions of 4 veterinary drugs (Tetracycline, Chlortetracycline, Sulfamethazine, and Sulfadiazine) were estimated in the current inventory, by averaging the concentrations measured by Hamscher et al. (2005) in Germany in 2001–2003. In this case, the emissions factor was applied without any distinction in livestock type and manure management for all the Member States. Emission profiles for these substances are shown in Table 7 and Table 8.

Table 6: Livestock and manure management system used in the model and its association with data from the original source.

Livestock	Manure management system	Livestock considered from FAOSTAT
Dairy cattle	solid	Dairy cattle
Dairy cattle	liquid	
Non- dairy cattle	solid	Non-dairy cattle, horses, mules, donkeys and buffaloes
Non- dairy cattle	liquid	
Swine	solid	Swine for breeding and for market
Swine	liquid	
Sheep and goat	-	Sheep and goats
Layer chicken	-	Layer chicken
Broiler chicken	-	Broiler chicken and turkeys
Duck	-	Duck

Table 7: Emission profiles of heavy metals for different groups of the livestock and management system. Adapted from Leclerc and Laurent (2017)

Livestock	Manure type	Concentration of heavy metals (g/kg N)							
		As	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Dairy cattle	solid	3.46E-02	1.25E-02	3.13E-01	9.58E-01	5.00E-03	1.83E-01	1.58E-01	4.96E+00
Dairy cattle	liquid	1.44E-02	8.00E-03	1.38E-01	8.40E-01	1.80E-03	1.24E-01	1.12E-01	4.14E+00
Non- dairy cattle	solid	3.46E-02	1.25E-02	3.13E-01	9.58E-01	5.00E-03	1.83E-01	1.58E-01	4.96E+00
Non- dairy cattle	liquid	1.88E-02	1.04E-02	1.80E-01	1.10E+00	2.35E-03	1.62E-01	1.46E-01	5.40E+00
Swine	solid	3.46E-02	1.79E-02	5.00E-01	8.46E+00	1.07E-03	2.96E-01	1.29E-01	3.31E+01
Swine	liquid	9.60E-03	3.00E-03	9.40E-02	1.93E+00	6.00E-04	1.20E-01	3.00E-02	9.34E+00
Sheep and goat	-	6.75E-02	1.41E-02	8.10E-01	1.36E+00	7.08E-03	4.35E-01	4.07E-01	6.16E+00
Layer chicken	-	9.56E-03	7.50E-03	1.22E-01	1.16E+00	9.38E-04	1.31E-01	6.00E-02	8.83E+00
Broiler chicken	-	1.02E-02	8.00E-03	4.00E-01	1.78E+00	1.00E-03	1.24E-01	7.40E-02	7.06E+00
Duck	-	1.95E-02	2.25E-02	2.78E-01	2.84E+00	2.11E-03	3.39E-01	1.97E-01	1.54E+01

Table 8: Emission profiles of veterinary drugs per manure mass.

Veterinary drugs (mg/kg manure)			
Chlortetracycline	Tetracycline	Sulfadiazine	Sulfamethazine
0.95	29.6	7.4	7.2

4.3.4 Emissions from sewage sludge

As for manure, also the use of sewage sludge in agriculture involves the release of HMs into soil. The emissions of HMs can be calculated based on the HM content of sewage sludge and the annual use of sewage sludge by Member State. The emission of a specific HM for a given country and year (HM $emission_{i,c,y}$) was calculated as follows (Equation 6):

$$HM\ emission_{i,c,y}(kg\ HM) = \ Sewage\ sludge\ use_{c,y} * HM\ content\ \left(\frac{kg\ HM_{i,c}}{kg\ sewage\ sludge}\right) \text{[Eq. 6]}$$

Data on the use of sewage sludge were retrieved from Eurostat (2020j). Average concentration profiles for 7 HMs in sewage sludge were collected from EC (2010b) and the UN's Global Atlas of Excreta, Wastewater Sludge, and Biosolids Management (UN-HABITAT, 2008) and assumed to be representative of the entire time series. Data gaps on these profiles for some countries were filled assuming that countries with similar regulation on sewage sludge application (e.g., concentration of pollutant allowed in the sludge) have similar emission. Hence, Austria profile was modelled as Germany, Croatia as Belgium, Denmark as Slovenia, Greece and Luxembourg as Cyprus, Ireland as Spain, and Romania as Poland, as documented in Leclerc et al. (2019).

4.3.5 Emissions due to pesticides use

Data on the use of pesticides in agriculture are difficult to find, due to confidentiality. Pesticide emissions were estimated based on agricultural crops per country and pesticides use per type of crop. The emission of a specific pesticide for a given country and year (Pesticide emission$_{i,c,y}$) was calculated as follows (Equation 7):

$$Pesticide\ emission_{i,c,y}(kg) = \sum_{crop=1}^{crop=9} Cultivated\ area_{c,crop,y}(ha) * Pesticide\ use\ \left(\frac{kg\ pesticide_i}{ha\ crop}\right) \quad \text{[Eq. 7]}$$

On one hand, the extent of cultivated land was obtained from Eurostat for 9 types of crops (Eurostat, 2020k). Crops considered included cereals, maize, potatoes, sugar beet, oil seeds, fruit, citrus fruit, vegetables and vines. On the other hand, average pesticides use (by chemical family) per crop (in kg/ha) for European countries has been documented by Eurostat for the period 1997-2003 (Eurostat, 2007). The period was considered to be representative for subsequent years. Data for Romania, Bulgaria and Croatia were not present and due to their non-negligible crop production, proxies for pesticide use were introduced by Leclerc et al. (2019). Pesticide application data of Spain, Czech Republic and Slovakia have been used, respectively.

To consider the division among the environmental compartments air, water and soil, the assumptions made by Fantke et al. (2011) were used (Table 9): for herbicides 74% is considered emitted to the soil, 15% to air and 1% to water, for all other products the percentages are 20% 15% and 1% respectively, the remaining fraction is considered to stay on the plant surface and thus not considered in the inventory (as reported in the table).

Table 9: Share of pesticides mass attributed to the emission to the different environmental compartment.

Substance	Soil (%)	Air (%)	Water (%)	Plant surface (%)
Herbicides	74	15	1	10
Other pesticides	20	15	1	64

Future refinements of modelling emissions due to pesticide use may involve the use of Eurostat dataset on pesticide sales[11] in order to complement and align data on pesticides.

4.3.6 Emission of pharmaceuticals

The emissions of different pharmaceuticals are included in the inventory using the method described in Leclerc et al. (2019). Pharmaceuticals emissions were estimated based on pharmaceuticals sales. The emission of a specific pharmaceutical for a given country and year (Pharmaceuticals emission$_{i,c,y}$) was calculated as follows (Equation 8):

$$Pharmaceuticals\ emission_{i,c,y}(kg) = sales_{i,c,y}(kg) * excretion\ rate_i \left(\frac{kg}{kg}\right) * \left(\left(1 - D_{c,y}\right) + (1 - R_i) * D_{c,y}\right) \quad \text{[Eq.8]}$$

The national sales (sales$_{i,c,y}$) were retrieved for 21 pharmaceuticals from the literature (Table 10). Data were available for nine EU countries (AT, FI, FR, DE, ES, NL, PL, SE, UK) in selected years (1995, 1997-2003, 2005, 2006, 2009). For those countries with data availability, data gaps in sales were filled by using country-specific profiles (i.e., sales per capita) for gaps in the time frame. For the remaining countries, European sales profiles (i.e., sales per capita) were used to estimate country values. Sales data are assumed as equivalent to the consumption in the Member State. An excretion rate (excretion$_i$) is employed to model the amount of chemical expelled by the human body and emitted in wastewater. Excretion rates are retrieved from Perazzolo et al. (2010). To model the final emission of the pharmaceutical to the water environment after wastewater treatment, the removal of these substances in the WWTP is estimated based on a removal rate (R_i) specific of each substance (Table 10) and the share of population connected to WWTP ($D_{c,y}$) (Eurostat, 2020e). Note that for the unconnected population (1 - $D_{c,y}$), it is assumed that the removal rate is 0.

Table 10 shows the list of substances, the main source of data for sales and removal rates, and their presence in EF3.0. The substances are contextualized as emissions to water, unspecified

[11] Eurostat dataset: aei_fm_salpest09

Table 10: Substances, data sources, and elaboration requirements and presence of a corresponding CF in the EF 3.0 method for pharmaceuticals emissions to water.

Substance	Data source (sales, removal rate)	Data elaboration	CF in EF 3.0
Ibuprofen	Rosal et al. 2010; Gros et al. 2012	Calculation	Yes
17α-ethynyl estradiol (EE2)	Habibi et al. 2009	Calculation	Yes
Trimethoprim	Kosma et al., 2014, Igos et al. 2012; Rosal et al. 2010	Calculation	Yes
17β-estradiol (E2)	Habibi et al. 2009	Calculation	Yes
Diazepam	Verlicchi et al. 2012	Calculation	Yes
Erythromycin	Rosal et al. 2010	Calculation	Yes
Atenolol	Igos et al. 2012; Rosal et al. 2010	Calculation	No
Bezafibrate	Rosal et al. 2010	Calculation	Yes
Carbamazephin	Igos et al. 2012; Rosal et al. 2010; Miao et al. 2005; Gao et al. 2012	Calculation	Yes
Clarithromycin	Igos et al. 2012	Calculation	No
Clindamycin	Verlicchi et al. 2012	Calculation	No
Clofibric acid	Rosal et al. 2010	Calculation	No
Diclofenac	Rosal et al. 2010; Gros et al. 2012; Igos et al. 2012	Calculation	Yes
Iopamidol	Petrovic and Barcelo, 2007	Calculation	No
Iopromid	Verlicchi et al. 2012	Calculation	Yes
Metoprolol	Rosal et al. 2010	Calculation	Yes
Naproxen	Rosal et al. 2010; Gros et al. 2012	Calculation	No
Propanolol	Rosal et al. 2010	Calculation	No
Roxythromycin	Verlicchi et al. 2012	Calculation	No
Sotalol	Verlicchi et al. 2012	Calculation	No
Sulfamethoxazole	Rosal et al. 2010; Gros et al. 2012; Igos et al. 2012	Calculation	Yes

4.4 Particulate Matter (PM)

Data collected on particulate matter included nitrogen oxides (NO_x), sulphur dioxide (SO_x), ammonia (NH_3) and particulate matter $PM_{2.5}$ (particles with a diameter of 2.5 micrometres or less). Data were retrieved from EMEP/CEIP (2020), which is a database of pollutant managed by the Centre on Emission Inventories and Projections. Although the EMEP database includes information on PM10, this emission was excluded as PM2.5 is a fraction of PM_{10}, being $PM_{2.5}$ the responsible for most of the health damage. Therefore, PM10 was excluded to avoid double counting, consistently with Sala et al. (2015).

The final inventory includes 4 substances out of the 11 covered in the EF 3.0 impact assessment model (Fantke et al., 2016; as in UNEP, 2016). Emissions compiled for the PM category are reported as emissions to air, unspecified.

Table 11: Substances, data sources, and elaboration requirements and presence of a corresponding CF in the EF 3.0 method for Particulate Matter.

Substance	Source	Data elaboration	CF in the EF3.0
NO_x	EMEP	No elaboration	Yes
SO_x	EMEP	No elaboration	Yes
NH_3	EMEP	No elaboration	Yes
PM2.5	EMEP	No elaboration	Yes

4.5 Ionising Radiation (IR)

Data on the emission of radionuclides (i.e., a chemical element undergoing radioactive decay) to the environment were compiled for the Ionising Radiation (IR) category. The inventory included emissions originating from the following activities:

— electricity production from nuclear plants
— reprocessing of spent nuclear fuel
— extraction of oil and gas
— combustion of coal
— gypsum plaster disposal
— non-nuclear activities (e.g., from medical sector and research)

The final inventory includes 72 substances, being only 26 characterized in EF3.0 (Frischknecht et al., 2000), which includes a total of 189 substances. The number of elementary flows is higher due to the presence of emission of the same radionuclide in more than one compartment. The number of substances, number of elementary flows and compartment per each source of ionising radiation is shown in Table 12. Note that radionuclides can originate from different sources. The complete list of radionuclides is shown in Annex 1. The attribution of the different emissions to specific compartments depends on the emission source, as indicated in Table 12.

Table 12: Overview of emission source, number of radionuclides, environmental compartments and data sources considered for elementary flows regarding ionising radiation. Calculations are detailed in the next sections.

Emission source	**Number of radionuclides**	**Number of elementary flows**	**Environmental compartment**	**Data sources**
Nuclear electricity production	3	4	Air, water	Calculation based on PRIS (2020) and UNSCEAR (2016)
Reprocessing of spent nuclear fuel	15	22	Air, water	RADD (2020)
Extraction of oil and gas	19	19	Air	Calculation based on Eurostat (2020a) and (EC-JRC 2017)
Combustion of coal	7	7	Air	Calculation based on Eurostat (2020b) and UNSCEAR (2016)
Disposal of gypsum	71	116	Air, water, sea water	Calculation based on Eurostat (2020c) and Wernet et al. (2016)
Non-nuclear activities	12	12	Sea water	OSPAR (2020)

4.5.1 Emissions due to electricity production from nuclear plants

Nuclear plant emissions were modelled according to electricity production from nuclear plants by country and emission factors from electricity generation for different technologies of nuclear plant. The emission of a specific radionuclide by country and year (Radionuclide emission$_{i,c,y}$) was calculated as follows (Equation 9):

$$Radionuclide\ emission_{i,c,y}(kBq) = \sum_{tech=1}^{tech=7} Electricity\ production_{tech,y}(GWh) * Emission\ factor \left(\frac{kBq\ radionuclide_{i,tech}}{GWh}\right) \quad \text{[Eq. 9]}$$

Data on electricity production and technology of the nuclear plants were collected from the Power Reactor Information System created by the International Atomic Energy Agency (PRIS, 2020). Emissions profiles per generated electricity (in GWh) were created using information for 7 types of nuclear plants from the United Nation Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 2016).

Active nuclear plants are present in the following EU28 countries: Belgium, Bulgaria, Czechia, Finland, France, Germany, Hungary, Netherlands, Romania, Slovakia, Slovenia, Spain, Sweden and United Kingdom. Lithuania had active nuclear plants only until 2009.

The emission of Iodine-131 and Carbon-14 were reported as emission to air (unspecified), while emissions of Hydrogen-3 were contextualized both to air (unspecified) and water (unspecified).

Table 13: Radionuclides, data source, data elaborations and presence of a corresponding CF in the EF method for the emissions from nuclear plants.

Radionuclides	**Source**	**Data elaboration**	**CF in the EF3.0**
Iodine-131	UNSCEAR (2016)	Calculated from amount of nuclear electricity produced.	Yes
Hydrogen-3	UNSCEAR (2016)	Calculated from amount of nuclear electricity produced.	Yes
Carbon-14	UNSCEAR (2016)	Calculated from amount of nuclear electricity produced.	Yes

4.5.2 Emissions from reprocessing of spent nuclear fuel

The spent nuclear fuel still contains a valuable quantity of fissile material. This fuel can be reprocessed to recover the unused material and to remove substances which act as reaction poison. Reprocessing takes place in special facilities and involves the emissions of radionuclides into the environment.

Data on emissions from reprocessing of spent nuclear fuel were collected from the Radioactive Discharges Database (RADD, 2020). The database reports the emission of several radionuclides to air and to water resulting from all the active facilities in Europe. The emissions of 15 radionuclides to air and to water were considered for a total amount of 22 elementary flows. A summary of radionuclides considered is shown in Table 14. Emissions were reported as emissions to air (unspecified) and water (unspecified).

Table 14: Emission source, radionuclides, data sources and presence of a corresponding CF in the EF method for the emissions from nuclear plants.

Radionuclide	**Source**	**CF in the EF3.0**
Carbon-14	RADD (2020)	Yes
Cesium-134	RADD (2020)	Yes
Cesium-137	RADD (2020)	Yes
Cobalt-58	RADD (2020)	Yes
Cobalt-60	RADD (2020)	Yes
Hydrogen-3	RADD (2020)	Yes
Iodine-129	RADD (2020)	Yes
Iodine-131	RADD (2020)	Yes
Iodine-133	RADD (2020)	Yes
Krypton-85	RADD (2020)	Yes
Manganese-54	RADD (2020)	Yes
Plutonium	RADD (2020)	Yes
Uranium-234	RADD (2020)	Yes
Uranium-235	RADD (2020)	Yes
Uranium-238	RADD (2020)	Yes

4.5.3 Emissions from extraction of oil and gas

Oil and gas activities lead to discharge of radionuclides into the environment. Radionuclide emissions from extraction of oil and gas were modelled according to gas and oil extraction by country and emission factors. The emission of a specific radionuclide by country and year (Radionuclide emission$_{i,c,y}$) was calculated as follows (Equation 10):

$$Radionuclide\ emission_{i,c,y}(kBq) = Fossil\ fuel\ extraction_{c,y}(kg) * Emission\ factor\ \left(\frac{kBq\ radionuclide_i}{kg}\right)$$

[Eq. 10]

Data on domestic crude oil and natural gas extraction were retrieved from Eurostat (2020a). The emissions profile of crude oil extraction was employed for the calculation, which was considered to be representative also of gas extraction, based on data of the EF dataset "*Crude oil mix technology mix of conventional (primary, secondary and tertiary production) and unconventional production (oil sands, in-situ) consumption mix, to consumer*" (EC-JRC, 2017), considering 19 elementary flows. All the emissions are contextualized as emission to air, unspecified.

Table 15: Emission source, number of radionuclides, data sources and presence of a corresponding CF in the EF method for the emissions from oil and gas extraction.

