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Consumption Footprint and Domestic Footprint Monitoring Report 2024

Updates in methodology, data and policy uses

Sanye Mengual, E., Pasqualino, R., Omodara, L., Frankowska, A., Wierzgala, P., Chiorrini, A., Bennett, M.J., Listorti, G., Sala, S.

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Contact information
Name: Serenella Sala
Address: Via E. Fermi, 2417, Ispra (VA), Italy
Email: Serenella.sala@ec.europa.eu

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https://joint-research-centre.ec.europa.eu

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Contents

Abstract

The European Commission - Joint Research Centre developed a framework including the **Consumption Footprint (CF)** and the **Domestic Footprint (DF)** models, which have become established as a means for monitoring progress of EU environmental performance. These models are based on **life cycle assessment (LCA) principles, and employ the Environmental Footprint (EF) method to produce a set of 16 indicators** (available also as single weighted score) to assess the environmental impacts of EU production and consumption, and can be compared with the planetary boundaries. This report presents the latest methodological updates and results of these models in the context of monitoring EU performance. The **DF** combines official statistics and modelled data regarding resource extraction and emissions to the environment within the EU territory **from the year 2000 to 2022**. The **CF** is a full bottom-up LCA model making use of 164 representative products and official statistics for **2010-2022** to assess the environmental impacts (including biodiversity footprint) of five areas of consumption (food, mobility, housing, household goods, appliances), thus accounting for both production and trade.

The EU CF has increased by 9% from 2010 to 2022 (as a single score), with **food consumption being the primary driver of environmental impacts**, followed by housing (especially for space heating) and mobility (mainly due to the use of private cars), while the EU **DF** decreased (-29% as a single score). These two opposite trends highlight the role of the **EU-27 as a net importer of environmental impacts that occur in third countries**.

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Authors

Esther Sanyé Mengual: coordination of methodological update, data collection and model simulations, as well as text review.

Roberto Pasqualino: overall drafting and contribution to methodological update.

Linda Omodara: contribution to data collection and contribution to initial drafting of Section 3, Section 4, Section 5, and Annex 3.

Angelina Frankowska contribution to data collection and contribution to initial drafting of Section 2, Section 8 and Annex 7.

Piotr Wierzgala: data collection and processing, model simulation

Andrea Chiorrini: data collection and processing, model simulation

Michael Bennett: project coordination and text review

Giulia Listorti: project coordination and text review

Serenella Sala: conceptualisation and overall coordination

1 Introduction

In the global context of a triple planetary crisis[1], the ability to understand consumption patterns and their related environmental impacts is essential to exploring how the well-being of EU citizens can be decoupled from resource use and associated environmental impacts. It is also very valuable to assess what changes might be necessary in order for the related environmental impacts to reduce, to then remain within planetary boundaries (PBs) as a measure of absolute sustainability.

As part of its commitment towards more sustainable production and consumption, the European Commission developed a Life Cycle Assessment (LCA)-based framework[2], which allows one to assess the environmental impacts associated with EU consumption and production (Sanyé-Mengual and Sala 2023). The framework includes two different models: (i) the **Domestic Footprint (DF)**, whose aim is to quantify the overall impacts of domestic production and consumption that takes place within EU or Member States boundaries (a territorial perspective), and (ii) the **Consumption Footprint (CF),** whose aim is to assess the environmental impacts of consumption at EU and Member States level, including embodied impacts due to trade (an overall consumption perspective). The LCA-based framework assesses the environmental impact of EU production and consumption across the 16 environmental impact indicators of the **Environmental Footprint** (EC 2021a), which the European Commission recommends as a method for the LCA of products and organisations[3].

The DF and CF models are complementary and are relevant in the context of:

- Achieving the Sustainable Development Goals (SDGs) adopted in the **2030 Agenda for Sustainable Development** (UN 2015), in particular **SDG 12 on Responsible consumption and production, and SDG8 on Sustainable economic growth**, as well as contributing to other SDGs.
- Measuring to what extent Europe is ensuring "**living well within the limits of our planet"**, including assessing the appropriateness of including a lead indicator and targets, as foreseen in the **7th and 8th Environment Action Programmes** (EPC 2022).
- Monitoring progress towards the **8th Environment Action Programme** and the **European Green Deal** (EC 2019) ambitions, such as those in the **New Circular Economy Action Plan** (EC 2020b), the **Biodiversity Strategy** (EC 2020c), the **Chemical Strategy for Sustainability** (EC 2020d),the **Zero Pollution Action Plan** (EC 2021b), and the **food system** (EC, 2025), fostering a system perspective as in the Farm to Fork Strategy (EC 2020a).
- Contributing to **EU product policy** towards making sustainable products the norm, such as the Ecodesign for Sustainable Product Regulation (ESPR) (EC 2022a).
- Contributing to the updated **Better Regulation initiative** (EC 2023a), unveiling the potential role of LCA for policy analysis throughout the policy cycle.
- Contributing to implementing the **Beyond Gross Domestic Product (GDP) Roadmap** (EC 2009).

[1] "The triple planetary crisis refers to the three main interlinked issues that humanity currently faces: climate change, pollution, and biodiversity loss. Each of these issues has its own causes and effects and each issue needs to be resolved if we are to have a viable future on this planet." (UNFCCC) https://unfccc.int/blog/what-is-the-triple-planetary-crisis

[2] https://eplca.jrc.ec.europa.eu/sustainableConsumption.html

[3] https://environment.ec.europa.eu/publications/recommendation-use-environmental-footprint-methods_en

- Contributing to the transition towards an EU **Bioeconomy** (EC 2018), through identifying the environmental hotspots and monitoring progress towards their objectives over time.

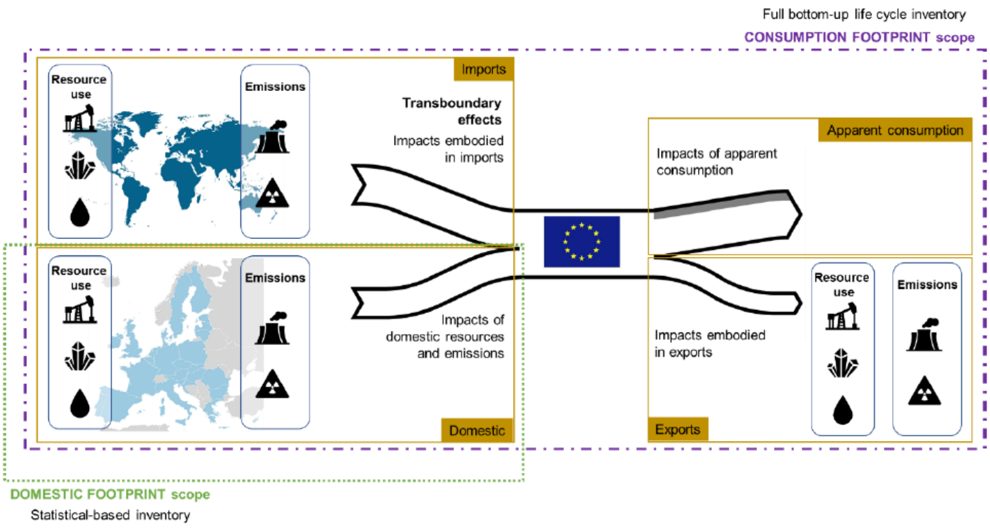
These models and key findings for the period 2000-2021 (for DF) and 2010-2021 (for CF) were presented in the 2023 Science for Policy report "Consumption Footprint and Domestic Footprint: Assessing the environmental impacts of EU consumption and production" (Sanyé-Mengual & Sala, 2023). This Technical Report provides an update with data until 2022 as well as details methodological updates of the Consumption Footprint (Sanyé Mengual et al., 2023a) and the Domestic Footprint (Sanyé Mengual et al., 2022) models.