Substance	**Source**	**Data elaboration**	**CF in the EF3.0**
Carbon-14	Eurostat 2020a	Calculated from amount of oil and gas produced.	Yes
Cesium-134	Eurostat 2020a	Calculated from amount of oil and gas produced.	Yes
Cesium-137	Eurostat 2020a	Calculated from amount of oil and gas produced.	Yes
Cobalt-58	Eurostat 2020a	Calculated from amount of oil and gas produced.	Yes
Cobalt-60	Eurostat 2020a	Calculated from amount of oil and gas produced.	Yes
Hydrogen-3	Eurostat 2020a	Calculated from amount of oil and gas produced.	Yes
Iodine-129	Eurostat 2020a	Calculated from amount of oil and gas produced.	Yes
Iodine-131	Eurostat 2020a	Calculated from amount of oil and gas produced.	Yes
Krypton-85	Eurostat 2020a	Calculated from amount of oil and gas produced.	Yes
Lead-210	Eurostat 2020a	Calculated from amount of oil and gas produced.	Yes
Plutonium	Eurostat 2020a	Calculated from amount of oil and gas produced.	Yes
Polonium-210	Eurostat 2020a	Calculated from amount of oil and gas produced.	Yes
Radium-226	Eurostat 2020a	Calculated from amount of oil and gas produced.	Yes
Radon-222	Eurostat 2020a	Calculated from amount of oil and gas produced.	Yes
Thorium-230	Eurostat 2020a	Calculated from amount of oil and gas produced.	Yes
Uranium-234	Eurostat 2020a	Calculated from amount of oil and gas produced.	Yes
Uranium-235	Eurostat 2020a	Calculated from amount of oil and gas produced.	Yes
Uranium-238	Eurostat 2020a	Calculated from amount of oil and gas produced.	Yes
Xenon-133	Eurostat 2020a	Calculated from amount of oil and gas produced.	Yes

4.5.4 Emissions from combustion of coal

Combustion of coal for electricity generation leads to discharge of radionuclides into air. These emissions are modelled according to the amount of coal used in electricity by country and emission profile of coal burning plant. The emission of a specific radionuclide by country and year (Radionuclide emission$_{i,c,y}$) was calculated as follows (Equation 11):

$$Radionuclide\ emission_{i,c,y}(kBq) = \ Gross\ electricity\ from\ coal_{c,y}(GWh) * Emission\ factor_i\ \left(\frac{kBq\ radionuclide}{GWh}\right) \qquad \text{[Eq. 11]}$$

Data on domestic electricity production were retrieved from Eurostat (2020b) while the emissions profile were retrieved from UNSCEAR (2016). The radionuclides are contextualized as emissions to air, unspecified.

Table 16: Emission source, number of radionuclides, data sources and presence of a corresponding CF in the EF method for the emissions from coal combustion.

Radionuclide	Source	Data elaboration	CF in the EF3.0
Lead-210	Eurostat (2020b)	Calculated from coal consumption for electricity production.	Yes
Polonium-210	Eurostat (2020b)	Calculated from coal consumption for electricity production.	Yes
Radium-226	Eurostat (2020b)	Calculated from coal consumption for electricity production.	Yes
Radon-222	Eurostat (2020b)	Calculated from coal consumption for electricity production.	Yes
Thorium-230	Eurostat (2020b)	Calculated from coal consumption for electricity production.	Yes
Uranium-234	Eurostat (2020b)	Calculated from coal consumption for electricity production.	Yes
Uranium-238	Eurostat (2020b)	Calculated from coal consumption for electricity production.	Yes

4.5.5 Emissions from gypsum plaster disposal

Gypsum plaster end-of-life is also responsible of radionuclides discharge into the environment. Radionuclide emissions from gypsum plaster disposal were modelled according to gypsum production data by country and emission factors. The emission of a specific radionuclide by country and year (Radionuclide emission$_{i,c,y}$) was calculated as follows (Equation 12):

$$Emission_{i,c,y}(kBq) = Gypsum\ plaster\ disposal_{c,y}(kg) * Emission\ factor_i \left(\frac{kBq}{kg_{gypsum\ plaster}}\right) \quad \text{[Eq. 12]}$$

Data on gypsum plaster production from the PRODCOM database[12] (Eurostat, 2020c) were used as a proxy for the amount of gypsum plaster disposed. The emission factor of gypsum disposal was employed, based on the ecoinvent v3.03[13] dataset 'Waste gypsum {GLO}| market for | Alloc Def, S' (Wernet et al., 2016), considering 71 substances emitted to air, water and sea water for a total amount 116 elementary flows. The complete list of radionuclides from this source is included in Table A-4 (Annex 1).

4.5.6 Emissions from non-nuclear activities

Radionuclides are also used and emitted into the environment from activities related to sectors other than nuclear. Data on these emissions were retrieved from OSPAR Data & Information Management System (OSPAR, 2020). The activities considered were medical sector, research and university, phosphate industry, titanium dioxide manufacturing, radiochemical production and water discharged at offshore facilities. Overall, data regarding 13 radionuclides flows were retrieved, as shown in Table 17.

[12] The item selected in the PRODCOM database was: "*23522000 Plasters consisting of calcinated gypsum or calcium sulphate (including for use in building, for use in dressing woven fabrics or surfacing paper)*".
[13] This dataset has not been updated in the latest version of the ecoinvent database (v3.6).

Table 17: Emission source, number of radionuclides, data sources and presence of a corresponding CF in the EF method for the emissions from non-nuclear activities.

Substance	Source	CF in the EF3.0
Iodine-131	OSPAR	Yes
Hydrogen-3	OSPAR	Yes
Carbon-14	OSPAR	Yes
Phosphorus-32	OSPAR	No
Sulphur-35	OSPAR	No
Chromium-51	OSPAR	No
Iodine-125	OSPAR	No
Lead-210	OSPAR	Yes
Polonium-210	OSPAR	Yes
Radium-226	OSPAR	Yes
Radium-228	OSPAR	No
Thorium-228	OSPAR	No
Americum-241	OSPAR	Yes

4.6 Photochemical Ozone Formation (POF)

For the Photochemical Ozone Formation impact category, the considered emissions to air included nitrogen oxides (NO_x), sulphur oxides (SO_x), and NMVOCs. Data were retrieved from the EMEP database (EMEP, 2020), as described for Particulate Matter (section 4.4). Since NMVOCs are the main chemical family responsible for ozone formation, a detailed inventory was created by disaggregating into individual substances following the procedure described in Laurent and Hauschild (2014). The procedure consists of the use of NMVOCs' speciation profile at country level defined for 2000-2010. These speciation profiles, expressed as kg of substance per kg of NMVOC, were used together with total NMVOC emissions from EMEP to calculate the final mass of substance emitted to air.

The emission of the individual substances for a given country and year was calculated as follows (Equation 13):

$$Substance\ emission_{i,c,y}(kg) = \ NMVOCs\ emission_{c,y}(kg) * Speciation_{i,c,y}\ \left(\frac{kg}{kg\ NMVOC}\right) \qquad \text{[Eq. 13]}$$

The final inventory includes 87 substances out of 133 for which the EF 3.0 has a CF in the underpinning impact assessment model (Van Zelm et al., 2008). The extensive list of substances is shown in Table A-5. The emissions are contextualized as emissions to air, unspecified.

4.7 Acidification (AC)

For the Acidification (AC) impact category, the emissions into air of acidifying substances were collected in the inventory. Data on emissions of nitrogen oxides (NO_x), sulphur oxides (SO_x) and ammonia (NH_3) were retrieved from EMEP (2020) (Table 18). Note that emissions into air in the data source include also those derived from volatilisation of ammonia related to application of fertilisers and manure to soil.

Inventory data were available for three flows out of the 9 covered in the EF 3.0 impact assessment model (Seppälä et al., 2006; Posch et al., 2008). In particular, missing flows are nitrogen monoxide, sulphur trioxide and sulphur oxides. This is a data gap already acknowledged in Sala et al. (2015) associated to the lack of country-level data. Acidification elementary flows are regionalized at the country-level for all Member States (e.g., ammonia, to air, ES for Spain) except Cyprus and Malta, in alignment with the EF 3.0 method. The emissions are reported as "emissions to air, unspecified".

Table 18: Substances, data sources, and elaboration requirements and presence in EF 3.0 method for Acidification.

Substance	Source	CF in the EF3.0
NO_x	EMEP 2020	Yes
SO_x	EMEP 2020	Yes
Ammonia	EMEP 2020	Yes

4.8 Eutrophication, terrestrial (TEU)

Terrestrial eutrophication impacts results from the emissions of nitrogen to air, including nitrogen oxides (NO_x) and ammonia (NH_3). Data on these emissions were retrieved from EMEP (2020), as for particulate matter and acidification impact categories.

The final inventory covers 2 substances out of 6 for which a CF is available in EF 3.0 (Seppälä et al., 2006; Posch et al., 2008) (Table 19). These emissions were contextualized as emission to air (unspecified) and regionalized at country-level for all Member States except Cyprus and Malta, in alignment with EF 3.0. The emissions are reported as “emissions to air, unspecified”.

Table 19: Substances, data sources, and elaboration requirements and presence of a corresponding CF in the EF 3.0 method for Terrestrial Eutrophication.

Substance	**Source**	**CF in the EF3.0**
NO_x	EMEP 2020	Yes
Ammonia	EMEP 2020	Yes

4.9 Eutrophication, freshwater and marine (FEU and MEU)

The inventory for aquatic eutrophication (both freshwater and marine) was calculated based on a mass balance of nitrogen and phosphorus in the environment considering both emissions to soil (and transfer to water) and direct emissions to water. For this purpose, a model for emissions from agricultural activities was used together with a model of emissions to water from wastewater treatment, according to the procedure described in Sala et al. (2015), which is based on the methodology developed by Van Drecht et al. (2003, 2009).

4.9.1 Emissions from agriculture

Nitrogen emissions to water due to agricultural activities are first emitted to soil. Direct emissions come from synthetic fertilizers, animal manure applied to soils, N-fixing crops, and crop residue. Indirect emissions are soil (re-)emissions resulting from nitrogen that has leached from the soil or from atmospheric deposition. The direct and indirect emissions are lowered with losses to water, emission to air (volatilization) and output. Nitrogen output consists of removal of nutrients through harvest and grazing, as well as from removal of crop residues from the field. The nitrogen balance is summarized in the following equations: All data were retrieved from UNFCCC (2020) at country level for all years in the time-series, based on national inventories. Due to lack of N output data, this value was estimated based on N input and N output data provided by Eurostat (2020d) (Equation 17).

$$N_{soil} = N_{input} - N_{water} - N_{air} - N_{output} \quad \text{[Eq.14]}$$

$$N_{water}(kg) = fraction_{LEACH} * \left(N_{manure} + N_{fertiliser}\right)(kg) \quad \text{[Eq.15]}$$

$$N_{air}(kg) = fraction_{GASM} * N_{manure}(kg) + fraction_{GASF} * N_{fertiliser}(kg) \quad \text{[Eq.16]}$$

$$N_{output}(kg) = N_{input}(kg) * \left(\frac{N_{output,Eurostat}}{N_{input,Eurostat}}\right) \quad \text{[Eq.17]}$$

Regarding phosphorous, Eurostat (2020d) data were used. Data gaps for some years and countries were estimated for phosphorus input (P_{input}) based on nitrogen input data from UNFCCC (2020), and for phosphorus output (P_{output}) based on nitrogen output data from Eurostat (2020d). The underlying assumption is that there is correlation between total phosphorous and total nitrogen, both for inputs and outputs (Sala et al., 2014). Loss to water (P_{water}) was estimated to be 10% of P_{input} according to Bouwman et al. (2009). The phosphorous emission to soil was calculated as follows (Equation 18):

$$P_{soil}(kg) = P_{input}(kg) - P_{water}(kg) - P_{output}\,(kg) \quad \text{[Eq.18]}$$

The reported factors from UNFCCC for nitrogen leaching from soil and for nitrogen volatilisation have been used. In particular, for Cyprus the factor for nitrogen leaching is set to 0 by UNFCCC, hence it results in absence of nitrogen leaching from agricultural activities.

4.9.2 Emissions from wastewater

The N and P emissions from wastewater were estimated for the years 2000-2018 and all 28 countries, including both industrial and household emissions as in the method by Van Drecht et al. (2009). The emission of nitrogen to surface water depends on the emissions by humans and on the characteristics of the wastewater treatment (e.g., technology and number of people connected). The N emission to surface water per country and year ($N_{water,c,y}$) was calculated considering the nitrogen intake per person, the share of population connected to different types of wastewater treatment (D_i) and their removal efficiency (R_i), as follows (Equation 19):

$$N_{water,c,y}\,(kg) = N_{human,c,y}\left(\frac{kg}{person}\right) * \sum_{i=0}^{i=3} D_i(1 - R_i) \ * Population_{c,y}\,(person) \qquad \text{[Eq.19]}$$

The nitrogen intake was estimated by Van Drecht et al. (2009) as 16% of the protein intake, which was retrieved from FAO (2020). Removal efficiency (R_i) depends on the WWTP technology (i) considered (no treatment, primary, secondary and tertiary treatment) and data were retrieved from Eurostat (2020e).

The emissions of phosphorous consider those from human and from detergents and depend on the removal efficiency of WWTP (Equation 19). First, the human emissions of Phosphorus (P_{human}) were estimated based on nitrogen emissions by multiplying with a factor 1/6 according to Van Drecht et al. (2009). Second, emissions of phosphorus from detergents use was included in the model using data on laundry and dishwasher detergents retrieved from the report "*Non-surfactant Organic Ingredients and Zeolite-based Detergents*" (RPA, 2006) and an average fraction of phosphorus in the detergents, as determined in Van Drecht et al. (2009). The amount of detergent used were retrieved at country level. For 11 countries these data were missing, and the average values of the available countries were considered representative. Lastly, the removal efficiency of WWTP was considered as for nitrogen emissions, based on Eurostat (2020e). The emissions of phosphorous to water per country and year ($P_{water,c,y}$) were estimated as follows (Equation 20):

$$P_{water,c,y}(kg) = \left(\frac{1}{6} N_{human,c} + [Laundry\ detergent_c \ * 0.25 + Dishwasher\ detergent_c * 0.117]\right)\left(\frac{kg}{person}\right) * \sum_{i=0}^{i=4} D_{i,c}(1 - R_i) * Population_{c,y}\,(person) \qquad \text{[Eq.20]}$$

For marine eutrophication, Nitrogen oxides and Ammonia to air were retrieved from EMEP (2020).

The final inventory covers one substance out of 4 for freshwater eutrophication (Table 20) and three substances out of 8 for marine eutrophication (Table 21), for which a CF is available in EF 3.0 (Struijs et al. (2009) as applied in ReCiPe 2008 (Goedkoop et al., 2008)). The emission of Phosphorus and Nitrogen are contextualized as emission to water (unspecified) and soil (unspecified), while Nitrogen oxides and Ammonia are considered as emissions to air (unspecified).

Table 20: Substances, data sources, and elaboration requirements and presence of a corresponding CF in the EF 3.0 method for Freshwater Eutrophication.

Substance	**Source**	**Data elaboration**	**CF in the EF3.0**
Phosphorus, total	Eurostat (2020d)	Flow calculated with Van Drecht et al. (2003, 2009) model	Yes

Table 21: Substances, data sources, and elaboration requirements and presence of a corresponding CF in the EF 3.0 method for Marine Eutrophication.

Substance	**Source**	**Data elaboration**	**CF in the EF3.0**
Nitrogen, total	UNFCCC (2020), Eurostat (2020d)	Flow calculated with Van Drecht et al. (2003, 2009) model	Yes
Nitrogen oxides	EMEP (2020)	No elaboration performed.	Yes
Ammonia	EMEP (2020)	No elaboration performed.	Yes

4.10 Water Use (WU)

Inventory data for the water use impact category considered the consumption of freshwater. The freshwater consumption of a given country and year (Freshwater consumption$_{c,y}$) was calculated as follows (Equation 21):

$$Freshwater\ consumption_{c,y}\ (kg) =\ Gross\ freshwater\ abstraction_{c,y}\ (kg) * \frac{Consumption_c}{Abstraction_c} \quad \text{[Eq. 21]}$$

Data on gross freshwater abstraction were retrieved from Eurostat (Eurostat, 2020f). The amount of net water consumed was modelled using data on the country-specific ratio between water consumption and water abstraction from WaterGAP (Müller Schmied et al., 2014) in 2010.

For two Member States, data on water abstraction were incomplete and a specific data gap filling action was required:

- The overall water abstraction was not reported for Finland. Since water abstraction per sectors (agriculture, public water supply, quarry and mining and manufacturing industry) data were available, the aggregation of the sector-specific water abstraction was considered.
- For Italy, data were estimated from national data sources. A periodical survey on water use is published by the national statistics agency with data for the years 2008, 2012 and 2015 (ISTAT, 2020a). As well, data for 2018 were retrieved from a public notice of the same agency (ISTAT, 2020b). Linear interpolation was used to fill gaps for the missing years.

Freshwater consumption was reported in the inventory as a country-level regionalized elementary flow (e.g., Freshwater, DE for Germany) as this category is regionalized for all Member States in the EF 3.0 method. The inventory covers 1 flow from the 11 flows available in the EF 3.0.

Table 22: Water flows, data source, data elaboration requirements and presence of a corresponding CF in the EF 3.0 method for Water Use.

Substance	**Source**	**Data elaboration**	**CF in the EF3.0**
Freshwater	Eurostat (2020f)	Calculated value. Data gap filling procedure implemented for Finland and Italy.	Yes

4.11 Land Use (LU)

Impacts due to land use consider both land occupation and land transformation. The inventories for land occupation and land transformation were built from LULUCF data retrieved from the UNFCCC database (UNFCCC, 2020). The classification in 10 types of land management was aggregated into 6 land occupation flows (i.e., forest, agriculture, grassland/pasture/meadows, wetlands, urban, unspecified) and 12 land transformation flows (i.e., from/to forest, agriculture, grassland/pasture/meadows, wetlands, urban, unspecified). The mapping between UNFCCC land management and EF elementary flows is provided in Table A-6.

For Denmark, UNFCC data include Greenland as unspecified land occupation. However, this value was corrected as 0 in the inventory towards excluding Greenland.

The final inventory covers 18 out of 171 for which a CF is available in EF 3.0 (Soil quality index based on an updated LANCA model (De Laurentiis et al., 2019) and on the LANCA CF version 2.5 (Horn and Meier, 2018) (Table 23). Land use elementary flows were regionalized at the country-level (e.g., land occupation, forest, ES for Spain) for all Member States in alignment with the EF 3.0 method.

Table 23: Land use flows, data source, data elaboration requirements and presence of a corresponding CF in the EF 3.0 method for Land Use.

land use and transformation type	Source	CF in the EF3.0
Forest	UNFCCC	Yes
Agriculture	UNFCCC	Yes
Grassland/pasture/meadows	UNFCCC	Yes
Wetlands	UNFCCC	Yes
Urban	UNFCCC	Yes
Unspecified	UNFCCC	Yes
From forest	UNFCCC	Yes
From agriculture	UNFCCC	Yes
From grassland/pasture/meadows	UNFCCC	Yes
From Wetlands	UNFCCC	Yes
From urban	UNFCCC	Yes
From unspecified	UNFCCC	Yes
To forest	UNFCCC	Yes
To Agriculture	UNFCCC	Yes
To Grassland/pasture/meadows	UNFCCC	Yes
To Wetlands	UNFCCC	Yes
To Urban	UNFCCC	Yes
To Unspecified	UNFCCC	Yes

4.12 Resource Use, fossils (FRD)

Data on energy carriers for the Resource Use, fossils impact category (FRD) were taken from Eurostat (Eurostat 2020g, 2020l). Data were retrieved for all the six flows characterised in the EF 3.0 (van Oers et al., 2002): Brown coal, Crude oil, Hard coal, Natural gas, Nuclear and Peat (Table 24). For the compilation of hard coal and peat, aggregation of different fossil resources was performed, as following:

- Hard coal: Anthracite, coking coal, Sub-bituminous coal and other bituminous coal
- Peat: Peat and Peat products

Additionally, the inventory compiled data on primary energy from renewable sources (geothermic, hydropower, solar energy, wind power) retrieved from Eurostat (2020l) although not characterised in the EF 3.0, in alignment with Sala et al. (2014).

Table 24: Energy and resource flows, data source, data elaboration requirements and presence of a corresponding CF in the EF 3.0 method for Resource Use, fossils.

Elementary flows	**Source**	**Data elaboration**	**CF in the EF3.0**
Hard Coal	Eurostat (2020g)	Aggregation of anthracite, coking coal, sub-bituminous coal and other bituminous coal	Yes
Brown Coal	Eurostat (2020g)	No elaboration performed	Yes
Peat	Eurostat (2020g)	Aggregation of peat and peat products	Yes
Crude oil	Eurostat (2020g)	No elaboration performed	Yes
Natural gas	Eurostat (2020g)	No elaboration performed	Yes
Nuclear	Eurostat (2020g)	No elaboration performed	Yes
Primary energy from geothermics	Eurostat (2020l)	No elaboration performed	No
Primary energy from hydro power	Eurostat (2020l)	No elaboration performed	No
Primary energy from solar energy	Eurostat (2020l)	No elaboration performed	No
Primary energy from wind power	Eurostat (2020l)	No elaboration performed	No

4.13 Resource Use, minerals and metals (MRD)

Inventory data regarding the Resource Use, minerals and metals impact category (MRD) included the extraction of various minerals and metals (Table 25).

The inventory was compiled from different data sources:

— Most of the data for minerals and metals were retrieved from the British Geological Survey (BGS, 2020).

— When BGS included data gaps or inconsistencies in the time-series, these were filled with data from World Mining Data (WMD, 2020) and Euromines (Euromines, 2020).

— Data for sulphur production were retrieved from the United States Geological Survey (USGS, 2020) complemented with data from Wold Mining Data (WMD, 2020).

The final inventory includes 36 resources, out of which 27 are characterised in the EF 3.0 method (van Oers et al., 2002). The available CFs for resources are 48.

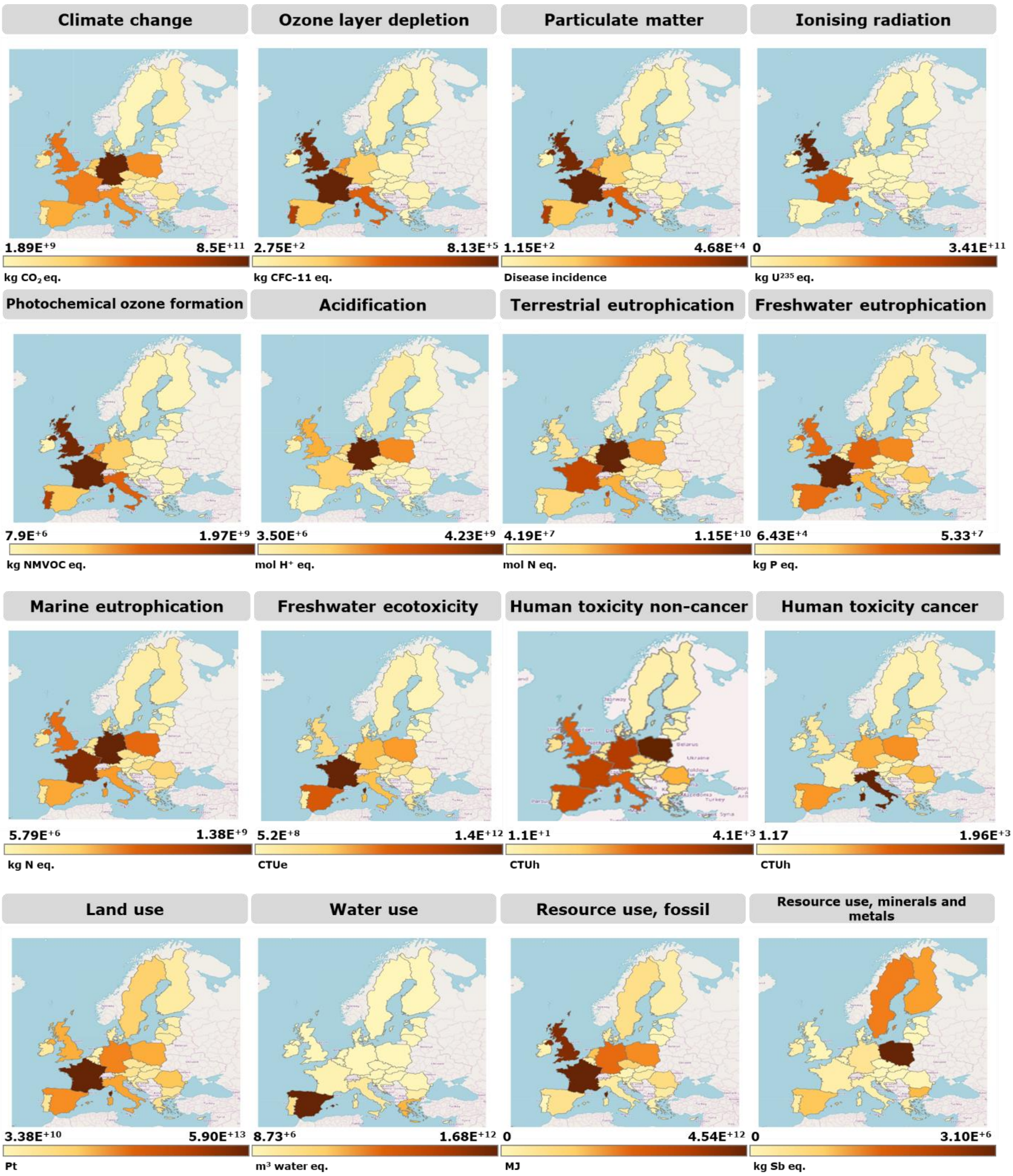
Table 25: Minerals and metals flows, data source, data elaboration requirements and presence in the list of resources covered by a CF in the EF 3.0 method for Resource Use, minerals and metals.

Substance	Source	CF in the EF3.0
Sand and gravel	BGS (2020); Euromines (2020)	No
Aluminum primary	BGS (2020)	Yes
Arsenic white	BGS (2020)	Yes
Bauxite	BGS 2020; WMD (2020)	No
Bismuth	BGS (2020)	Yes
Cadmium	BGS (2020)	Yes
Kaolin	BGS (2020); WMD (2020)	No
Chromium	BGS (2020)	Yes
Cobalt	BGS (2020)	Yes
Copper	BGS (2020)	Yes
Diatomite	BGS (2020)	No
Feldspar	BGS (2020)	No
Fluorspar	BGS (2020)	No
Germanium	BGS (2020)	Yes
Gallium	BGS (2020)	Yes
Gold	BGS (2020)	Yes
Gypsum	BGS (2020)	No
Indium	BGS (2020)	Yes
Iron	BGS (2020)	Yes
Lead	BGS (2020); Euromines (2020)	Yes
Lithium	BGS (2020); Euromines (2020)	Yes
Manganese	BGS (2020); Euromines (2020); WMD (2020)	Yes
Mercury	BGS (2020)	Yes
Molybdenum	BGS (2020)	Yes
Nickel	BGS (2020); Euromines (2020)	Yes
Palladium	BGS (2020)	Yes
Platinum	BGS (2020)	Yes
Selenium	BGS (2020)	Yes
Silver	BGS (2020), WMD (2020)	Yes
Strontium	BGS (2020)	Yes
Sulphur	USGS (2020), WMD, (2020)	Yes
Talc	BGS (2020)	No
Tin	BGS (2020)	Yes
Tungsten	BGS (2020)	Yes
Vermiculite	BGS (2020)	No
Zinc	BGS (2020)	Yes

5 EU and Member State Domestic Footprint for the period 2000 - 2018

This section reports the results of the Domestic Footprint for the EU-28 and individual Member States for the period 2000-2018. A detailed analysis of this indicator will be available in the corresponding section of the Consumption Footprint Platform[14]. An overview of EU Domestic Footprint in 2018, its evolution along time for the period 2000-2018, the role of the different EU Member States, the relevance of difference impact categories and the contribution of elementary flows is provided in this chapter. As well, observed issues in the underlying data to compile the domestic inventory are reported.

Figure 4: Domestic Footprint: impact per Member State, by impact category (2018).



[14] https://eplca.jrc.ec.europa.eu/ConsumptionFootprintPlatform.html

5.1 The Domestic Footprint of the EU-28 (2018)

The EU Domestic Footprint for 2018[15] is reported in Table 26, including characterized, normalised and weighted results (according to EF factors as reported in Table 1) as well as the role of the different impact categories into the aggregated single score. Three impact categories represent more than half of the total impact: Climate Change, Particulate Matter and Human Toxicity non-cancer[16].

Table 26: EU-28 Domestic Footprint for 2018: characterized, normalised and weighted results, and share of the overall single score by impact category.

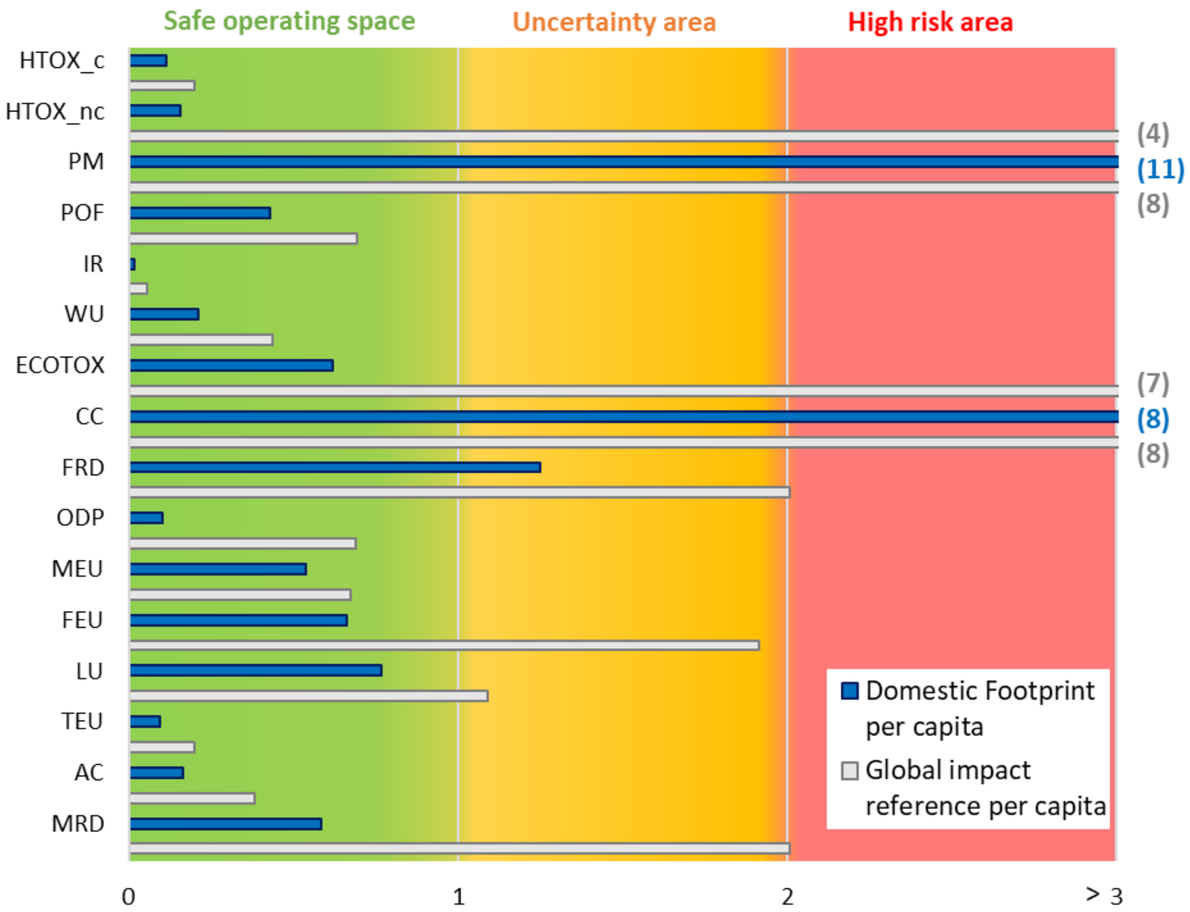
Impact category	Unit	Characterized	Normalised	Weighted	Share of the single score
Climate change	kg CO_2 eq	4.13E+12	7.40E-02	1.56E-02	32.5%
Ozone depletion	kg CFC-11 eq	4.13E+06	1.12E-02	7.04E-04	1.5%
Human toxicity, non-cancer	CTUh	2.67E+04	1.53E-03	2.82E-05	0.1%
Human toxicity, cancer	CTUh	8.16E+03	4.28E-02	9.12E-04	1.9%
Particulate matter	Disease incidence	4.08E+05	9.94E-02	8.91E-03	18.6%
Ionising radiation	kBq U^{235} eq	6.03E+11	2.07E-02	1.04E-03	2.2%
Photochemical Ozone formation	kg NMVOC eq	1.30E+10	4.60E-02	2.20E-03	4.6%
Acidification	molc H^+ eq	1.21E+10	3.16E-02	1.96E-03	4.1%
Eutrophication, terrestrial	molc N eq	4.29E+10	3.52E-02	1.31E-03	2.7%
Eutrophication, freshwater	kg CFC-11 eq	2.85E+08	2.57E-02	7.20E-04	1.5%
Eutrophication marine	molc N eq	7.99E+09	5.93E-02	1.75E-03	3.7%
Land use	Pt	2.95E+14	5.22E-02	4.15E-03	8.6%
Ecotoxicity, freshwater	CTUe	5.75E+12	6.75E-03	1.32E-04	0.3%
Water use	m^3 world eq	2.86E+12	3.62E-02	3.08E-03	6.4%
Resource use, fossils	MJ	2.07E+13	4.62E-02	3.85E-03	8.0%
Resource use, minerals and metals	kg Sb eq	9.52E+06	2.17E-02	1.64E-03	3.4%

Considering an absolute sustainability perspective, the EU Domestic Footprint was assessed against the PBs adapted to the EF impact categories (Sala et al., 2020). Figure 5 displays the assessment for EU-28 Domestic Footprint per capita in 2018. Both PBs on climate change and particulate matter are largely transgressed (10.7 and 8.2 times, respectively) laying on the high-risk area. Only impacts due to fossil resources use are found in the uncertainty area when compared to the corresponding PB. The remaining 13 impact categories remain within the safe operating space for humanity. Compared to global impacts (Crenna et al., 2019), the territorial impacts of EU domestic production and consumption activities are mainly lower. At the global level, three other impact categories are placed in the uncertainty area, including freshwater eutrophication, land use and resource use of minerals and metals.

[15] Note that comparison to previous results (Sala et al., 2019) should consider the update of the impact assessment method (from EF2.0 to EF3.0), including the regionalization of several impact categories (Land Use, Water Use, Acidification and Terrestrial Eutrophication), and the update of the normalization factor for Ionising Radiation, toxicity-related impact categories and Land Use. Additionally, inventories have been revised systematically to be consistent with new release of data.

[16] Major contributors to this impact category are heavy metals as Mercury and Lead.

Figure 5: EU-28 Domestic footprint (2018) impact per citizen compared to global impacts and Planetary Boundaries.