The document is organized as follows: Section 2 explains the methodology underpinning the DF and CF models and recent updates. Section 3 reviews how the models are used in the policy cycle and lists some recent contributions to policy. Section 4 and Section 5 provide the updated assessment of the evolution of DF and CF indicators. Section 6 and Section 7 delve into the analysis of relative and absolute sustainability by focusing on decoupling and comparing results against the planetary boundaries framework. Section 8 introduces the assessment of the biodiversity footprint, which is new to this report update. Section 9 provides an overview of the platform. Section 10 shows different geographical scales of use of the models, and Section 11 concludes the document. Annexes complement these sections with further technical details of the models and their updates.

2 Methodological framework to assess the environmental impacts of EU consumption and production

The EU produces and imports goods and services for its consumption, and it exports outside the EU. It is, therefore, essential to estimate the environmental impacts generated due to the consumption of goods, taking the different producers within and outside the EU into account. Striving to reduce pressures on the ecosystem to ensure sustainable behavioural patterns, the EU Commission has introduced policies to achieve a reduction in environmental impacts. To identify if those policy measures show a positive effect, it is crucial to exclusively assess the environmental impacts caused by domestic (within the EU) production. For this purpose, the JRC has developed a framework to evaluate the environmental impacts of EU consumption and production by combining two different approaches (Sanyé Mengual and Sala, 2023a). A domestic-based approach is reflected by the Domestic Footprint (DF) (Sanyé Mengual et al., 2022), which accounts for the environmental impacts attributed to all activities within the EU, excluding any imported goods. The consumption-based approach, which considers imports, is represented by the Consumption Footprint (CF) (Sanyé Mengual et al., 2023a). **The CF uses the concept of "apparent consumption" of products (i.e., consumption calculated from official statistics as domestic production plus imports minus exports) as the indicative volume of products that drive environmental impacts of consumption.** The two different frameworks are illustrated in Figure 1.

Figure 1. The JRC framework to assess the environmental impact of the EU consumption footprint, including the Consumption Footprint (CF) and the Domestic Footprint (DF)



Source: Sanyé Mengual and Sala (2023).

Both approaches follow standardised LCA methodology (ISO 2006a, 2006b) to estimate environmental impacts at the country and EU levels. However, the CF applies a full bottom-up process-based[4] LCA, where the single products are analysed to calculate the environmental impacts and then scale up to the product group and sector level. In contrast, the DF conducts a statistical-

[4] Process based LCA indicates that the type of data that compose the inventory of the study, are disaggregated at the level of single industrial processes, which compose the supply chain under assessment.

based inventory, staying at the top level for a broad analysis rather than breaking the impacts down to the product level. The next sections describe in more detail the CF and DF models.

The CF and the DF models employ the Environmental Footprint (EF) impact assessment method to estimate 16 environmental impact indicators. In particular, the assessment uses the EF 3.1 method (Andreasi Bassi et al., 2023). This method has been selected as it is recommended by the European Commission (EC, 2021a). Table 1 gives an overview of the impact categories assessed, the unit (or reference substance), and the impact scale at which the environment is assessed (global or regional scale). Annex 1 provides a more comprehensive description of the impact categories. Since the EF method does not yet consider impacts on biodiversity, this is complemented with a biodiversity loss impact assessment based on the ReCiPe2016 method (Huijbregts et al. 2017) (see Chapter 2.3).

Table 1. Overview of the 16 impact categories of the Environmental Footprint method used for the Domestic Footprint and the Consumption Footprint models

Impact category name	Unit	Impact scale
Climate change	Carbon dioxide (kg CO_2 equivalent)	Global
Particulate matter	Particulate Matter-2.5 (kg $PM_{2.5}$ equivalent)	Local/regional
Ionising radiation	Uranium-235 (kg U_{235} equivalent)	Local/regional
Photochemical ozone formation	Non-methane volatile organic compounds (kg NMVOC equivalent)	Local/regional
Eutrophication, terrestrial	Nitrogen (mol N equivalent)	Local/regional
Ozone depletion	Trichlorofluoromethane (kg CFC-11 equivalent)	Global
Acidification	Hydrogen (mol H^+ equivalent)	Local/regional
Eutrophication, freshwater	Phosphorus (kg P equivalent)	Local/regional
Eutrophication, marine	Nitrogen (kg N equivalent)	Local/regional
Human toxicity, non-cancer	Comparative Toxic Unit for humans (CTUh)	Local/regional
Water use	(m^3 equivalent)	Local/regional
Resource use, minerals and metals	Antimony (kg Sb equivalent)	Global
Ecotoxicity, freshwater	Comparative Toxic Unit for ecosystems (CTUe)	Local/regional
Human toxicity, cancer	Comparative Toxic Unit for humans (CTUh)	Local/regional
Land use	(Pts)	Local/regional
Resource use, fossils	Fossil resource use share (Megajoule)	Global

Source: Adapted from Sanyé Mengual and Sala (2023).

Box 1. Nomenclature used in this framework: Distinction between model and indicator

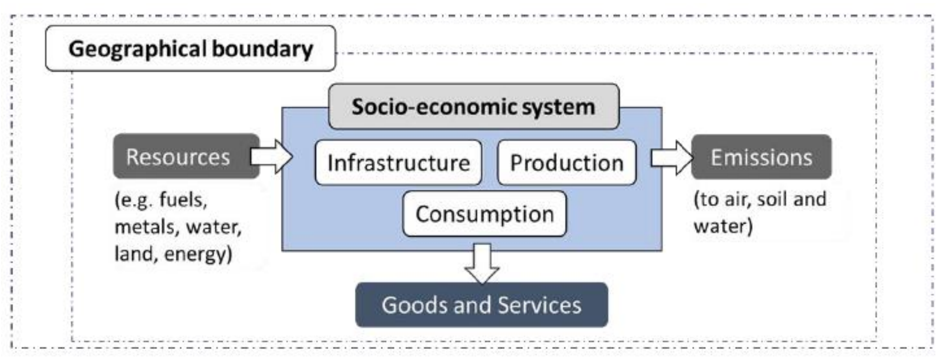
Model: analytical representation or quantification of a real-world system, used to make projections or to assess the behaviour of the system under specified conditions. The Consumption Footprint and the Domestic Footprint are models that use official statistical and life cycle inventory data to estimate environmental pressures, such as greenhouse gas emissions. The models make use of specific impact assessment methods to transform pressures into a series of impact indicators, such as climate change in terms of global warming potential.

Indicator: metric which can be compared with historical data or generated by models by means of specific methods and approaches. In this study, the Environmental Footprint impact assessment method allows the generation of 16 different indicators that evaluate the environmental impacts of emissions to air, soil and water, and the use of resources. This set of indicators includes impacts such as climate change, eutrophication, land use or freshwater ecotoxicity.

2.1 Updates in the Domestic Footprint

The DF combines both statistical and modelled data of the extraction of resources and emissions to the environment due to EU production and consumption activities taking place within the EU territory (Figure 2) (Sanyé Mengual et al., 2022). The DF includes a set of 16 environmental impacts (Table 1) that can be aggregated as one single weighted score by applying normalization and weighting techniques (see Annex 1). These impacts are available per every Member State of the EU-27 and represent a robust dataset that can be used for monitoring EU environmental impacts on the domestic territory. The data are collected at an annual aggregation level from 2000-2022. Annex 2 lists the data sources used to compile the DF model.