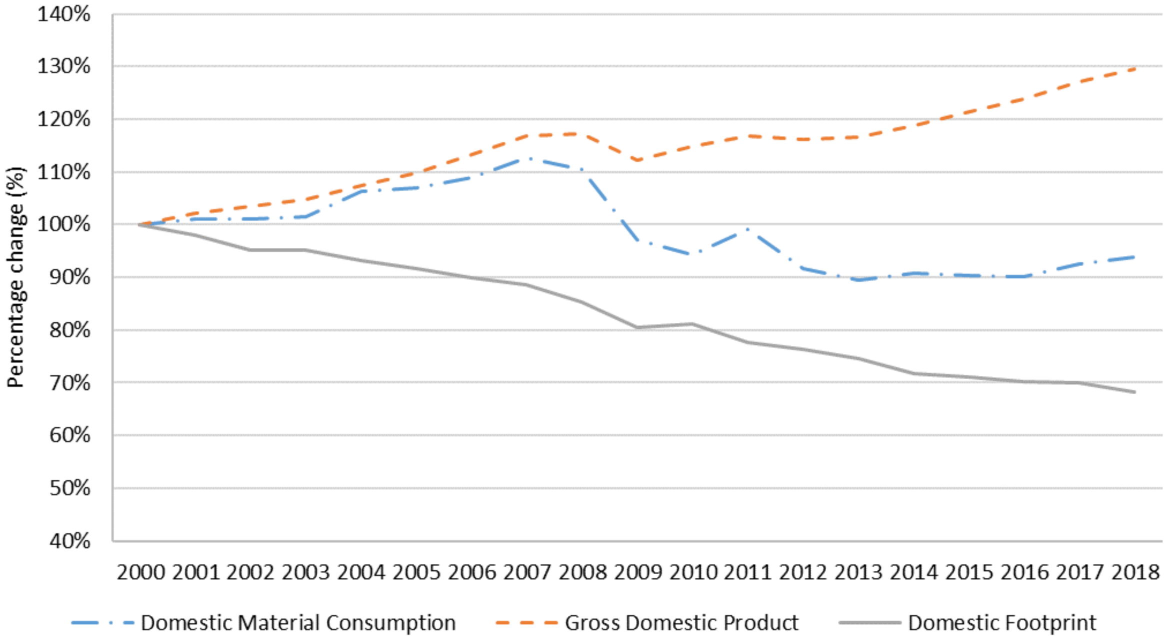


Note that the current estimation of HTOX_nc at the global level in Figure 5 is under elaboration within the revision of the global normalization factors of the Environmental Footprint method. Continuous refinement of the indicator and the Environmental Footprint method (including the normalization factors) may take place, the reader is encouraged to explore most updated results of the Domestic Footprint, which are available at the Consumption Footprint Platform - https://eplca.jrc.ec.europa.eu/ConsumptionFootprintPlatform.html.

5.2 Evolution of the Domestic Footprint over time

In the period 2000-2018 the single weighted score of the EU-28 Domestic Footprint decreased by 32% (Figure 6), following a steady decrease which has been even accelerated by the economic crisis of 2008. At the same time the Gross Domestic Product (GDP) (Eurostat, 2020m) grew by 30% confirming the absolute decoupling of environmental impacts of EU domestic production and consumption from economic growth. This result is in line with previous analysis for the period 2005-2014 (Sanyé-Mengual et al., 2019). Comparing the Domestic Footprint indicator with the trend of the Domestic Material Consumption (DMC), an indicator developed by ESTAT for assessing the use of resources (Eurostat, 2020n), differences in trends are observed (Figure 6). While the EU Domestic Footprint shows a constant decreasing trend along the whole period, DMC decrease starts only after 2008. The DMC trend highlights an increased resource efficiency in the EU economy, i.e., an increased economic value of produced goods and services (represented by GDP) but a decrease of the amount of materials resources consumed. The larger scope of the Domestic Footprint indicator, including resource use and environmental emissions, allows for confirming an increasing decoupling of EU production with lower environmental impacts per generated revenue along time.

Figure 6: Domestic Footprint single weighted score: trend over 2000-2018 compared with GDP and Domestic Material Consumption.



5.3 The role of the different Member States

Figure 7 shows the comparison of the Domestic Footprint single weighted score at country level. The comparison is presented as total impact, impact per capita (population) and impact per square kilometre (area). While the total impact in 2000 was mainly due to the biggest countries in terms of population (i.e., France, Germany, United Kingdom, Italy, Spain and Poland), in 2018 these countries significantly reduced their impact, apart from Poland with the smallest decrease.

Analysing the results per capita, the distribution of impacts appears to be narrower among Member States in 2018 than in 2000. Indeed, while the average impact for EU in 2000 was around 1.9E-10 points, with a maximum impact in Ireland (over 4.5E-10 points) and a minimum in Lithuania (less than 1.4E-10); in 2018 the average for EU was 1.9E-10, ranging between 3.1E-10 (Latvia) and 7.8E-11 (Malta). In general, a decreasing trend of impact per citizen can be seen in most of the countries. However, a slight increase in impact per capita can be observed in Latvia and Lithuania.

Figure 7: Domestic Footprint weighted score in EU Member States in 2000 and 2018. Total impact per country.

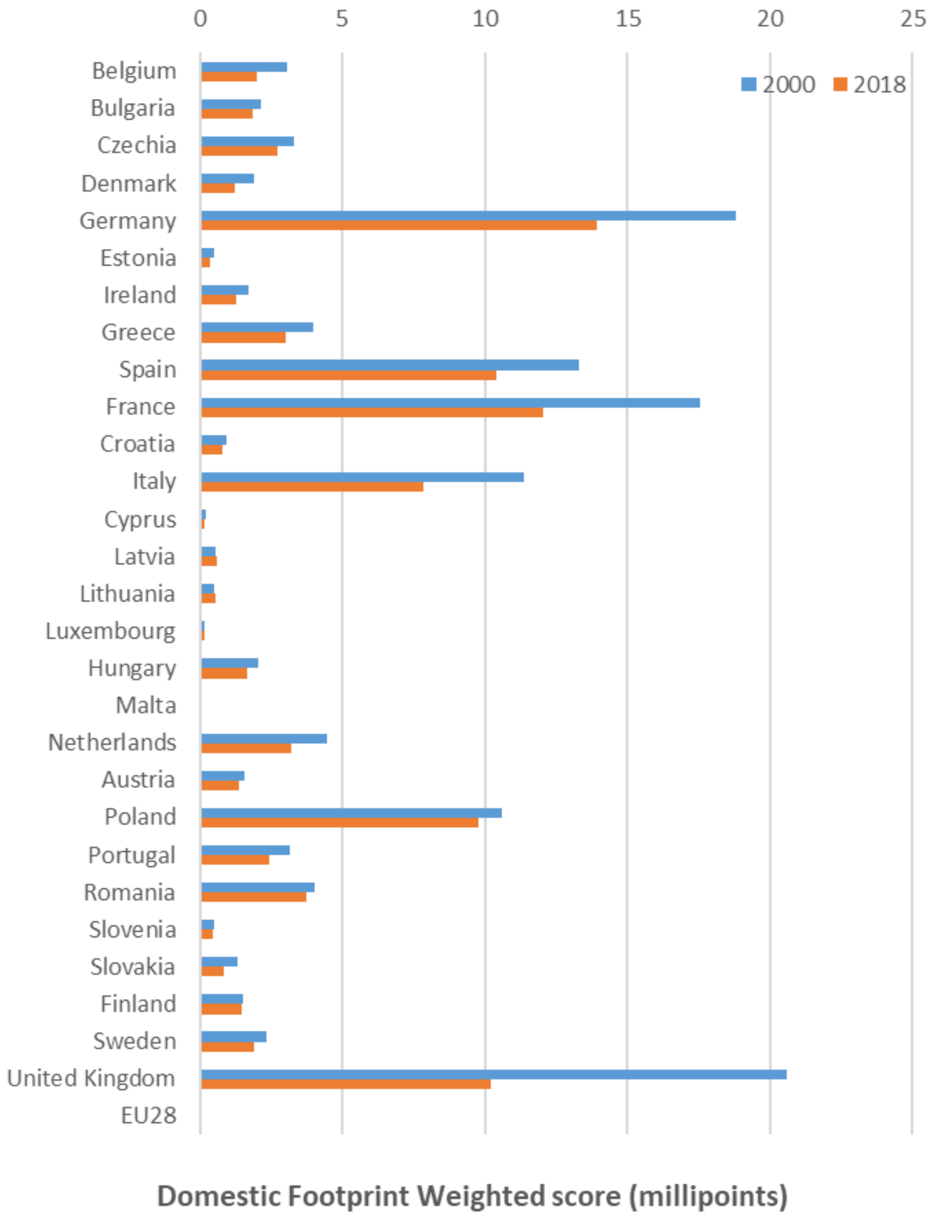


Figure 8: Domestic Footprint weighted score per citizen in EU Member States in 2000 and 2018.

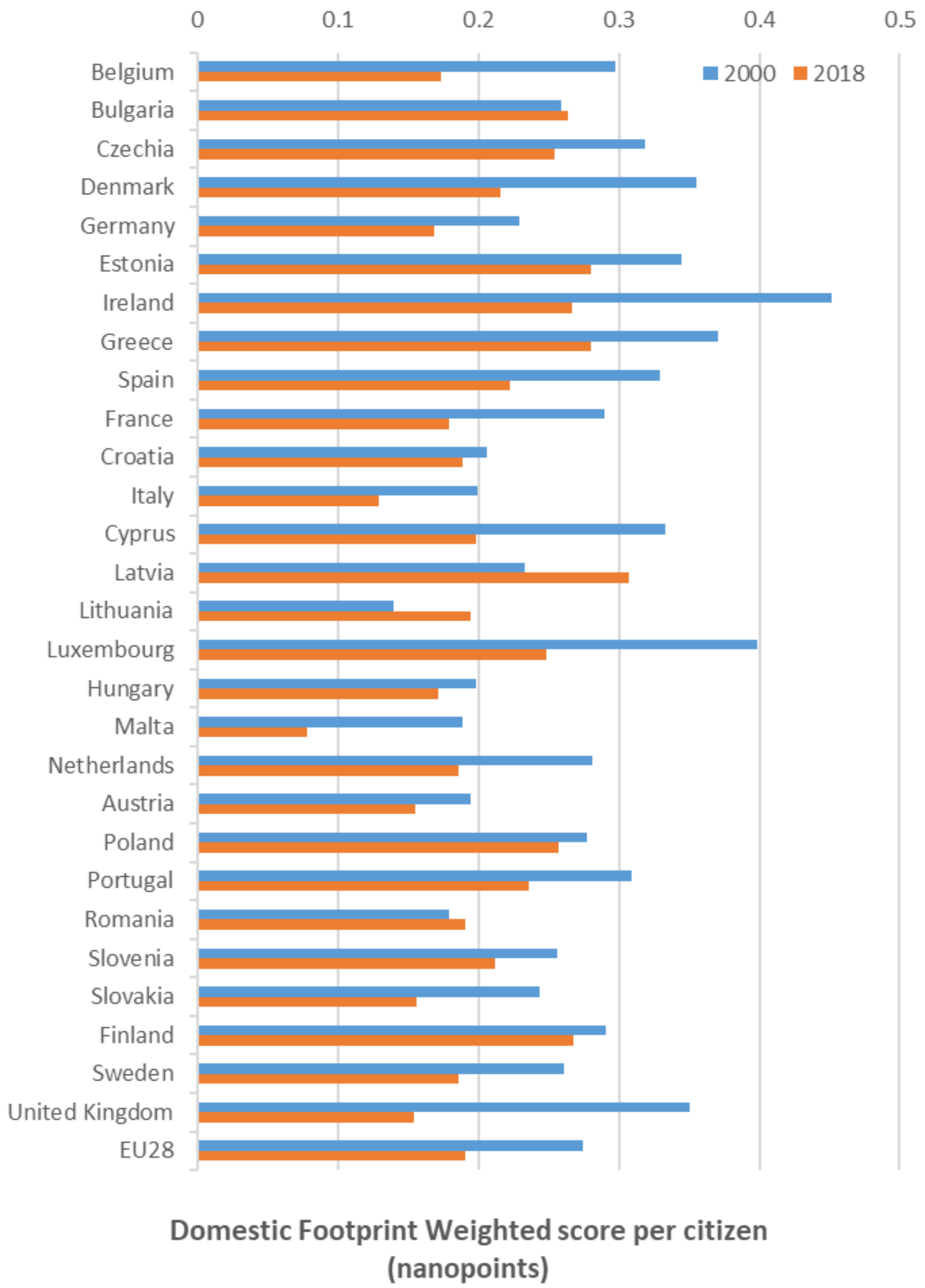
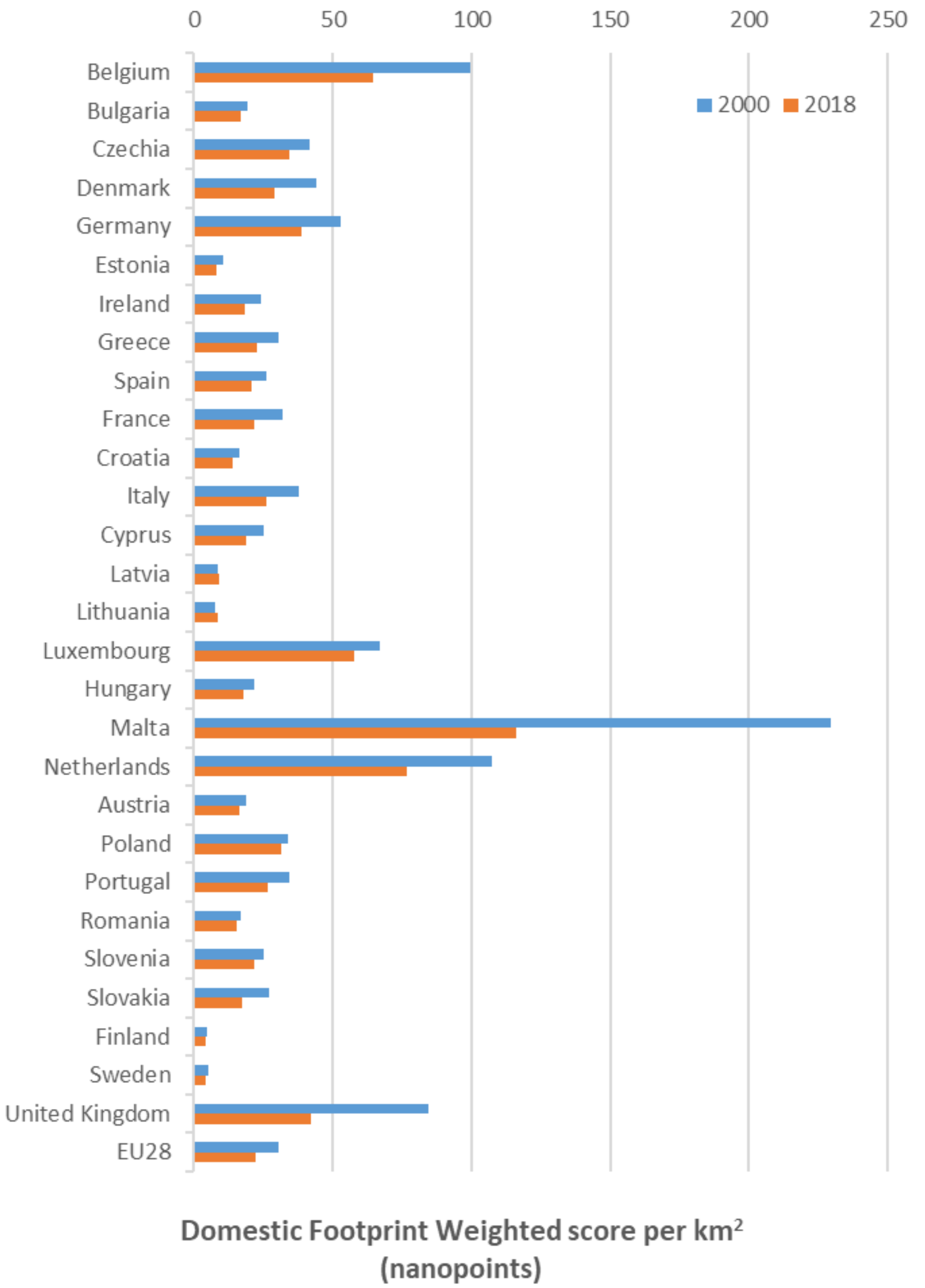


Figure 9: Domestic Footprint weighted score per km² in EU Member States in 2000 and 2018.