Figure 2. Scope of the Domestic Footprint model (DF)



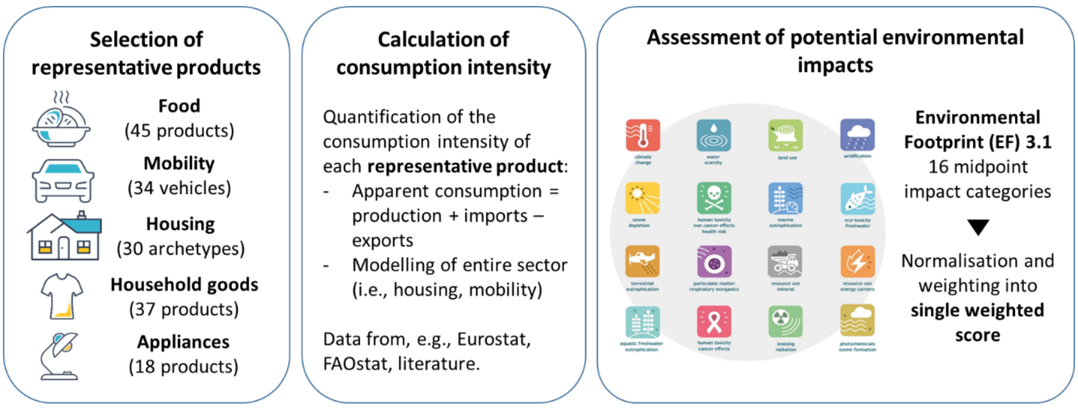
Source: Sanyé Mengual and Sala (2022).

The 2022 data updates of the Domestic Footprint were collected following the methodology depicted in Sanyé Mengual et al. (2022). Due to the uncertainties and possible inconsistencies with new data, checks for outliers were performed, and the suspected anomalies were listed and addressed as detailed in Annex 3.

2.2 Updates in the Consumption Footprint

The CF model (see Figure 3) quantifies the environmental impacts of EU consumption by mean of LCA and official statistics on the annual consumption for 164 representative products to calculate the environmental impacts of five different consumption areas (food, mobility, housing, household goods and appliances) (Sanyé Mengual et al., 2023a).

Figure 3. Scope of the Consumption Footprint model (CF)



Source: Sanyé Mengual et al. (2023a).

Table 2 provides an overview of the five areas of consumption, including the product groups and the number of representative products that have been evaluated. Annex 4 provides a detailed list of representative products.

Table 2. Overview of the content of the consumption footprint: product groups and number of representative products by area of consumption.

BoP	Product groups	Number of representative products
Food	Meat, Dairy, Oils, Cereal-based products, Beverages, Confectionary, Sugar, Coffee and tea, Fish and seafood, Pre-prepared meals, Tubers, Eggs, Vegetables, Legumes, Fruit, Nuts and seeds, Legume-based products	45
Housing	Archetypes (number of dwellings), Energy and water consumption	30
Mobility	Passenger cars, Motorcycles and mopeds, Public transport (bus), Rail transport, Air transport	34
Appliances	Refrigeration, Dishwashing, Washing, Electronics, Lighting, Air conditioning, Domestic cooking appliances, Cleaning appliances, Bathroom appliances	18
Household goods	Detergents, Sanitary products, Personal care products, Furniture, Bed matresses, Footwear, Clothing, Paper products, Plastic products	37

Source: Sanyé Mengual et al. (2023a).

The CF model has been updated by extending its data availability on annual consumption up to 2022, thus covering a time span of 13 years (2010 to 2022) (see Annex 5 for data sources). In addition to this, the data gap filling procedure regarding the building stock for the Basket of representative Products (BoP) housing has been improved to reduce the risk of generating not realistic behaviours and spikes for 2022, as described in Annex 6. No changes were implemented to the LCI data of the individual representative products neither in the use of the background LCI databases, namely ecoinvent 3.6 (Wernet et al., 2016) and Agrifootprint 5.0 (Blonk consultants, 2019).

2.3 Biodiversity footprint

The EF impact assessment method includes 16 environmental impact categories, none of which explicitly referring to biodiversity loss. To complement the EF, this report outlines how biodiversity loss can be considered as an additional category as Biodiversity Footprint, and proposes an in depth analysis on how this can be considered in section 8. The biodiversity footprint captures impacts on biodiversity loss, resulting in a declining number of species and reduced species diversity. The drivers of biodiversity loss have been identified as climate change, pollution, land use, overexploitation of resources and the spread of invasive species (IPBES, 2019).

Several LCA methods consider some aspects of the drivers for biodiversity loss (Sanyé-Mengual et al., 2023b), however, no method has been developed that simultaneously accounts for the variety of pressures on biodiversity, ecosystems, taxonomic groups, and essential biodiversity variables classes. In this study, the biodiversity indicator is based on the ReCiPe 2016 Life Cycle Impact Assessment (LCIA) method (Huijbregts et al. 2017). It is a global indicator that assesses multiple impact pathways on terrestrial, freshwater, and marine ecosystems. The biodiversity loss is expressed as the local species loss integrated over time (species lost per year). The biodiversity indicator is not a complete metric since not all species, in particular insects, are accounted for. However, it does consider numerous species groups, as listed in Table 3.

Table 3. Impact categories affecting biodiversity and the impacted taxonomic/species.

Impact category	**Taxonomic/species groups**	**Metric**[A]
Climate change (terrestrial, freshwater)	Plants, butterflies, birds, mammals, bony fishes	$Species{\cdot}yr/m^3_{consumed}$ $Species{\cdot}yr/kg_{emitted}$ $Species{\cdot}yr/m^2_{annual\ crop\ land}$
Photochemical ozone formation	Plants	$Species{\cdot}yr/kg_{emitted}$
Terrestrial acidification	Vascular plants	$Species{\cdot}yr/kg_{emitted}$
Toxicity (terrestrial, freshwater, marine)	Bacteria/Archaea/Protista, Plantae/Fungi, invertebrates, vertebrates (ectotherms). Depending on the substance and availability of ecotoxicological data	$Species{\cdot}yr/kg_{emitted}$ $Species{\cdot}yr/m^3_{consumed}$
Water use (terrestrial, freshwater)	Vascular plants, bony fishes	$Species{\cdot}yr/m^3_{consumed}$ $Species{\cdot}yr/kg_{emitted}$
Land use	Arthropods, other invertebrates, birds, amphibians, reptiles, mammals, vascular plants, moss	$Species{\cdot}yr/m^2_{annual\ crop\ land}$ $Species{\cdot}yr/kg_{emitted}$
Freshwater eutrophication	Cyanobacteria, silicon-based algae, non- silicon-based algae, macrophytes, aquatic invertebrates and fish	$Species{\cdot}yr/m^3_{consumed}$ $Species{\cdot}yr/kg_{emitted}$

Source: Damiani et al. (2023). Note: A metric is defined as the time-integrated species loss per m^3 of water consumed per kg of substance emitted per m^2 of land used

Table 3 also shows the different environmental pressures that impact those species, including the reference unit, noted as metric in the table. For instance, ReCiPe estimates climate change's implications on terrestrial species, such as plants, butterflies, birds and mammals, and bony fish that living in fresh waters. Regarding land use and land transformation, six different land use classes are considered, from used forests, pasture and meadows to crops/agricultural land and artificial land areas. Depending on the impacted ecosystem type (air, land, water), different functional units are defined. The biodiversity footprint assesses the compromised species per year due to the consumption of 1 m^3 of water, the release of 1 kg of emissions and the use of 1 m^2 of land (see Table 3).

Currently, the biodiversity impact is only quantified for the BoP Food of the CF at Member State level and at EU level for the years 2010 to 2022. The calculation involves the food consumption intensities per food product and the biodiversity impact of that product following the CF approach.

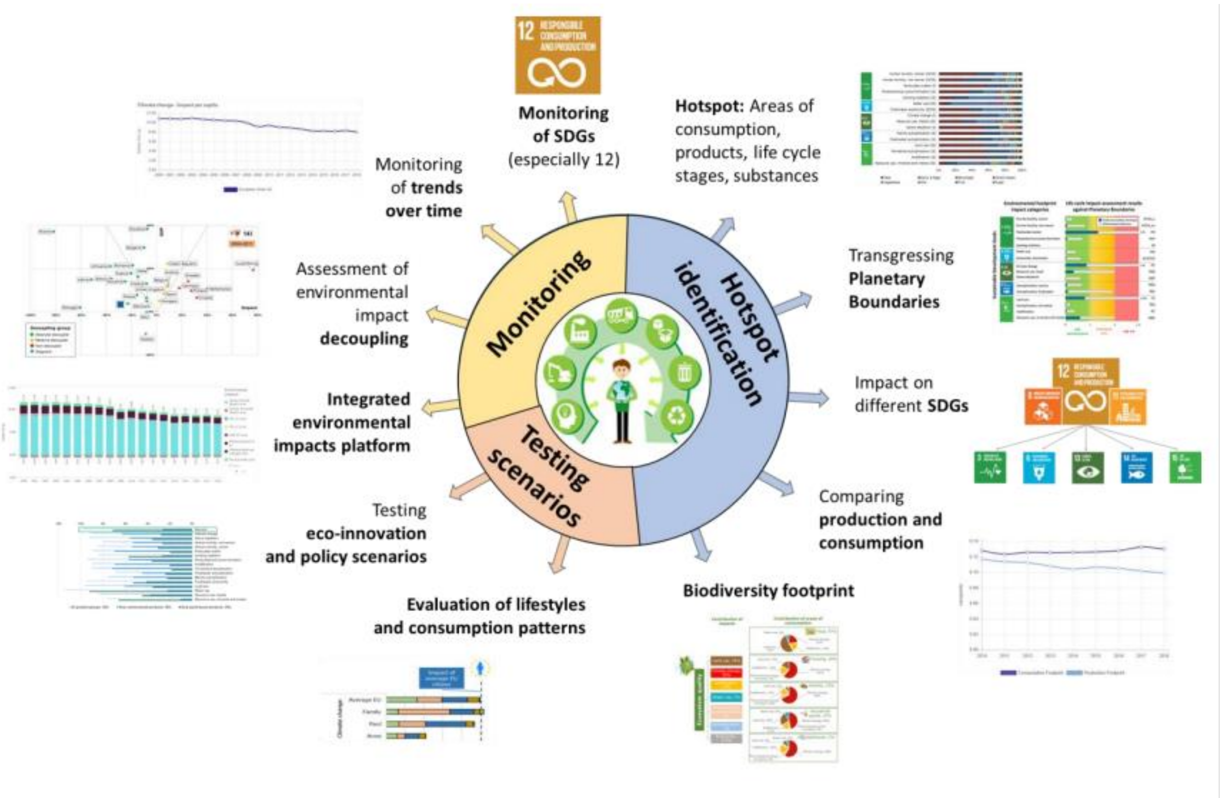
3 Providing support throughout the policy cycle

The DF and CF models can support EU policymaking in many ways (section 3.1). Examples of policy use of these models are illustrated in Section 3.2.

3.1 The Consumption Footprint and Domestic Footprint models in support to EU policy-making

The CF and DF models can support EU policymaking in various ways which can be distinguished in three groups: monitoring, hotspot identification and testing of scenarios, as detailed in Figure 4.

Figure 4. Overview of policy uses of the developed framework.



Source: Sanyé Mengual and Sala (2023).

— **Identifying environmental hotspots**: the granularity of the CF model provides multiple sources of information which allow to identify hotspots at different levels across a product supply chain. These include environmental issues with the highest relevance (e.g. 16 impact categories), areas of consumption level, product groups and products, life cycle stages of products, and most relevant resource used or emissions to the environment. It is also possible to assess the impacts on biodiversity, where the EF method is complemented with a life cycle impact assessment method addressing biodiversity loss (endpoint). On the other hand, the DF model supports identifying the most contributing pressures (emissions to the environment or resource extraction) to the environmental impacts which occur on the EU geographical territory. Both models enable to assess impacts in comparison with the planetary boundaries thus spotlighting the environmental impacts that require more urgent action (i.e., above or near to cross planetary boundaries).

— **Monitoring:** yearly updates of both the DF and CF models allow tracking the evolution of impacts associated with changes in production and consumption patterns. Annual data may be strategic for monitoring purposes, e.g. (a) how much the EU is decoupling environmental impacts from economic growth, (b) the benefits of transition towards a circular economy, (c) the ability of the EU to remain within planetary boundaries, or (d) progress related to the SDGs (especially SDG12 on responsible consumption and production). The models can also be employed to set targets for policy purposes as called by the European Parliament for circular economy, e.g. Sweden's parliament recently agreed on having a consumption-based perspective for climate targets[5].

— **Setting a baseline against which testing policy options and scenarios**: the modularity of the CF model can formulate scenarios affecting not only lifestyles but all the stages along the supply chain (from raw material extraction to end-of-life) as well as technological changes in the life cycle of products. The DF model sets a baseline for monitoring domestic impacts or assessing scenarios, for example, modelling exercises, such as the expected effect of the circular economy on resource use and climate change emissions.

— **Assessing lifestyles:** The CF model **can be used to evaluate lifestyles and consumption patterns,** which can be compared to the average lifestyles of citizens (Consumer Footprint) of the EU and Member States.

— **Assessing spillover effects to third countries:** Identifying transboundary and spillover effects is crucial, as the models could unveil the trade footprint, namely the amount of impacts embodied in imported goods.

3.2. Recent contributions of the DF and CF to EU policies

The DF and the CF models are registered in the Modelling Inventory and Knowledge Management System (MIDAS)[6] of the European Commission (EC-JRC 2024a) and have been used to support several policy initiatives in recent years, as shown in Figure 5.

Regarding **monitoring**, the CF is:

— included in the official public data sources of the European Commission (Eurostat 2024a),

— a headline indicator of:

- the Circular economy monitoring framework (Eurostat 2024b),
- the SDG monitoring framework (Eurostat 2024c),
- the 8th Environmental Action Programme (EC 2022b)

[5] https://www.climatechangenews.com/2022/04/08/sweden-set-to-be-worlds-first-country-to-target-consumption-based-emission-cuts/

[6] Domestic Footprint: https://web.jrc.ec.europa.eu/policy-model-inventory/explore/models/model-domestic-footprint/
Consumption Footprint: https://web.jrc.ec.europa.eu/policy-model-inventory/explore/models/model-consumption-footprint/

- and the EU Food System Monitoring Dashboard[7], regarding the area of consumption food for consumption footprint and biodiversity footprint (EC-JRC, 2024b)

— an indicator for 'green resilience' in the Resilience dashboard (EC 2023b)

— used as a 'signal indicator' in the monitoring of the Zero Pollution Action Plan with the CF being compared against the Planetary Boundaries (EC 2021b, EEA 2022, EEA-JRC 2025)

In addition to monitoring, the model has been used for **hotspot analysis** and **testing green transitions** in impact assessments and preparatory studies.