Since Member States contribute differently to the overall environmental impact, an analysis of the individual impact categories of the Domestic Footprint is provided in Figure 10. The impact per capita of the different Member States is ranked and compared with the impact of an average European citizen (set to 1). Differences among Member States can be determined by specific underlying socio-economic and environmental conditions, such as:

- The level of economic growth of the different Member States, in terms of GDP, can lead to a larger Domestic Footprint per capita. This can be observed for Climate change, with countries showing a large increase between 2000 and 2018 (e.g., Croatia, Czechia, Poland, Lithuania, Latvia, Estonia and Slovenia) associated to an economic growth larger than the average EU growth.
- The electricity market and the different technologies employed in the national electricity mix can determine the environmental profile of electricity consumption. This can largely affect some categories, such as

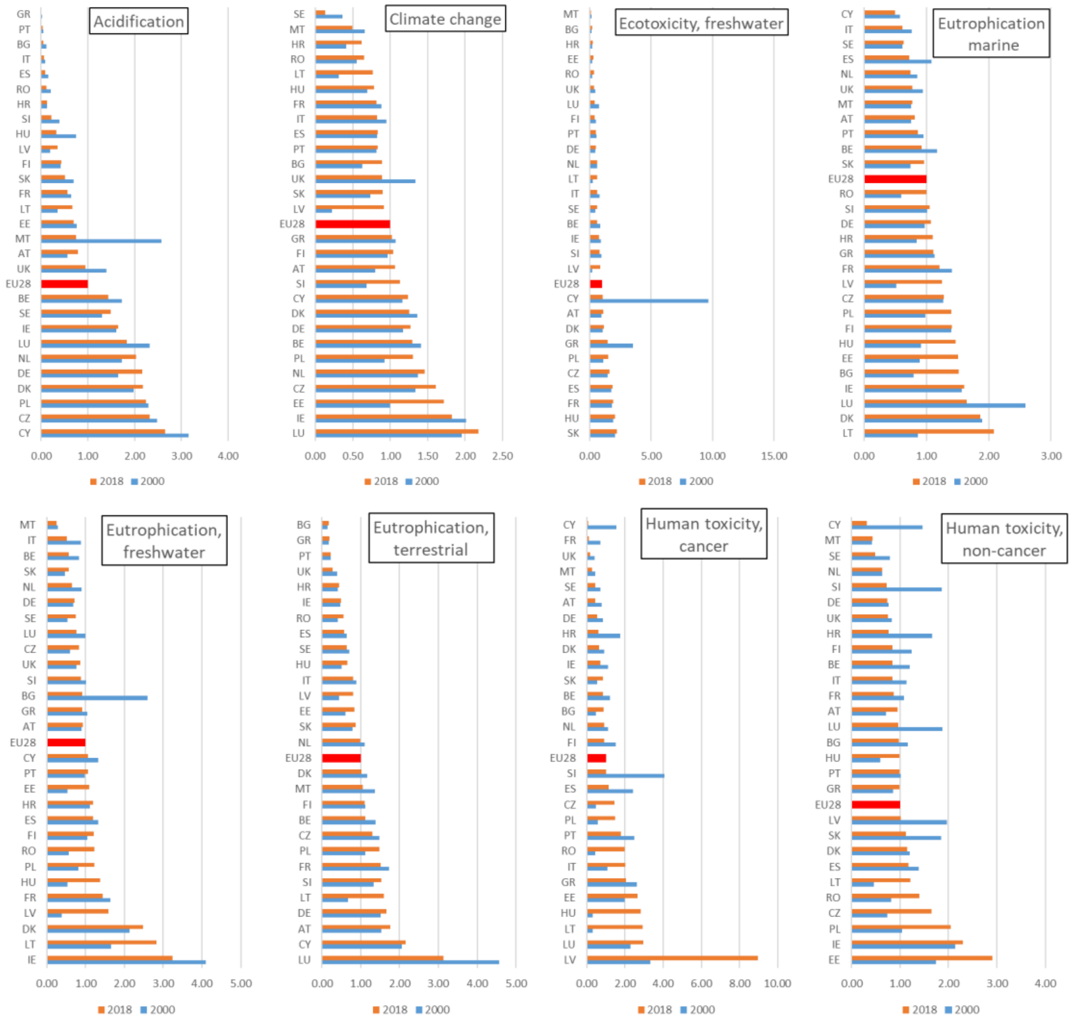
Ionising Radiation. This impact category is dominated by the contribution of France and United Kingdom with an impact per citizen that is respectively 2 and 4 times the EU average. This is due to the vast use of nuclear energy in these countries and to the reprocessing of spent nuclear fuel, which takes place only in these two countries.

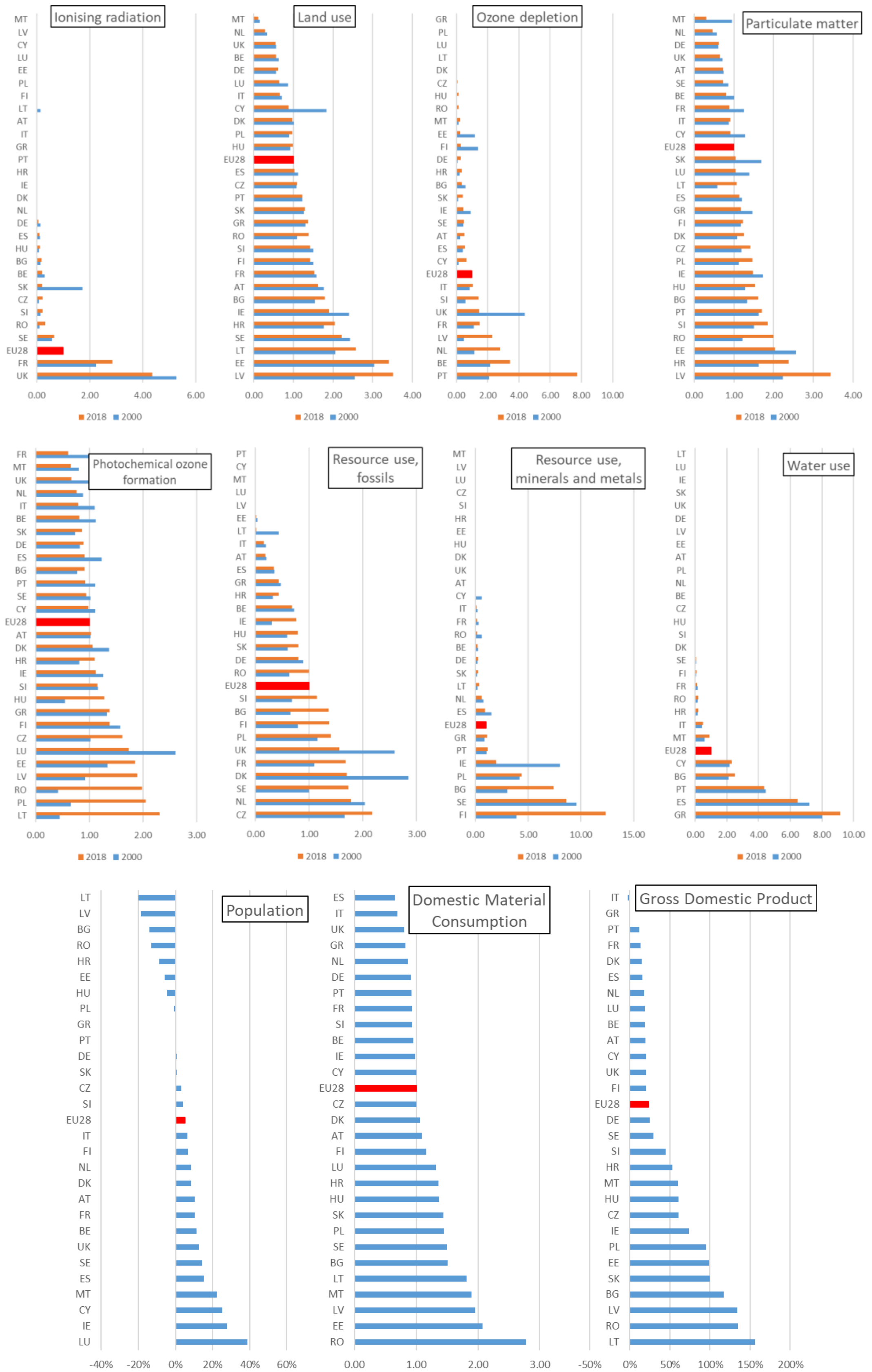
— The availability of natural resources varies among EU Member States setting the context for resource extraction and the role of specific countries in the global market. The market evolution and territorial conditions can affect categories such as Fossil Resource Depletion and Water Use.

  - Between 2000 and 2018, a pattern change was observed for Fossil Resource Depletion: on one hand, countries with a relevant impact (e.g., United Kingdom and Denmark) showed a significant reduction; on the other hand, a number of other countries showed an increase including both emerging economies (such as Poland, Czechia) and more developed countries (e.g., Finland).

  - Water use shows 5 countries with impact over the average (Greece, Spain, Portugal, Bulgaria and Cyprus) and two of them with impact close to the average (Malta and Italy). For the other Member States, Water use per citizen is considerably smaller. This can result from two aspects: firstly, a higher water use in these countries linked to, e.g., agricultural activities; and secondly, to a lower water availability in these countries, being water scarcity at the core of this impact category.

Figure 10: Domestic footprint per citizen in 2018 and 2000: Ranking of Member States per impact category and comparison with the EU average footprint. Change in population, domestic material consumption and gross domestic product by country between 2000 and 2018.





Note: The presented values for all impact categories and DMC correspond to the impact per citizen of the country over the impact of the average EU citizen (therefore EU value is 1). For the population, percentage change is shown, while for GDP absolute change in GDP per citizen.

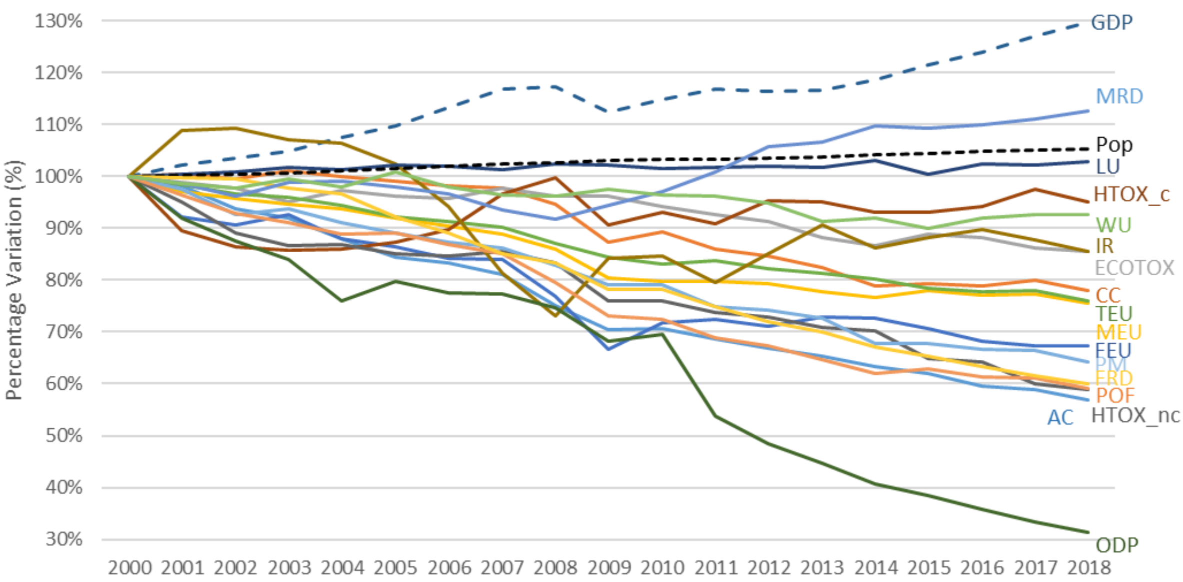
5.4 The relevance of an integrated approach, addressing different impact categories

When the trend of the impact categories along 2000-2018 is analysed individually (Figure 11), the different contribution to the overall decrease of the Domestic Footprint and the observed absolute decoupling can be further explored. There is a group of indicators in which the decreasing trend is steady along this period, including Climate Change, Eutrophication, Acidification, Ozone Depletion, Resource Depletion, Particulate Matter, Human Toxicity non-cancer and Photochemical Ozone Formation. The same trend appears also for Water Use but with a slower rate. This decreasing is mainly associated to the implementation of EU environmental policies targeting the decrease of environmental emissions and resource use, such as the Directive on National emissions ceilings (EC, 2001), the implementation of the EU Emissions Trading System (EC, 2003) or the Directive on air quality (EC, 2008) (Sanyé-Mengual et al., 2019).

On the contrary, there are two indicators with an increasing trend. Firstly, Land Use impacts shows a limited growth (+3%), lower than population which grew by 5% in this period (2000-2018), associated to an increasing transformation of natural land for anthropogenic uses (e.g., urbanisation and agricultural activities). Secondly, Minerals and Metals Resource Depletion shows the largest increase in impact, after a partial decrease in 2000-2008. The largest contribution to this impact category is due to the extraction of precious metals (e.g., silver and gold) which can be associated to an increased use of technological devices with electronic elements.

Lastly, Human Toxicity, cancer and Ionising Radiation showed a variable trend along the analysed period. The first one which is almost constant after and an initial decrease in 2001. For Ionising Radiation, a drop in impacts happened in the period 2004-2008 followed by a slow increase up to 2018. In this case the initial trend is due to the emissions from nuclear power plants in France and United Kingdom.

Figure 11: Environmental impact decoupling of the Domestic Footprint along 2000-2018, compared to Gross Domestic Product (GDP) and population.



Note: Results for 2000 are reported as 100%, and results for the other years are rescaled accordingly. Gross Domestic Product (GDP), and population data source: Eurostat (2020m; 2020n; 2020i). Acronyms are detailed in Table 1.

An analysis at the elementary flow level allows for exploring the role of the environmental pressures (i.e., resource use, emissions to the environment) originating from domestic activities. For the EU-28 Domestic Footprint in 2018 (Figure 11), it is possible to observe the following aspects:

Several indicators are driven by a small group of elementary flows. For example, Climate Change, Water Use, Particulate Matter, Ionising Radiation Freshwater and Marine Eutrophication are affected for more than 70% from a single substance/resource.

Ecotoxicity indicators are driven by several substances, all of them contributing for a small part of the impact. It is important to notice that most of these substances are emitted in agricultural activities (i.e., originating from the application of plant protection products).

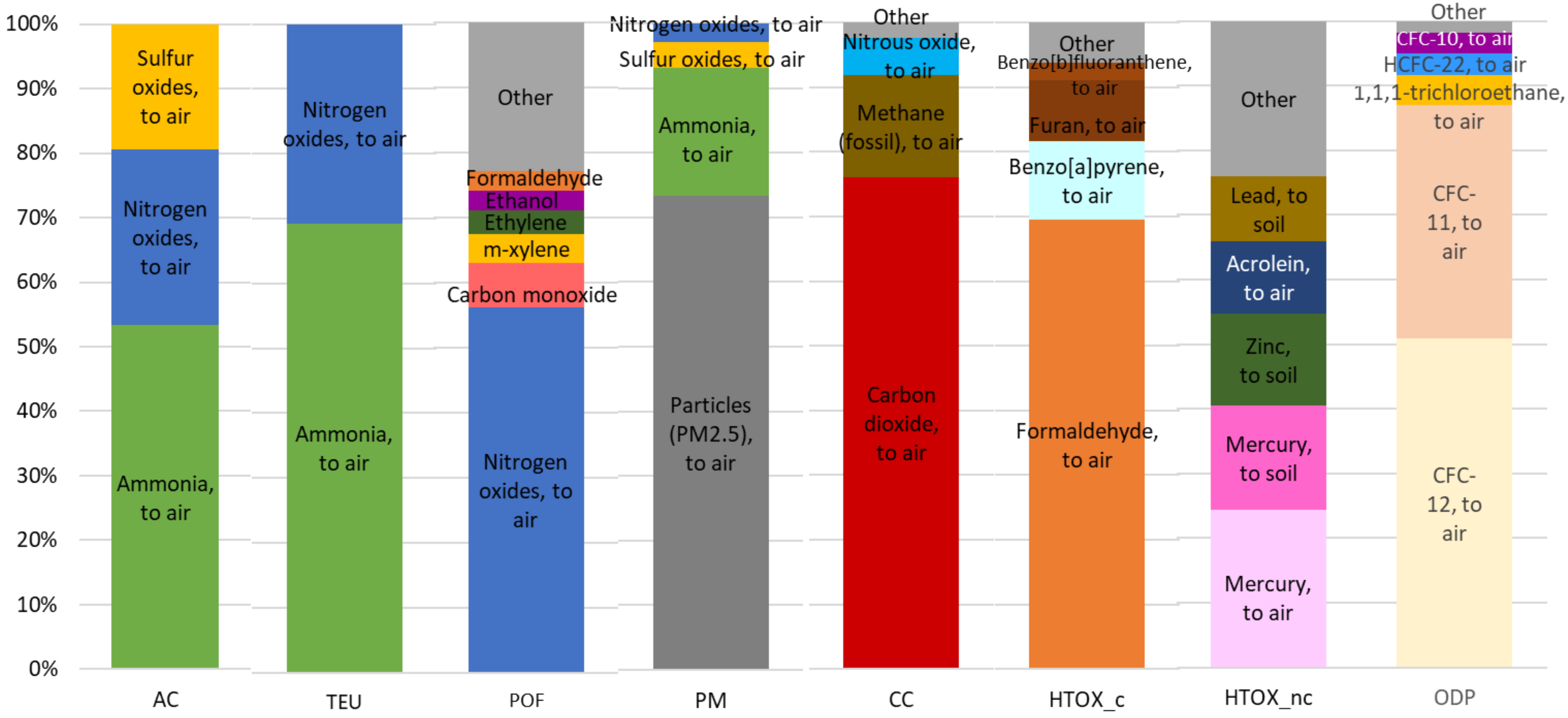
Some substances contribution to diverse environmental impacts, as nitrogen oxides or ammonia, both of them influencing four impact categories.

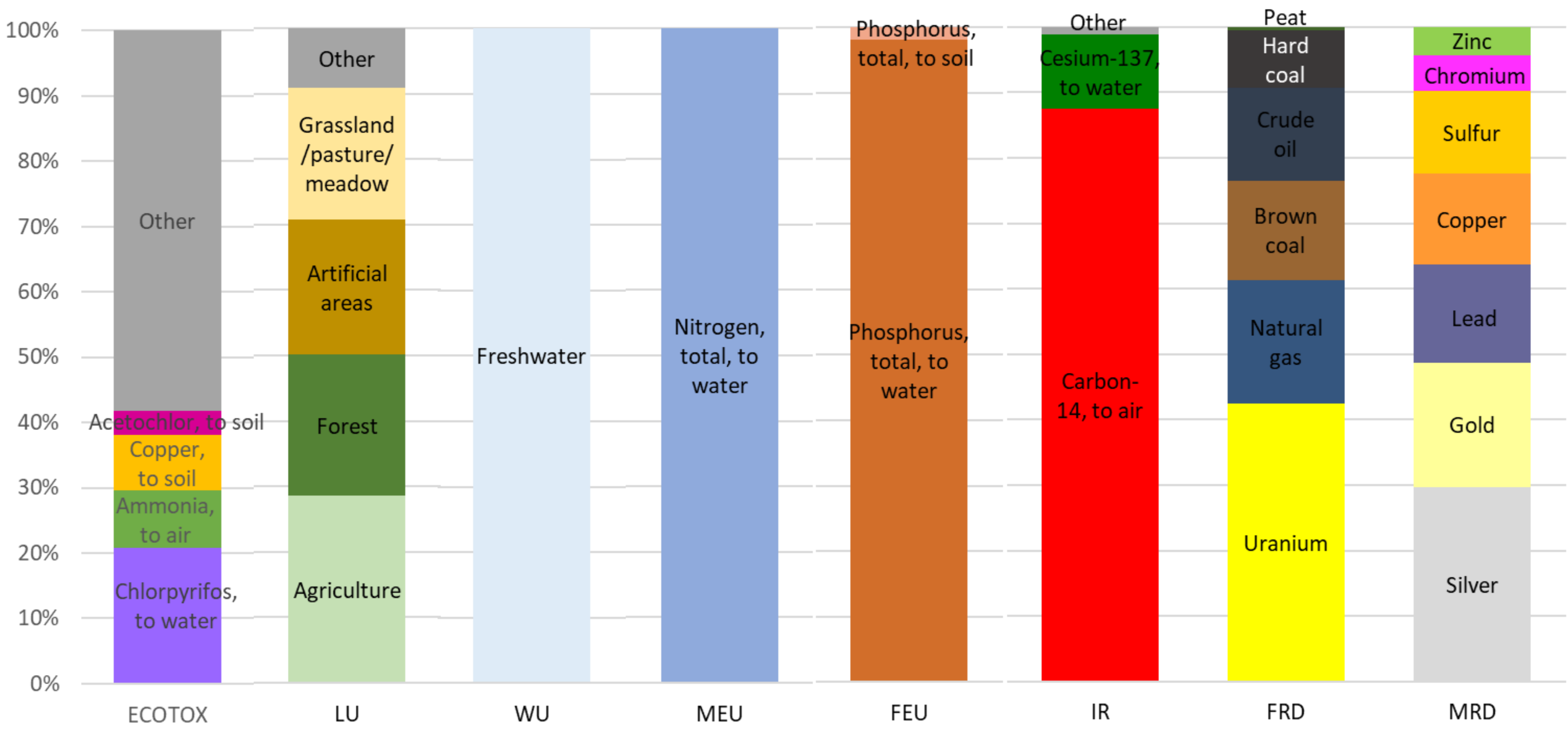
Some substances are linked to the same anthropic activities, such as:

- combustion of fossil fuels for heating, power generation or mobility is responsible of relevant emission of carbon dioxide, nitrogen oxides, sulphur oxides and particulate matter. These substances alone have influence on 6 impact categories (AC, TEU, CC, HTOX_nc, POF and PM). In addition, combustion of fossil fuels also contributes to FRD.
- agricultural activities on the other side are involved in the emission of ammonia, nitrogen and phosphorus in soil and water, pesticides, heavy metals and to water and land use. These substances significantly affect 9 indicators (AC, TEU, LU; WU, HTOX_nc, ECOTOX, POF, MEU, FEU).

These findings lead to the conclusion that a small group of substances is responsible for most of the EU domestic impacts across all impact categories. Reducing such emissions could address several environmental impacts simultaneously.

Figure 12: Domestic Footprint in EU: key emissions and resources driving the overall impact per impact category.



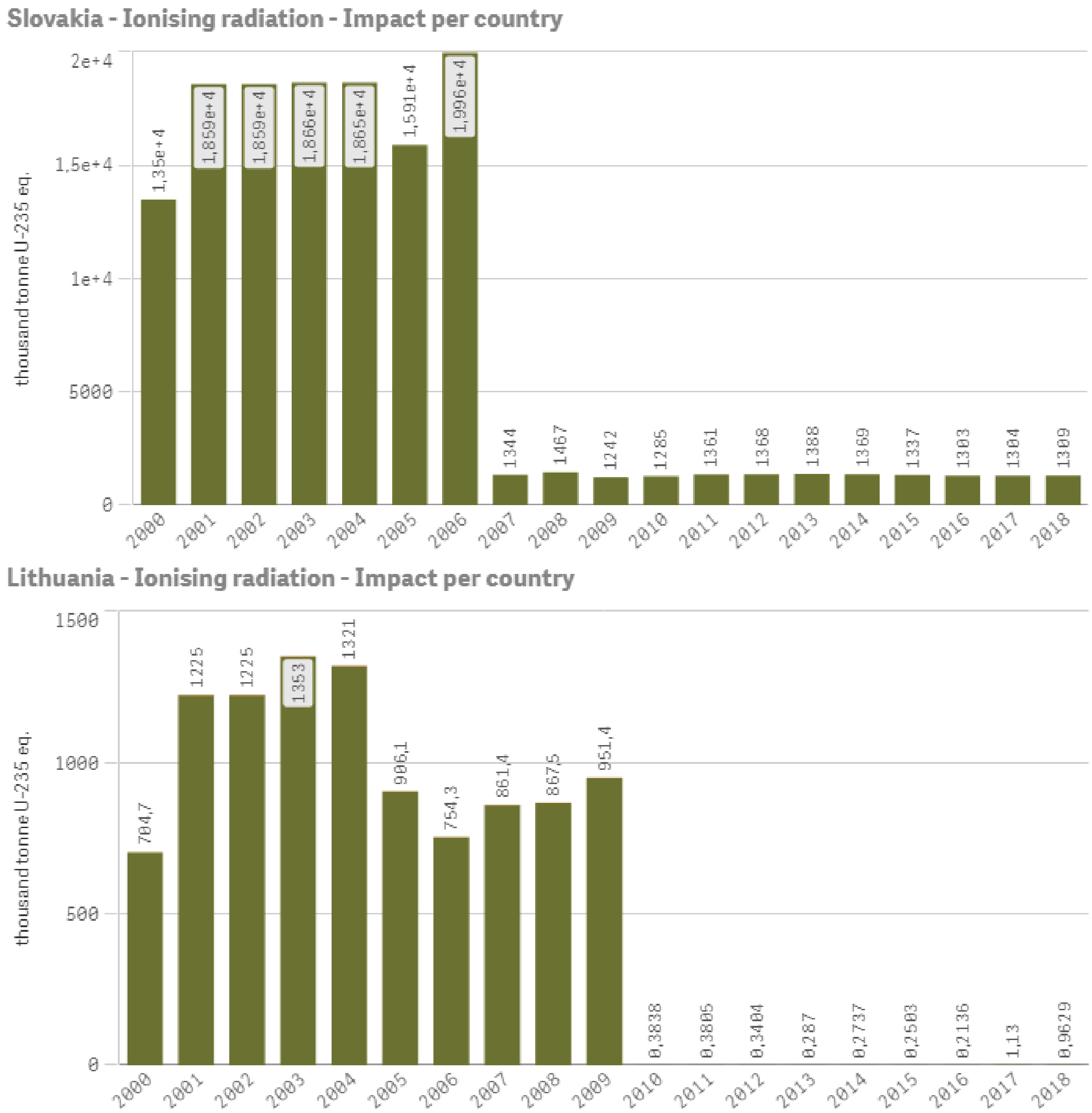

100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Other
Acetochlor, to soil
Copper, to soil
Ammonia, to air
Chlorpyrifos, to water
Other
Grassland /pasture/ meadow
Artificial areas
Forest
Agriculture
Freshwater
Nitrogen, total, to water
Phosphorus, total, to soil
Phosphorus, total, to water
Other
Cesium-137, to water
Carbon-14, to air
Peat
Hard coal
Crude oil
Brown coal
Natural gas
Uranium
Zinc
Chromium
Sulfur
Copper
Lead
Gold
Silver
ECOTOX
LU
WU
MEU
FEU
IR
FRD
MRD

5.5 Observed issues in underlying data

A systematic review of underlying data for compiling the inventory of EU and Member State Domestic Footprint unveiled variability along the analysed time frame. Abrupt changes in impact categories for specific countries were analysed towards identifying the source of this variability, e.g., socio-economic context leading to changes in resource use or environmental emissions, or underlying data from the employed sources. This systematic review was employed supported by the data visualization in the Consumption Footprint Platform.[17]

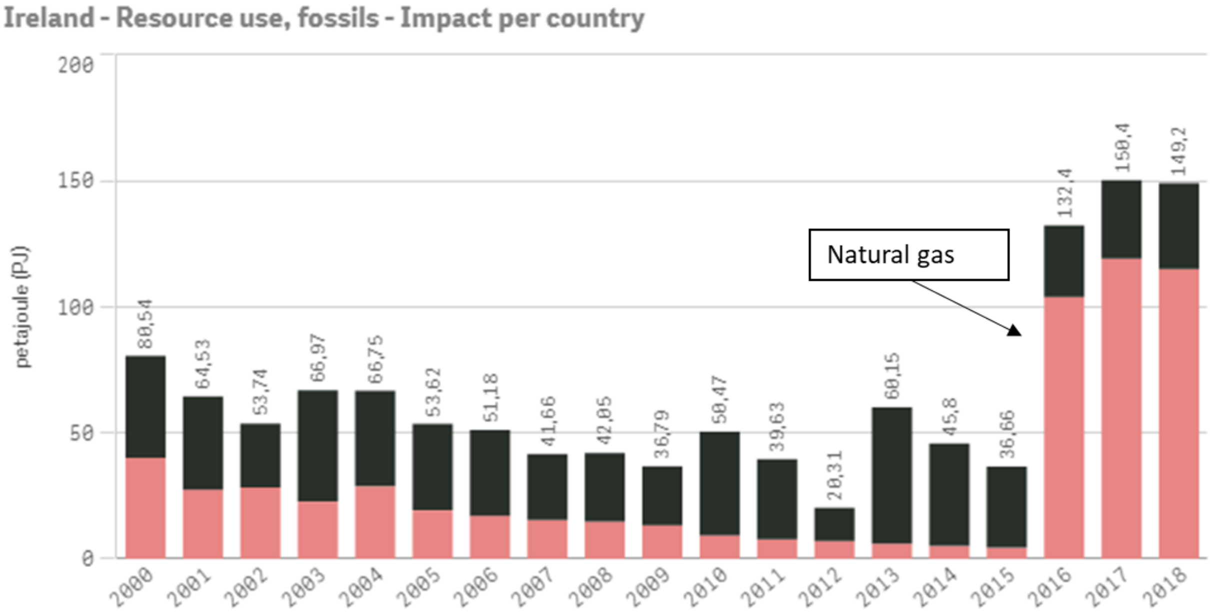
Regarding socio-economic characteristics, two aspects were observed. On one hand, changes in nuclear power capacity can affect the Ionising Radiation impact category. This is the case of the phase-out of nuclear plants in Lithuania in 2009 and the shutdown of the last heavy water power plant in Slovakia in 2006, both leading to a significant reduction of the Ionising Radiation impact (Figure 13). On the other hand, an increase in fossil resources extraction through the implementation of new energy plans can be observed in the Fossil Resource Depletion indicator. For example, Ireland shows an increase in impacts due to the start-up of a new gas field, i.e., the Corrib offshore facilities starting in late 2015 (Figure 14).

Figure 13: Time-series of Ionising Radiation impact for Lithuania and Slovakia.



[17] https://eplca.jrc.ec.europa.eu/ConsumptionFootprint/

Figure 14: Time-series of Fossil Resource Depletion for Ireland.



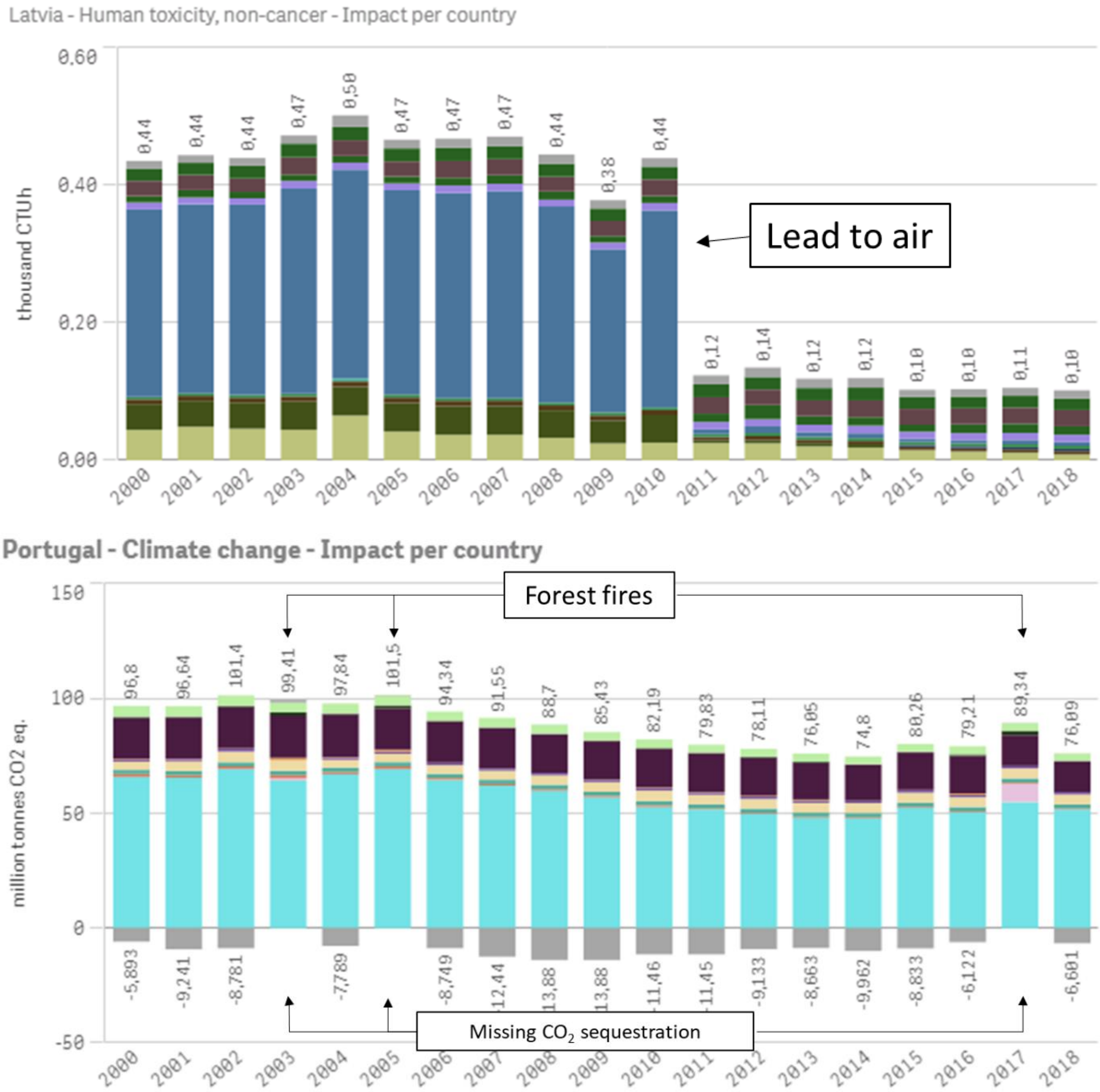
Concerning issues with underlying data, outlier values in the original data sources were identified and further investigated by contacting data providers. This analysis supported the identification of the following aspects (Figure 15):

- Abrupt changes in CO_2 emission due to Land Use change in some countries for specific years can be associated to different reasons[18], such as: a non-annual review of the Land Use, incidence of wildfires and changes in land use change.
- Outliers of emission of heavy metals to air for specific countries and years correspond to the official data reported by countries, for which the data source (EMEP) could not provide specific causes. In this case the best approach is to update emissions for all years every time that an update of the Domestic Footprint since every country resubmit all data every year.
- Carbon-14 emission to seawater for Sweden in 2010 was identified as outlier. The data source provider (OSPAR) confirmed that the value was incorrect and shall be disregarded[19].

[18] Although UNFCCC is the data source for these emissions, the underlying dataset for EU countries originated from the European Environment Agency (EEA).

[19] OSPAR consulted with the country as data provider confirming the error spotted during the systematic review.

Figure 15: Time-series of Climate Change impact for Portugal and Human Toxicity, non-cancer for Latvia.



6 Conclusions and outlook

The Domestic Footprint time-series has been evaluated for the period 2000-2018 at both EU and Member State level. The analysis included an update of the impact assessment method (i.e., EF 3.0), as well as a systematic review of the data and data sources. The analysis confirms the results of the previous assessments and leads to new insights on the European environmental impacts.

— There is a **clear path of decoupling of domestic environmental impacts from economic growth for the whole EU-28 area**. When compared to the trend of DMC, the absolute decoupling of environmental impacts shows a more intense decreasing than material consumption. Most of the impact categories show absolute decoupling for the assessed period, while impacts on the categories Land Use and Resource Depletion of Minerals and Metals increased. Notwithstanding the different economic growth of Member States, a convergence in the impact per citizen can be observed leading to a reduced variability among countries. This can be associated to domestic EU environmental policies leading to more environmentally friendly production technologies.

— However, **three planetary boundaries are transgressed** indicating that the environmental impacts due to EU domestic production and consumption are currently beyond science-based quantitative ecological thresholds, potentially pushing ecological processes to reach tipping points. This is the case of impacts on **Climate Change, Particulate Matter and Resource Depletion of Minerals and Metals**. However, it has to be noted that specific planetary boundaries are still very controversial, either for their scale-related nature (e.g. freshwater, which can be very critical when looked at watershed scale instead of the global scale) or not yet agreed in the scientific community (e.g. for novel entities, resulting in the boundaries for the toxicity related impact categories adopted here).