In the context of impact assessment, CF and DF provided support to:

— the 2030 Climate target plan (EC 2020e),

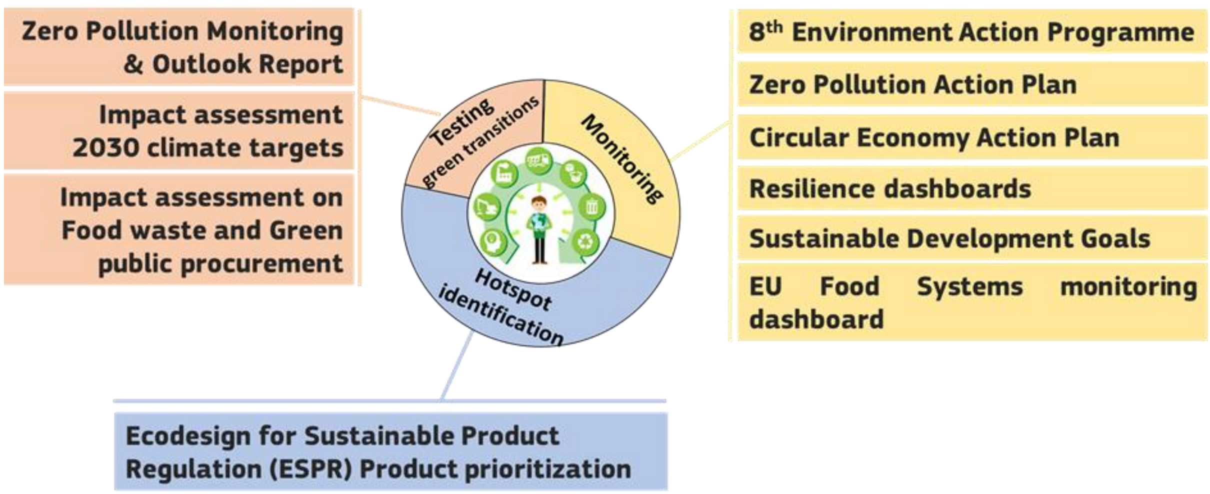
— Food waste reduction targets (EC 2023c),

— and ESPR (EC 2022c, EC 2023d).

Regarding preparatory studies, the CF has been used to quantify potential benefits of ESPR horizontal and product measures in the study of new priorities (Faraca et al. 2024).

As an example of outlook projections , a CF outlook for the year 2030 was modelled for the Zero Pollution Outlook 2022 (EC-JRC 2022), which included an assessment against the PB reference framework. This study was further updated in Pasqualino et al. (2025), and the Zero Pollution Monitoring and Outlook 2024 report (EEA-JRC 2025).

Figure 5. Overview of recent contribution of DF and CF to EU policies



Source: Adapted from Sanyé Mengual and Sala, (2023)

[7] https://datam.jrc.ec.europa.eu/datam/mashup/EU_FOOD_SYSTEM_MONITORING/index.html

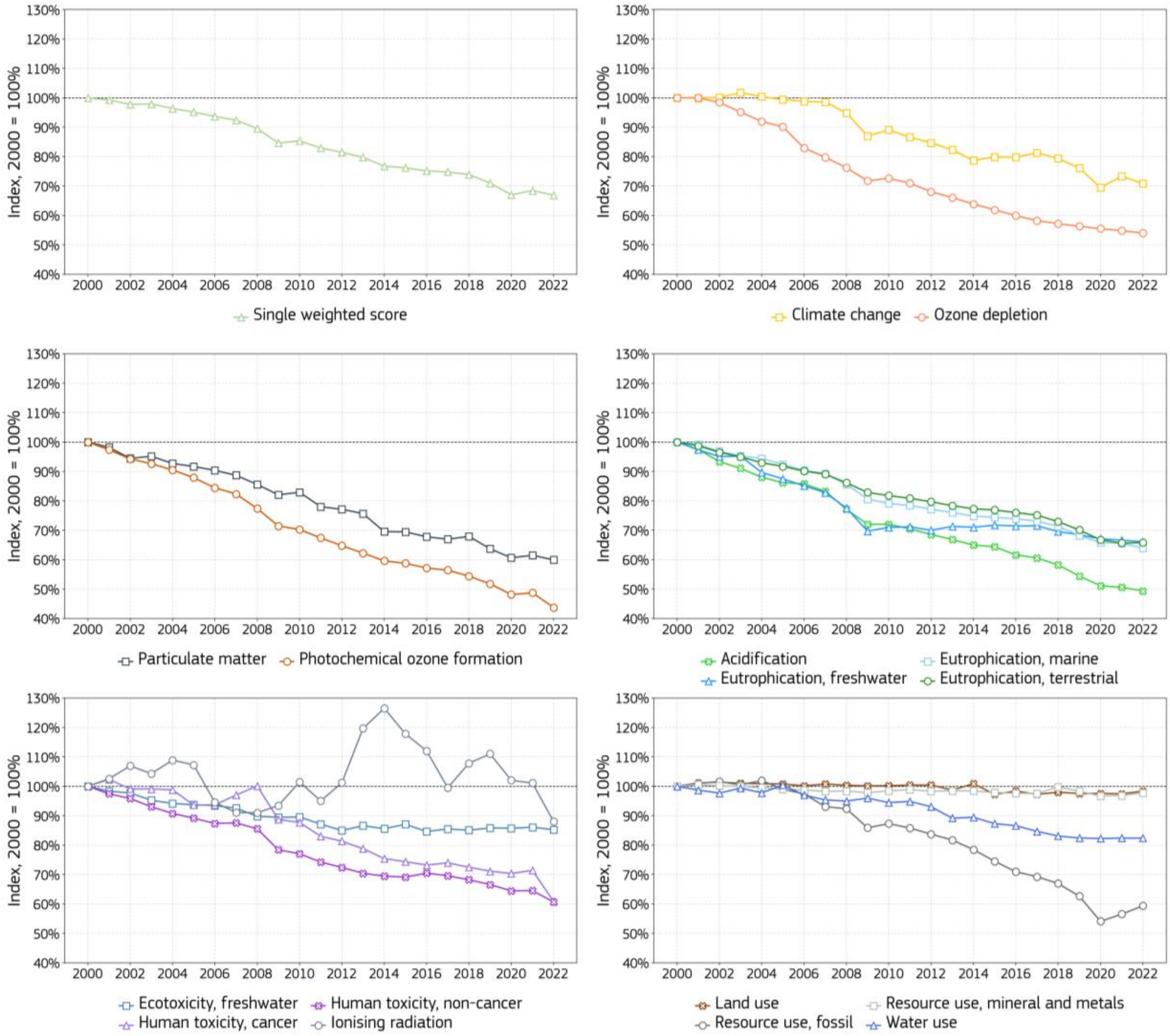
4 The environmental impact of domestic production and consumption in the EU: the Domestic Footprint

This chapter explores the DF of the EU-27 and the EU countries, focusing on the observed trends in the single weighted score and environmental impact categories for the period 2000-2022 (section 4.1), zooming in to the geographical distribution per country in 2022 (section 4.2), and relative change per country between 2010 and 2022 (section 4.3).

4.1. Evolution of the Domestic Footprint from 2000 to 2022

The **DF of the EU has shown a constant decrease since 2000** (Figure 6). In terms of a single weighted score, the EU DF has decreased by over 30% in the period 2000-2022, only showing a slight increase between 2020 and 2021 due to the reduction pace induced by the COVID pandemic (in 2020) and the post-pandemic economy recovery (in 2021).

Figure 6. Evolution of the EU Domestic Footprint from 2000 to 2022, by single weighted score and EF impact category.



Source: Consumption Footprint Platform (EC-JRC 2024c). Note: Results for 2000 are reported as 100%, and results for the other years are rescaled accordingly. All of the 16 EF categories are highly interdependent among each other, and the split in five chart is intended as being solely illustrative to support visualization and comparability of trend data.