— Several impact categories show impacts driven by a limited number of environmental pressures (i.e., resource use and emissions to the environment (e.g., carbon dioxide, nitrogen oxides, particulate matter and ammonia). Two activities were identified as main drivers for the emission of these substances: agriculture and fossil fuels consumption.

The methodological differences in the data sources, in data-coverage for countries may introduce uncertainty. In particular, toxicity related impacts are due to a high number of substances, for some of them (e.g., pesticides) complete data are not readily available, leading to uncertainty in impact trends. It is also worth noticing that extrapolation and gap-filling procedures may affect some of the resulting trend in the time-series.

In order to improve data quality, the next steps could encompass the following strategies:

— Introduce a systematic procedure to contact the main data provider in case data gaps or anomalies are found during the update of the Domestic Footprint.

— Create a set of automatized tools to retrieve, verify and process data from public databases according to the presented models.

— Constantly monitor the availability of new, reliable environmental data with the goal of using them to improve the Domestic Footprint model.

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List of abbreviations

AI	Active ingredient
BGS	British Geological Survey
CF	Characterisation factor
CTU	Comparative toxic units
DMC	Domestic Material Consumption
EF	Environmental Footprint
GDP	Gross Domestic Product
GHG	Greenhouse Gas
HCB	Hexachlorobenzene
HCFC	Hydrochlorofluorocarbon
HM	Heavy metal
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LULUCF	Land use, land-use change and forestry
NACE	Statistical classification of economic activities in the European Community
NF	Normalization Factor
NMVOCs	Non-methane volatile organic compounds
OEF	Organisation Environmental Footprint
PAH	Polycyclic-aromatic hydrocarbons
PB	Planetary Boundary
PFC	Perfluorinated compound
PEF	Product Environmental Footprint
POP	Persistent organic pollutant
SDG	Sustainable Development Goal
UNFCCC	United Nations Convention on Climate Change
UNSCEAR	United Nation Scientific Committee on the Effects of Atomic Radiation
USGS	United States Geological Survey
WMO	World Meteorological Service
WF	Weighting Factor
WWTP	Wastewater treatment plant

Impact categories

AC	Acidification
CC	Climate change
ECOTOX	Ecotoxicity, freshwater
FEU	Eutrophication, freshwater

FRD	Resource use, fossils
HTOX_c	Human toxicity, cancer
HTOX_nc	Human toxicity, non-cancer
IR	Ionising radiation, human health
LU	Land use
MEU	Eutrophication, marine
MRD	Resource use, mineral and metals
ODP	Ozone depletion
PM	Particulate matter
POF	Photochemical ozone formation, human health
TEU	Eutrophication, terrestrial
WU	Water use

List of figures

List of tables

Annexes

Annex 1. Elementary flows covered in domestic footprint

Table A-1: Substances, data sources and elaboration requirements and presence of a corresponding CF in EF3.0 method for Climate change

Substance	**Source**	**Data elaboration**	**CF in the EF 3.0**
carbon dioxide (biogenic)	UNFCCC (2020)	No elaboration performed	Yes
carbon dioxide (fossil)	UNFCCC (2020)	No elaboration performed	Yes
Carbon dioxide (land use change)	UNFCCC (2020)	No elaboration performed	Yes
methane (fossil)	UNFCCC (2020)	No elaboration performed	Yes
methane (biogenic)	UNFCCC (2020)	No elaboration performed	Yes
methane (land use change)	UNFCCC (2020)	No elaboration performed	Yes
nitrous oxide	UNFCCC (2020)	No elaboration performed	Yes
sulphur hexafluoride	UNFCCC (2020)	No elaboration performed	Yes
carbon monoxide (fossil)	EMEP (2020)	No elaboration performed	Yes
HCFC-141b	EDGAR	See section 4.2	Yes
HCFC-142b	EDGAR	See section 4.2	Yes
HCFC-21	E-PRTR (2020)	See section 4.3	Yes.
HCFC-22	E-PRTR (2020)	See section 4.3	Yes.
CFC-10	E-PRTR (2020)	See section 4.3	Yes.
CFC-11	EDGAR	See section 4.2	Yes
CFC-12	EDGAR	See section 4.2	Yes
1,1,2-trichlorotrifluoroethane	E-PRTR (2020)	See section 4.3	Yes.
1,2-dichloroethane	E-PRTR (2020)	See section 4.3	Yes.
Trichloromethane	E-PRTR (2020)	See section 4.3	Yes.
Dichloromethane	E-PRTR (2020)	See section 4.3	Yes.
methyl acetate	E-PRTR (2020)	See section 4.3	Yes.
volatile organic compound	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes

Table A-2 : Substances, data sources, and elaboration requirements and presence of a corresponding CF in EF 3.0 method for Toxicity impact categories.

Substance	**Source**	**Data elaboration**	**CF in the EF3.0**
1,1,1-trichloroethane	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
1,1,2,2-tetrachloroethane	E-PRTR (2020)	See section 4.3	Yes.
1,2-dichlorobenzene	EEA (2020),	See section 4.3	Yes.
1,2-dichloroethane	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
1,2,4-trichlorobenzene	E-PRTR (2020)	See section 4.3	Yes.
1,3-dichlorobenzene	E-PRTR (2020)	See section 4.3	Yes.
4-(1,1,3,3-tetramethylbutyl)phenol	E-PRTR (2020)	See section 4.3	Yes.
4,4'-isopropylidenediphenol	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
6-methylbenzotriazole	E-PRTR (2020)	See section 4.3	No.
Acenaphthene	EEA (2020)	See section 4.3	Yes.
Acenaphthylene	EEA (2020)	See section 4.3	No.
Aluminium	E-PRTR (2020), EEA (2020)	See section 4.3	No.
Anthracene	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Antimony	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Arsenic	E-PRTR (2020), Waterbase, Leclerc et al. (2017)	See section 4.3	Yes.
Asbestos	E-PRTR (2020)	See section 4.3	No.
Barium	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Benz[a]anthracene	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.

Benzene	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Benzo(g,h,i)perylene	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Benzo[def]chrysene	E-PRTR (2020), EEA (2020)	See section 4.3	No.
Benzo[e]acephenanthrylene	E-PRTR (2020), EEA (2020)	See section 4.3	No.
Benzo(k)fluoranthene	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Bromide	E-PRTR (2020)	See section 4.3	Yes.
Brominated diphenylethers	E-PRTR (2020), EEA (2020)	See section 4.3	No.
Cadmium	E-PRTR (2020), EEA (2020), Leclerc et al. (2017)	See section 4.3	Yes.
Calcium	E-PRTR (2020)	See section 4.3	No.
Chlorides	E-PRTR (2020), EEA (2020)	See section 4.3	No.
Chloro-alkanes	E-PRTR (2020)	See section 4.3	No.
Chlorobenzene	E-PRTR (2020)	See section 4.3	Yes.
Chromium	E-PRTR (2020), EEA (2020), Leclerc et al. (2017), EC (2010b), UN-HABITAT (2008)	See section 4.3	Yes.
Chromium trioxide	E-PRTR (2020)	See section 4.3	No.
Chrysene	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Cobalt	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Copper	E-PRTR (2020), EEA (2020), Leclerc et al. (2017), EC (2010b), UN-HABITAT (2008)	See section 4.3	Yes.
Cyanides	E-PRTR (2020), EEA (2020)	See section 4.3	No.
Di-(2-ethyl hexyl) phthalate	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Diammonium hydrogenorthophosphate	E-PRTR (2020), EEA (2020)	See section 4.3	No.
Dibenz[a,h]anthracene	EEA (2020)	See section 4.3	Yes.
Dibutyl phthalate	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Dichloromethane	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Diisobutyl phthalate	E-PRTR (2020)	See section 4.3	Yes.
Ethyl benzene	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Ethylene oxide	E-PRTR (2020)	See section 4.3	Yes.
Fluoranthene	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Fluorene	EEA (2020)	See section 4.3	No.
Fluorides	E-PRTR (2020)	See section 4.3	Yes.
Formaldehyde	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Halides, Total Organic	E-PRTR (2020), EEA (2020)	See section 4.3	No.
Halogenated organic compounds	E-PRTR (2020), EEA (2020)	See section 4.3	No.
Hexabromobiphenyl	E-PRTR (2020)	See section 4.3	No.
Hexachlorobenzene	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Hexachlorobutadiene	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Indeno(1,2,3-cd)pyrene	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Iron	E-PRTR (2020)	See section 4.3	Yes.
Lead	E-PRTR (2020), EEA (2020), Leclerc et al. (2017), EC (2010b), UN-HABITAT (2008)	See section 4.3	Yes.
Magnesium	E-PRTR (2020)	See section 4.3	Yes.
Manganese	E-PRTR (2020)	See section 4.3	Yes.
Mercury	E-PRTR (2020), EEA (2020), Leclerc et al. (2017), EC (2010b), UN-HABITAT (2008)	See section 4.3	Yes.
Molybdenum	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Naphthalene	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Nickel	E-PRTR (2020), EEA (2020), Leclerc et al. (2017), EC (2010b), UN-HABITAT (2008)	See section 4.3	Yes.
Nitrobenzene	E-PRTR (2020)	See section 4.3	No.
Nonylphenol and Nonylphenol ethoxylates	E-PRTR (2020)	See section 4.3	Yes.
Octylphenols and Octylphenol ethoxylates	E-PRTR (2020)	See section 4.3	No.
Organotin compounds	E-PRTR (2020)	See section 4.3	No
p-nonylphenol	E-PRTR (2020)	See section 4.3	Yes.
PCDD + PCDF	E-PRTR (2020)	See section 4.3	No.
Pentachlorobenzene	E-PRTR (2020)	See section 4.3	Yes.
Pentachlorophenol	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Phenanthrene	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Phenols	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.

Polychlorinated biphenyls	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Polycyclic aromatic hydrocarbons	E-PRTR (2020)	See section 4.3	Yes.
Pyrene	EEA (2020)	See section 4.3	Yes.
Selenium	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Silver	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Strontium	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Styrene	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Tetrachloroethylene	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Tetrachloromethane	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Tin	E-PRTR (2020), EEA (2020)	See section 4.3	No.
Toluene	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Trichlorobenzenes	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Trichloroethylene	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Trichloromethane	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Vanadium	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Vinyl chloride	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Xylenes	E-PRTR (2020), EEA (2020)	See section 4.3	Yes.
Zinc	E-PRTR (2020), Waterbase, Leclerc et al. (2017), EC (2010b), UN-HABITAT (2008)	See section 4.3	Yes.
Chlortetracycline	Hamscher et al. (2005)	See section 4.3	Yes.
Sulfadiazine	Hamscher et al. (2005)	See section 4.3	Yes.
Sulfamethazine	Hamscher et al. (2005)	See section 4.3	Yes.
Tetracycline	Hamscher et al. (2005)	See section 4.3	Yes.

Table A-3: List of pesticides included in the Domestic Footprint and presence of a corresponding CF in EF 3.0 method for Toxicity impact categories.

Substance	**CF in the EF3.0**	**Substance**	**CF in the EF3.0**	**Substance**	**CF in the EF3.0**	**Substance**	**CF in the EF3.0**
1,3-Dichloropropene	Yes	Desmetryn	Yes	Glufosinate	Yes	Prohexadione-calcium	No.
2,4-D	Yes	Diafenthiuron	No.	Glyphosate	Yes	Prometryn	Yes
2,4-DB	Yes	Dialifos	Yes	Guazatine	No.	Propachlor	Yes
4-CPA	Yes	Diazinon	Yes	Haloxyfop	No.	Propamocarb	Yes
Abamectin	No.	Dicamba	Yes	Haloxyfop-R	Yes	Propanil	Yes
Acephate	Yes	Dichlobenil	Yes	Heptenophos	Yes	Propaquizafop	Yes
Acetochlor	Yes	Dichlofluanid	Yes	Hexaconazole	No.	Propazine	Yes
Acidenzolar	Yes	Dichlorprop	Yes	Hexaflumuron	No.	Propham	Yes
Acifluorfen	Yes	Dichlorprop-P	Yes	Hexythiazox	Yes	Propiconazole	Yes
Aclonifen	Yes	Dichlorvos	Yes	Hymexazol	Yes	Propineb	Yes
Acrinathrin	Yes	Dicloran	Yes	Imazalil	Yes	Propoxur	Yes
Alachlor	Yes	Dicofol	Yes	Imazamethabenz	No.	Propyzamide	Yes
Aldicarb	Yes	Difenoconazole	Yes	Imazaquin	Yes	Prosulfocarb	Yes
Aldimorph	No.	Difenoxuron	Yes	Imidacloprid	Yes	Prosulfuron	Yes
Alloxydim-sodium	No.	Difenzoquat	Yes	Iodosulfuron	No.	prothiocarb	No.
Alpha-cypermethrin	Yes	Difenzoquat-M	No.	Ioxynil	Yes	Prothiofos	Yes
Ametryn	Yes	Diflubenzuron	Yes	Iprodione	Yes	Pymetrozine	Yes
Amidosulfuron	Yes	Diflufenican	Yes	Iprovalicarb	Yes	Pyraclostrobin	Yes
Amitraz	Yes	Dimefuron	No.	Isofenphos	Yes	Pyrazophos	Yes
Amitrol	Yes	Dimethachlor	Yes	Isopropalin	Yes	Pyridaben	Yes
Anilazine	Yes	Dimethenamid	Yes	Isoproturon	Yes	Pyridate	Yes
Atrazine	Yes	Dimethenamid-P	Yes	Isoxaben	Yes	Pyridfenox	Yes
Azafenidin	No.	Dimethoate	Yes	Kresoxim-Methyl	Yes	Pyrimethanil	Yes
Azinphos-ethyl	Yes	Dimethomorph	Yes	Lambda-Cyhalothrin	Yes	Quinalphos	Yes
Azinphos-methyl	Yes	Dimoxystrobin	Yes	Lenacil	Yes	Quinclorac	Yes
Aziprotryn	Yes	Diniconazole	No.	Lindane	Yes	Quinmerac	Yes
Azocyclotin	Yes	Dinitramine	Yes	Linuron	Yes	Quinoclamine	Yes
Azoxystrobin	Yes	Dinocap	Yes	Lufenuron	Yes	Quinomethionate	Yes
Barium Polysulfide	No.	Dinoterb	Yes	Malathion	Yes	Quintozene	Yes
Benalaxyl	Yes	Diquat	Yes	Maleic hydrazide	Yes	Quizalofop	Yes
Benazolin	Yes	Disulfoton	Yes	Mancozeb	Yes	Quizalofop-P-ethyl	No.
Bendiocarb	Yes	Dithianon	Yes	Maneb	Yes	Resmethrin	Yes
Benfluralin	Yes	Diuron	Yes	MCPA	Yes	Rimsulfuron	Yes