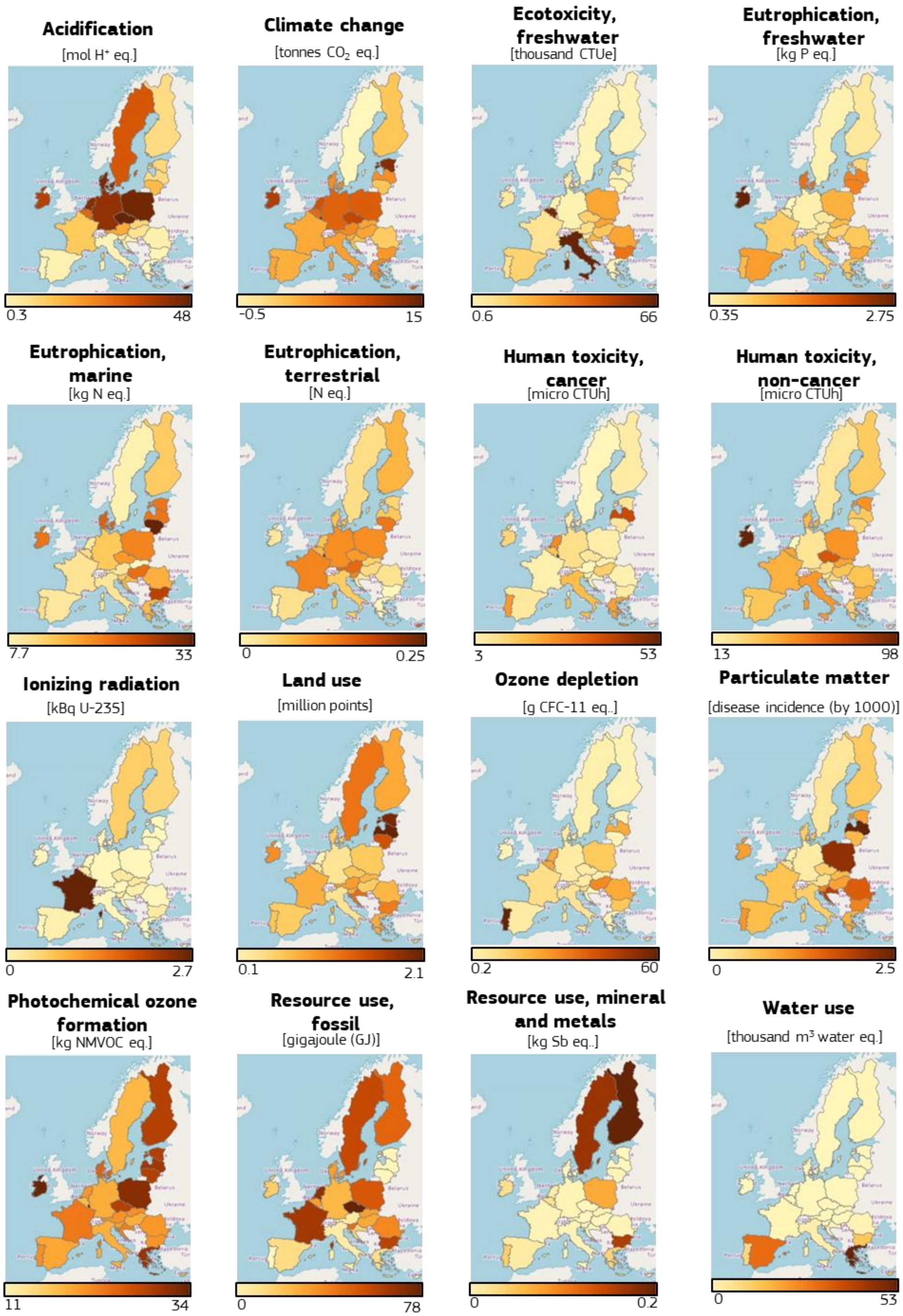
The evolution along the assessed period is different among the 16 EF environmental impact categories. The impact categories that decreased the most are those under control in the Montreal Protocol (UNEP, 1987) and subsequent regulatory frameworks, which aim to ban the most dangerous ozone-depleting substances, such as chlorofluorocarbons (CFCs), and hydrochlorofluorocarbons (HCFCs). This results in photochemical ozone formation reduced by -49%, and ozone depletion reduced by -44% between 2000 and 2022. Acidification (-47% between 2000 and 2022) shows one of the largest decreases thanks to the constant effort of EU and Member States in reducing air pollutants (EPC, 2016). On the other hand, two categories show a rather stable trend over this period due to the constraints in resources use on EU territory. These are land use (+2%) and resource use, minerals and metals (+2%). The impact category showing the most variable trend was ionising radiation, with overarching declining rate from 2014 to 2022. This decrease can be explained by changes in the nuclear power level in France, which is the largest EU producer of nuclear power, due to nuclear reactor maintenance and repair procedures (see Figure 7).

4.2. The Domestic Footprint in the different EU countries (2022)

The role of the different EU countries in the overall EU-27 DF depends on each country's different economic structures and technological deployment as well as on patterns of consumption, such as mobility. Figure 7 shows the DF per capita for EU countries in 2022 for each of the individual impact categories, highlighting the contributions of each country.

The geographical variability of domestic impacts varies among the different impact categories. The EU countries with a high GDP per capita often exhibit high impacts per capita (e.g. for climate change, marine eutrophication and fossil resource use). Regarding the spatial distribution, southern countries tend to show a lower impact intensity per capita, apart from the impact on water use and freshwater ecotoxicity (both linked with agricultural activities). Impacts are concentrated in specific countries for some categories because of their characteristics and the development of specific economic sectors, such as ionising radiation (nuclear plans in France) or resource use, minerals and metals (Nordic countries).

Figure 7. Domestic Footprint per capita by EU country and by individual impact categories in 2022.

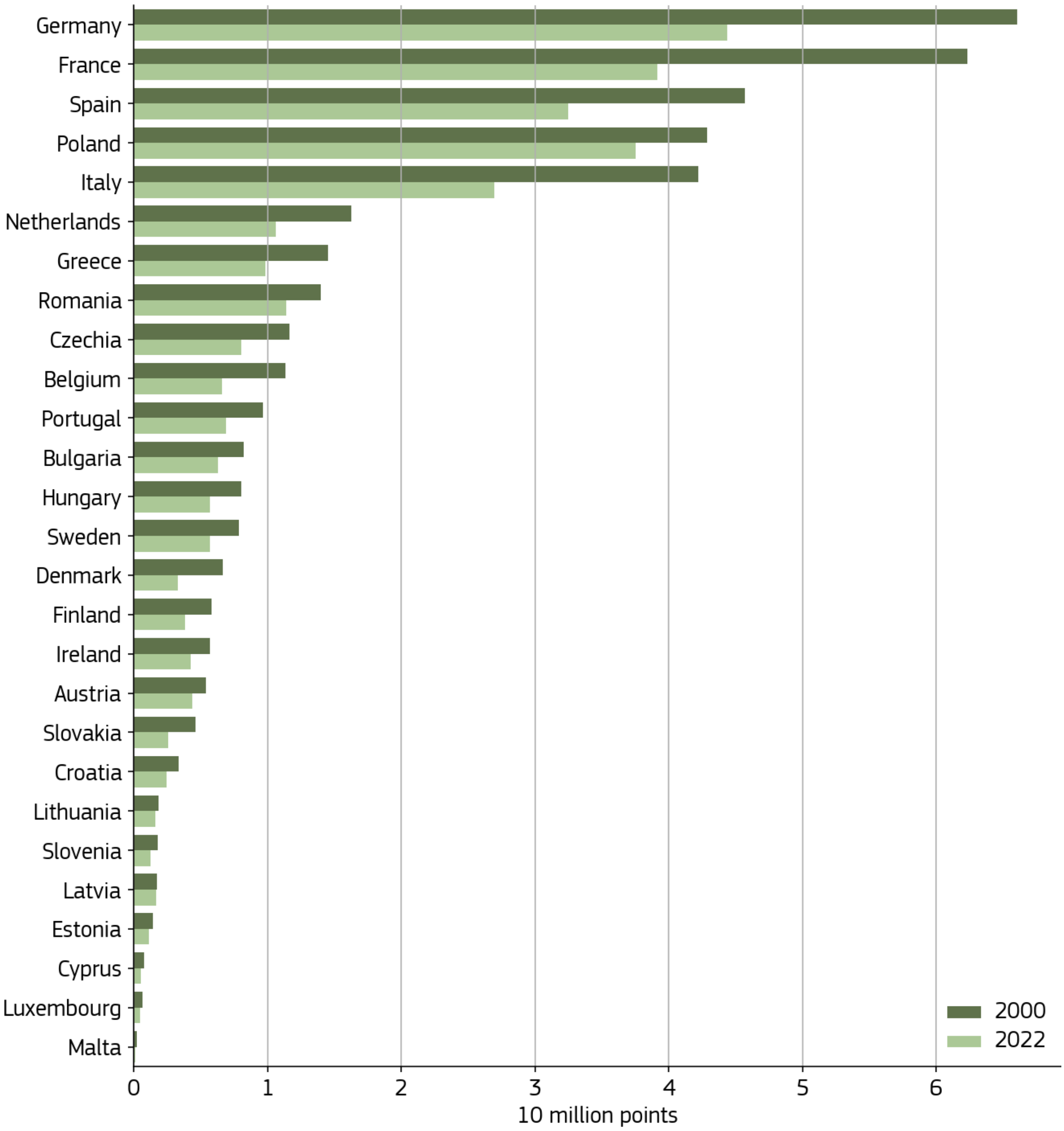


Source: Consumption Footprint Platform (EC-JRC 2024c).

4.3. How has the Domestic Footprint changed in the EU countries from 2000 to 2022?

This chapter compares the DF of the EU and the different EU countries in 2000 and 2022 from three perspectives: total impact, impact per capita and impact per area. Analysing the **total DF** by country enables to observe the contribution of the different EU countries to the total impact of the EU (Figure 8). The results showed that the overall DF decreased for all countries. Germany, France, Poland, Spain and Italy represent the countries with highest impact both in 2000 and 2022, and also correspond to the five most populated countries in the EU.

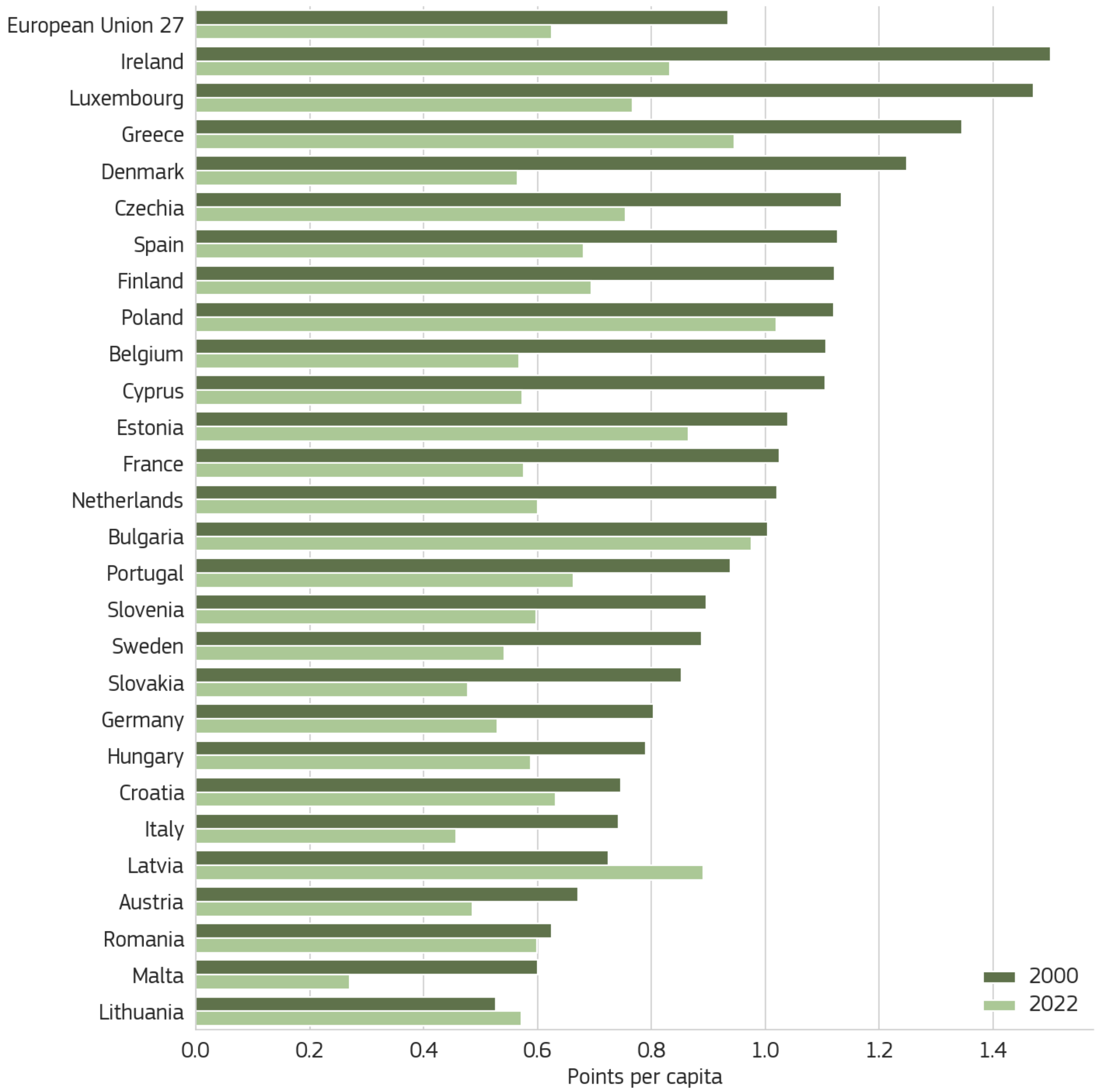
Figure 8. Total Domestic Footprint single weighted score of EU countries in 2000 and 2022.



Source: Own elaboration. Note: values are ranked by value in 2000.

When factoring in the population, Figure 9 compares the DF per capita of the EU and EU countries in 2000 and 2022. Results showed that the impact per capita was reduced in 2022 compared to 2000 for the EU and the different EU countries, apart from Latvia and Lithuania. All the impact of EU countries apart from Lithuania was reduced in 2022 compared to 2020. On the contrary, the EU countries that saw the highest decrease in their DF per capita are Malta (-54%), Denmark (-54%), Luxembourg (-47%) and Belgium (-46%).