Benfuracarb	Yes	DNOC	Yes	MCPB	Yes	Sethoxydim	Yes
Benfuresate	No.	Dodine	Yes	Mecoprop	Yes	Simazine	Yes
Benomyl	Yes	Endosulfan	Yes	Mecoprop-P	Yes	S-Metolachlor	Yes
Bensulfuron-methyl	No.	Epoxyconazole	No.	Mefenacet	Yes	Sodium 5-nitroguaiacolate	Yes
Bentazone	Yes	EPTC	Yes	Mepiquat	No.	Sodium orthonitrophenolate	Yes
Benzoximate	Yes	Esfenvalerate	Yes	Mepronil	No.	Sodium paranitrophenolate	Yes
Benzthiazuron	Yes	Ethalfluralin	Yes	Mesosulfuron-methyl	No.	Sodium-arsenite	No.
Beta-Cyfluthrin	Yes	Ethephon	Yes	Mesotrione	No.	Spinosad	No.
Bifenox	Yes	Ethiofencarb	Yes	Metalaxyl	Yes	Spiroxamine	Yes
Bifenthrin	Yes	Ethion	Yes	Metalaxyl-M	Yes	Sulcotrione	Yes
Bioresmethrin	Yes	Ethirimol	Yes	Metamitron	Yes	Sulfosulfuron	No.
Bitertanol	Yes	Ethofumesate	Yes	Metazachlor	Yes	Sulfotep	Yes
Boscalid	No.	Ethoprophos	Yes	Metconazole	Yes	Sulphur	Yes
Bromacil	Yes	Ethoxysulfuron	No.	Methabenzthiazuron	Yes	Tau-fluvalinate	Yes
Bromofenoxim	Yes	Etridiazole	Yes	Methamidophos	Yes	TCA	Yes
Bromopropylate	Yes	Famoxadone	Yes	Methidathion	Yes	Tebuconazole	Yes
Bromoxynil	Yes	Fenamidone	Yes	Methiocarb	Yes	Tebufenozide	Yes
Bromuconazole	Yes	Fenamiphos	Yes	Methomyl	Yes	Tebufenpyrad	Yes
Bupirimate	Yes	Fenarimol	Yes	Methoprotryne	Yes	Tebutam	No.
Buprofezin	Yes	Fenazaquin	Yes	Methoxyfenozide	Yes	Tebuthiuron	Yes
Butocarboxim	Yes	Fenbuconazole	Yes	Metiram	Yes	Teflubenzuron	Yes
Butralin	Yes	Fenbutatin-oxide	Yes	Metobromuron	Yes	Tefluthrin	Yes
Cadusafos	Yes	Fenfuram	Yes	Metolachlor	Yes	Temephos	Yes
Calcium compounds	No.	Fenhexamid	Yes	Metosulam	Yes	Tepraloxydim	Yes
Calcium-polysulfide	No.	Fenitrothion	Yes	Metoxuron	Yes	Terbacil	Yes
Captan	Yes	Fenothiocarb	No.	Metribuzin	Yes	Terbufos	Yes
Carbaryl	Yes	Fenoxaprop	No.	Metsulfuron-methyl	No.	Terbumeton	Yes
Carbendazim	Yes	Fenoxaprop-P	Yes	Mevinphos	Yes	Terbuthylazine	Yes
Carbofuran	Yes	Fenoxycarb	Yes	Molinate	Yes	Terbutryn	Yes
carbophenothion	Yes	Fenpiclonil	Yes	Monalide	No.	Tetraconazole	Yes
Carbosulfan	Yes	Fenpropathrin	No.	Monocrotophos	Yes	Tetracopper-tricalciumsulfate	No.
Carboxin	Yes	Fenpropidin	Yes	Monolinuron	Yes	Tetradifon	Yes
Chlorbromuron	Yes	Fenpropimorph	No.	Monuron	Yes	Thiabendazole	Yes
Chlorbufam	Yes	Fenpyroximate	No.	Myclobutanil	Yes	Thiacloprid	No.
Chlorfenapyr	No.	Fenthion	Yes	Naled	Yes	Thiamethoxam	Yes
Chlorfenson	Yes	Fentin	No.	Napropamide	Yes	Thidiazuron	Yes
Chlorfenvinphos	Yes	Fentin acetate	Yes	Naptalam	No.	Thifensulfuron-methyl	No.
Chloridazon	Yes	Fentin hydroxide	Yes	Neburon	Yes	Thiobencarb	Yes
Chlormephos	Yes	Fenuron	Yes	Nicosulfuron	Yes	Thiofanox	Yes
Chlormequat	No.	Fenvalerate	Yes	Nitrothal-isopropyl	Yes	Thiometon	Yes
Chlorothalonil	Yes	Fipronil	Yes	Norflurazon	Yes	Thiophanate-methyl	Yes
Chlorotoluron	Yes	Flamprop	No.	Nuarimol	Yes	Thiram	Yes
Chlorpropham	Yes	Flamprop-M	No.	Ofurace	No.	Tolclofos-methyl	No.
Chlorpyrifos	Yes	Flazasulfuron	Yes	Omethoate	Yes	Tolylfluanid	Yes
Chlorpyrifos-Methyl	Yes	Florasulam	Yes	Oryzalin	Yes	Tralkoxydim	Yes
Chlorsulfuron	Yes	Fluazifop	Yes	Other fungicides	No.	Tralomethrin	Yes
Chlorthal	Yes	Fluazifop-P-butyl	Yes	Other herbicides	No.	Triadimefon	Yes
Chlozolinate	No.	Fluazinam	Yes	Other insecticides	No.	Triadimenol	Yes
Clethodim	Yes	Flubenzimine	No.	Oxadiargyl	No.	Tri-allate	Yes
Clodinafop	No.	Flucycloxuron	No.	Oxadiazon	Yes	Triapenthenol	No.
Clomazone	Yes	Flucythrinate	Yes	Oxadixyl	Yes	Triasulfuron	Yes
Clopyralid	Yes	Fludioxonil	Yes	Oxamyl	Yes	Triazophos	Yes
Copper	Yes	Flufenacet	Yes	Oxine-copper	Yes	Triazoxide	Yes
Copper carbonate	No.	Flufenoxuron	Yes	Oxydemeton-methyl	Yes	Tribenuron-methyl	Yes
Copper chelate	No.	Flumetsulam	Yes	Oxyfluorfen	Yes	Trichlorfon	Yes
Copper hydroxide	Yes	Fluometuron	Yes	Paclobutrazol	Yes	Triclopyr	Yes
Copper oxide	Yes	Fluorodifen	Yes	Paraquat	Yes	Tridemorph	Yes
Copper oxychloride	No.	Fluoroglycofen	No.	Parathion	Yes	Tridiphane	Yes
Copper salt	No.	Flupoxam	No.	Parathion-Methyl	Yes	Trietazine	Yes
Copper sulphate	No.	Flupyrsulfuron	Yes	Penconazole	Yes	Trifloxystrobine	No.
Cyanamide	Yes	Fluquinconazole	Yes	Pendimethalin	Yes	Triflumizole	Yes
Cyanazine	Yes	Flurochloridone	Yes	Permethrin	Yes	Triflumuron	Yes
Cyclanilide	Yes	Fluroxypyr	Yes	Petroleum oils	No.	Trifluralin	Yes
Cycloate	Yes	Flurtamone	Yes	Phenmedipham	Yes	Triflusulphuron	No.
Cycloxydim	Yes	Flusilazole	Yes	Phorate	Yes	Triforine	Yes
Cycluron	No.	Flutolanil	Yes	Phosalone	Yes	Trinexapac-Ethyl	Yes
Cyfluthrin	Yes	Flutriafol	Yes	Phosmet	Yes	Triticonazole	Yes

Cyhexatin	Yes	Folpet	Yes	Phosphamidon	Yes	Vamidothion	Yes
Cymoxanil	Yes	Fomesafen	Yes	Phosthiazate	Yes	Vernolate	Yes
Cypermethrin	Yes	Fonofos	Yes	Phoxim	Yes	Vinclozolin	Yes
Cyproconazole	No.	Foramsulfuron	Yes	Picoxystrobine	Yes	Zeta-cypermethrin	Yes
Cyprodinil	Yes	Formetanate	Yes	Pirimicarb	Yes	Zineb	Yes
Cypromazine	Yes	Formothion	Yes	Pirimiphos-Methyl	Yes	Ziram	Yes
Dalapon	Yes	Fosetyl	No.	Primisulfuron	No.	Zoxamide	No.
Deltamethrin	Yes	Fuberidazole	Yes	Prochloraz	Yes		
Demeton-S-methyl	Yes	Furalaxyl	Yes	Profenofos	Yes		
Desmedipham	Yes	Furathiocarb	No.	Prohexadione	No.		

Note: the source of data and the data elaboration are described in Section 4.3.5

Table A-4: Substances, data sources, and elaboration requirements and presence of a corresponding CF EF 3.0 method for Ionising Radiation.

Radionuclides	**Source**	**Data elaboration**	**CF in the EF3.0**
Actinides, radioactive, unspecified	Eurostat (2020c)	Calculated as described in Section 4.5	No
Aerosols, radioactive, unspecified	Eurostat (2020c)	Calculated as described in Section 4.5	No
Antimony-122	Eurostat (2020c)	Calculated as described in Section 4.5	No
Antimony-124	Eurostat (2020c)	Calculated as described in Section 4.5	Yes
Antimony-125	Eurostat (2020c)	Calculated as described in Section 4.5	Yes
Argon-41	Eurostat (2020c)	Calculated as described in Section 4.5	No
Barium-140	Eurostat (2020c)	Calculated as described in Section 4.5	No
Carbon-14	RADD (2020), PRIS 2020, Eurostat (2020a), Eurostat (2020c), OSPAR (2020)	Calculated as described in Section 4.5	Yes
Cerium-141	Eurostat (2020c)	Calculated as described in Section 4.5	No
Cerium-144	Eurostat (2020c)	Calculated as described in Section 4.5	No
cesium-134	RADD (2020), Eurostat (2020a), Eurostat (2020c)	Calculated as described in Section 4.5	Yes
Cesium-136	Eurostat (2020c)	Calculated as described in Section 4.5	No
Cesium-137	RADD (2020), Eurostat (2020a), Eurostat (2020c)	Calculated as described in Section 4.5	Yes
Chromium-51	Eurostat (2020c), OSPAR (2020)	Calculated as described in Section 4.5	No
Cobalt-57	Eurostat (2020c)	Calculated as described in Section 4.5	No
Cobalt-58	RADD (2020), Eurostat (2020a), PRODCOM (2020)	Calculated as described in Section 4.5	Yes
Cobalt-60	RADD (2020), Eurostat (2020a), Eurostat (2020c)	Calculated as described in Section 4.5	Yes
Hydrogen-3	RADD (2020), PRIS 2020, Eurostat (2020a), Eurostat (2020c)	Calculated as described in Section 4.5	Yes
Iodine-129	RADD (2020), Eurostat (2020c), OSPAR (2020)	Calculated as described in Section 4.5	Yes

Radionuclides	**Source**	**Data elaboration**	**CF in the EF3.0**
Iodine-131	RADD (2020), PRIS (2020), Eurostat (2020a), Eurostat (2020c),	Calculated as described in Section 4.5	Yes
Iodine-133	RADD (2020), Eurostat (2020a), Eurostat (2020c), OSPAR (2020)	Calculated as described in Section 4.5	Yes
Iron-59	RADD (2020), Eurostat (2020a), Eurostat (2020c),	Calculated as described in Section 4.5	No
krypton-85	RADD (2020), Eurostat (2020a),Eurostat (2020c),	Calculated as described in Section 4.5	Yes
Krypton-85m	Eurostat (2020c),	Calculated as described in Section 4.5	No
Krypton-87	Eurostat (2020c),	Calculated as described in Section 4.5	No
Krypton-88	Eurostat (2020c)	Calculated as described in Section 4.5	No
Krypton-89	Eurostat (2020c)	Calculated as described in Section 4.5	No
Lanthanum-140	Eurostat (2020c)	Calculated as described in Section 4.5	No
Lead-210	Eurostat (2020a), Eurostat (2020c)	Calculated as described in Section 4.5	Yes
Manganese-54	Eurostat (2020c), OSPAR (2020)	Calculated as described in Section 4.5	Yes
Molybdenum-99	RADD (2020), Eurostat (2020c)	Calculated as described in Section 4.5	No
Niobium-95	Eurostat (2020c)	Calculated as described in Section 4.5	No
Noble gases, radioactive, unspecified	Eurostat (2020c)	Calculated as described in Section 4.5	No
Plutonium	Eurostat (2020a), Eurostat (2020c)	Calculated as described in Section 4.5	Yes
Plutonium-238	RADD (2020),	Calculated as described in Section 4.5	Yes
Polonium-210	Eurostat (2020a), Eurostat (2020c)	Calculated as described in Section 4.5	Yes
Potassium-40	Eurostat (2020c), OSPAR (2020)	Calculated as described in Section 4.5	No
Protactinium-234	Eurostat (2020c)	Calculated as described in Section 4.5	No
Radioactive species, alpha emitters	Eurostat (2020c)	Calculated as described in Section 4.5	No
Radioactive species, Nuclides, unspecified	Eurostat (2020c)	Calculated as described in Section 4.5	No
Radioactive species, other beta emitters	Eurostat (2020c)	Calculated as described in Section 4.5	No
Radium-224	Eurostat (2020c)	Calculated as described in Section 4.5	No
Radium-226	Eurostat 2020a, Eurostat (2020c)	Calculated as described in Section 4.5	Yes
Radium-228	Eurostat (2020c), OSPAR (2020)	Calculated as described in Section 4.5	No
Radon-220	Eurostat (2020c), OSPAR (2020)	Calculated as described in Section 4.5	No

Radionuclides	**Source**	**Data elaboration**	**CF in the EF3.0**
Radon-222	Eurostat (2020a), Eurostat (2020c)	Calculated as described in Section 4.5	Yes
Ruthenium-103	Eurostat (2020c)	Calculated as described in Section 4.5	No
Silver-110	Eurostat (2020c)	Calculated as described in Section 4.5	Yes
Sodium-24	Eurostat (2020c)	Calculated as described in Section 4.5	No
Strontium-89	Eurostat (2020c)	Calculated as described in Section 4.5	No
Strontium-90	Eurostat (2020c)	Calculated as described in Section 4.5	Yes
Technetium-99m	Eurostat (2020c)	Calculated as described in Section 4.5	No
Tellurium-123m	Eurostat (2020c)	Calculated as described in Section 4.5	No
Tellurium-132	Eurostat (2020c)	Calculated as described in Section 4.5	No
Thorium-228	Eurostat (2020c)	Calculated as described in Section 4.5	No
Thorium-230	Eurostat (2020a), Eurostat (2020c)	Calculated as described in Section 4.5	Yes
Thorium-232	Eurostat (2020c)	Calculated as described in Section 4.5	No
Thorium-234	Eurostat (2020c)	Calculated as described in Section 4.5	No
Uranium alpha	Eurostat (2020c)	Calculated as described in Section 4.5	No
Uranium-234	Eurostat (2020a), Eurostat (2020c)	Calculated as described in Section 4.5	Yes
Uranium-235	RADD (2020), Eurostat (2020a), Eurostat (2020c)	Calculated as described in Section 4.5	Yes
Uranium-238	RADD (2020), Eurostat (2020a), Eurostat (2020c)	Calculated as described in Section 4.5	Yes
Xenon-131m	Eurostat (2020c)	Calculated as described in Section 4.5	No
Xenon-133	Eurostat (2020a), Eurostat (2020c)	Calculated as described in Section 4.5	Yes
Xenon-133m	Eurostat (2020c)	Calculated as described in Section 4.5	No
Xenon-135	Eurostat (2020c)	Calculated as described in Section 4.5	No
Xenon-135m	Eurostat (2020c)	Calculated as described in Section 4.5	No
Xenon-137	Eurostat (2020c)	Calculated as described in Section 4.5	No
Xenon-138	Eurostat (2020c)	Calculated as described in Section 4.5	No
Zinc-65	Eurostat (2020c)	Calculated as described in Section 4.5	No
Zirconium-95	Eurostat (2020c)	Calculated as described in Section 4.5	No

Table A-5: Substances, data sources, and elaboration requirements and presence of a corresponding CF in EF 3.0 method for Photochemical Ozone Formation.

Substance	Source	Data elaboration	CF in the EF3.0
NO_x	EMEP (2020)	No elaboration	Yes.
SO_x	EMEP (2020)	No elaboration	Yes.
acetaldehyde	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
acetic acid	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
acetone	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
benzaldehyde	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
benzene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
butadiene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
cumene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
cyclohexane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
ethane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
ethanol	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
ethyl acetate	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
ethylene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
ethylyne	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
formaldehyde	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
formic acid	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
heptane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
hexane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
isobutane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
isoprene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
isopropanol	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
methanol	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
methyl ethyl ketone	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
m-xylene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
n-butane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
n-butanol	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
n-butyl-acetate	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
octane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
pentane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
propane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
propene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
propionic acid	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
styrene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
tetrachloroethene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
toluene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
trichloroethene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
volatile organic compound	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
1,1,2-trichloro-1,2,2-trifluoroethane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
1,1,3-trimethylcyclohexane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
1,1-dimethylcyclohexane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
1,2,3,4-tetrahydronaphthalene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
1,2,3-trimethylbenzene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
1,2,4,5-tetramethylbenzene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
1,2,4-trimethylbenzene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes

Substance	**Source**	**Data elaboration**	**CF in the EF3.0**
1,2-dichloroethene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
1,2-dimethylcyclohexane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
1,3,5-trimethylbenzene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
1,3-diethylbenzene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
1,3-dimethylcyclohexane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
1,4-dimethylcyclohexane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
1-butene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
1-ethyl-2,3-dimethylbenzene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
1-ethyl-3,5-dimethylbenzene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
1-ethyl-4-methylcyclohexane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
1-hexene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
1-methyl-4-tert-butylbenzene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
1-pentene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
1-tridecanol	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
2,2,5-trimethylhexane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
2,2-dimethylbutane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
2,3-dimethylbutane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
2,3-dimethylpentane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
2,4-dimethylheptane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
2,4-dimethylpentane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
2,5-dimethylhexane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
2-chlorophenol	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
2-ethyltoluene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
2-methy-1-butene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
2-Methyl propanoic acid	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
2-methyl-2-butene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
2-methylbutane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
2-methylheptane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
2-methylhexane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
2-methylnonane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
2-methyloctane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
2-methylpentane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
2-pentene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
3,3,4-trimethylhexane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
3-ethyltoluene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
3-Methyl butanoic acid	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
3-methylheptane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
3-methylhexane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
3-methylpentane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
4-ethyl phenol	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
4-ethylcyclohexane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
4-ethyltoluene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
4-isopropyltoluene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
4-Methyl phenol	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
4-methylheptane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
4-propylheptane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
acetophenone	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes

Substance	Source	Data elaboration	CF in the EF3.0
acrolein	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
acrylonitrile	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
aldehydes, unspecified	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
Benzofuran	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
Benzonitrile	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
benzylalcohol	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
Butanoic acid	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
butylbenzene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
butyraldehyde	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
chlorobenzene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
chlorodifluoromethane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
chlorofluoromethane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
cis-2-butene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
cis-2-pentene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
crotonaldehyde	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
cycloheptane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
cyclohexanol	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
cyclohexanone	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
cyclopentane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
decanes	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
diacetonalcohol	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
dibutyladipat	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
dichlorofluoromethane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
Dimethyl sulphide	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
Dimethylfuran	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
dioxane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
ethylenglycol	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
furane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
Furfural	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
glyoxal	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
heptenes, unspecified	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
hexanal	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
hexanone	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
hexylcyclohexan	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
i-butylacetate	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
indane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
isophorone	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
kresol	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
m/p-xylene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
methylacetate	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
methylcyclohexane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
methylglyoxal	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
methylisobutylketone	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
n-decane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
n-dodecane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
n-heptane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
n-hexane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
n-nonane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
n-propanol	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
n-undecane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
o-xylene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
Pentanoic acid	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
pentanol	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No

Substance	Source	Data elaboration	CF in the EF3.0
pentylbenzene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
phenol	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
propionaldehyde	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
propylacetate, unspecified	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
propylcyclopentane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
propyne	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
p-xylene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
sec.-butanol	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
terpenes	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
tetrahydrofurane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
tolylaldehyde	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
trans-2-pentene	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes
trichloroethane	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	No
valeraldehyde	Laurent & Hauschild (2014)	Calculated from aggregated NMVOC	Yes

Table A-6: Mapping of land use type as reported in UNFCCC in the EF3.0 elementary flows.

UNFCCC land use type	EF 3.0 land use type
Forest land (managed)	Forest
Forest land (unmanaged)	
Cropland	Agriculture
Grassland (managed)	Grassland/pasture/meadows
Grassland (unmanaged)	
Wetlands (managed)	Wetlands
Wetlands (unmanaged)	
Settlements	Urban
Other land	Unspecified

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