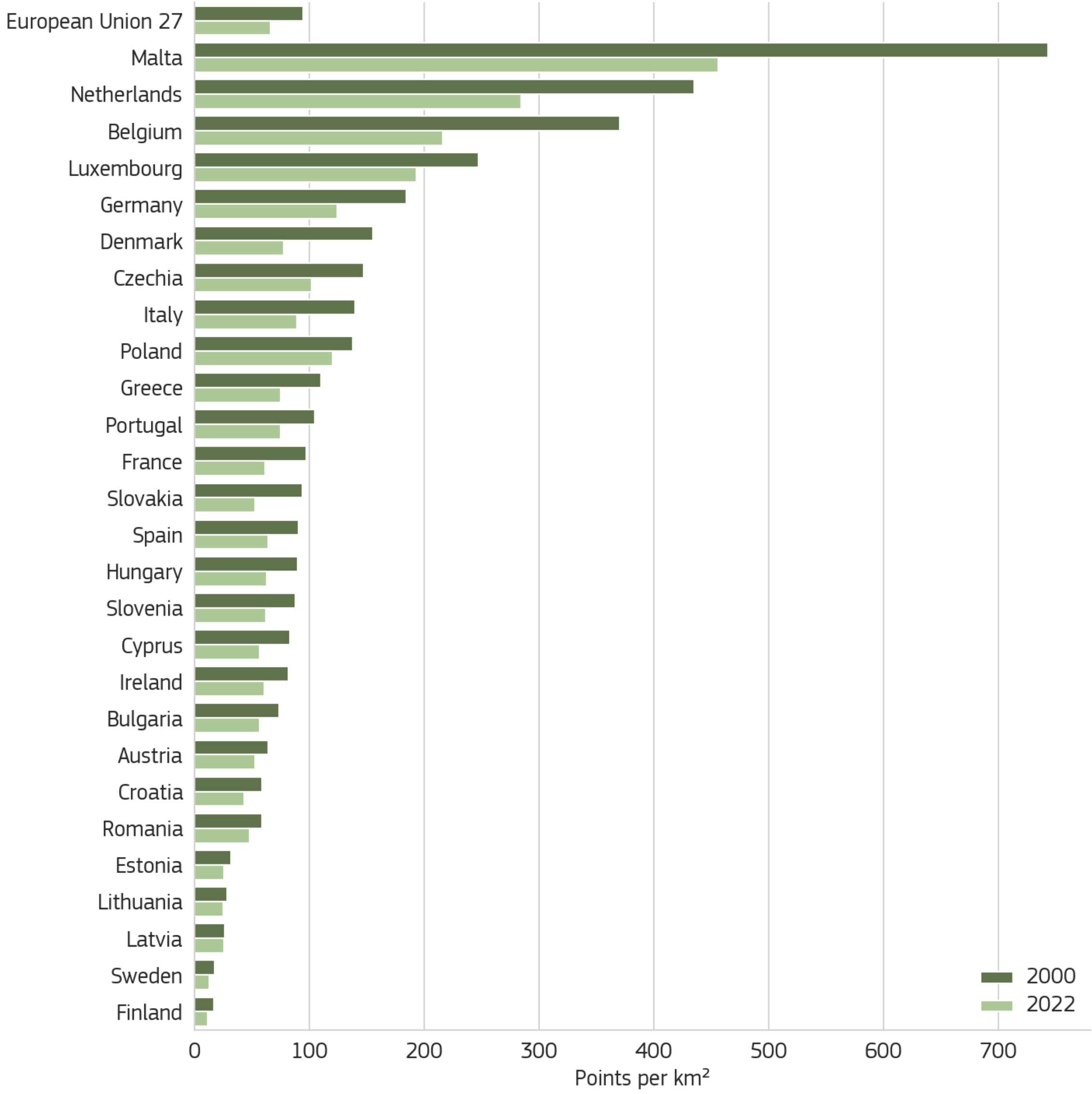
Figure 9. Domestic Footprint per capita of the EU and EU countries in 2000 and 2022, in terms of single weighted score (points per inhabitant), ranked by 2022 value.



Source: Own elaboration.

If the size of the different countries is considered, the **DF per country surface area** shows a different distribution compared to the previous graphs (Figure 10). The DF per area decreased for the EU and all EU countries between 2000 and 2022, apart from Latvia, which showed a slight increase. The highest DF per area are those of Malta, Netherlands, Belgium, and Luxembourg. This result highlights the large DF density in small countries in the EU.

Figure 10. Domestic Footprint per surface area of the EU and EU countries in 2000 and 2022, in terms of single weighted score (points per square kilometre (km^2)), ranked by value in 2000.



Source: Own elaboration.

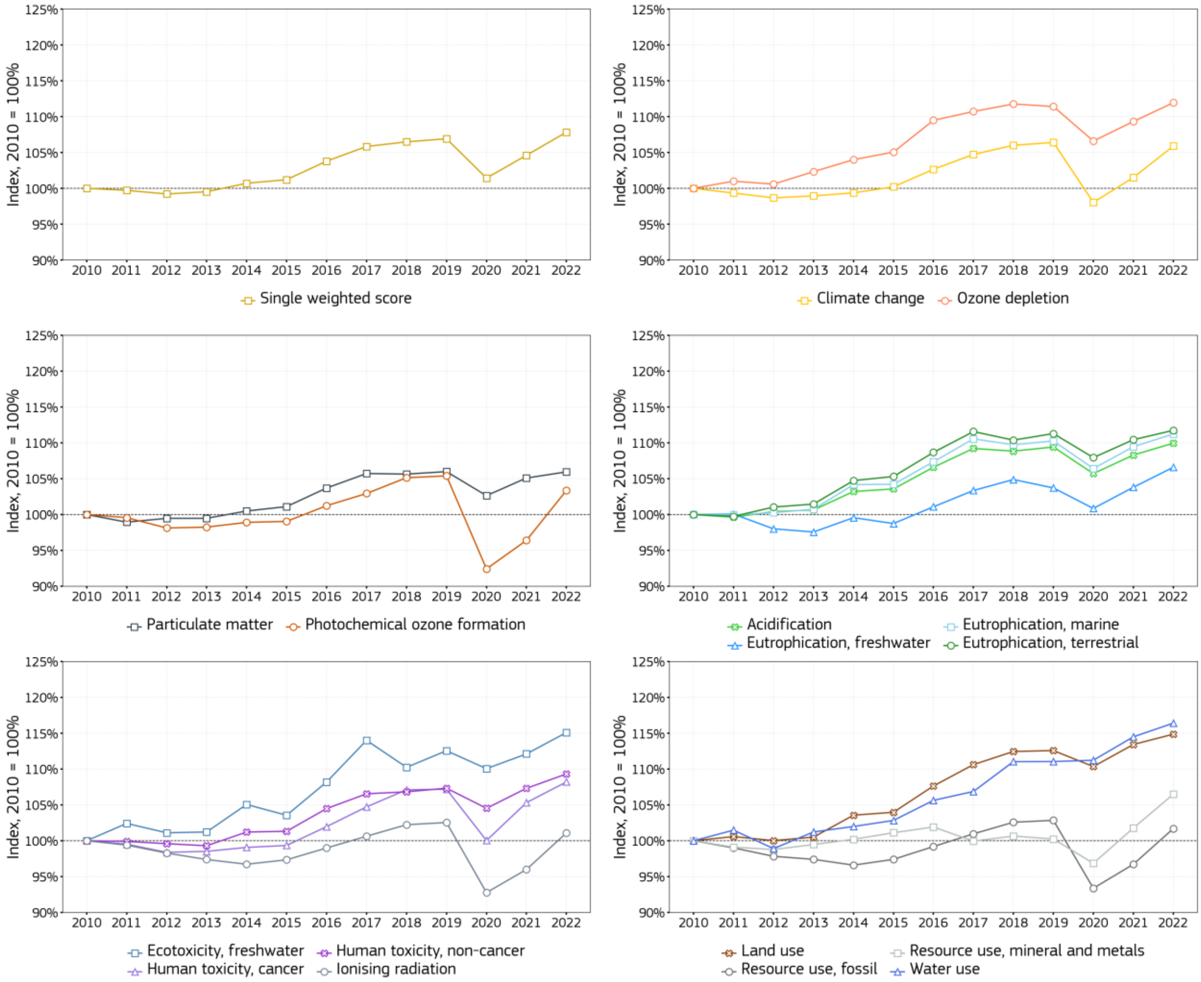
5 The environmental impact of EU consumption patterns: the Consumption Footprint

This chapter explores the CF of the EU and EU countries for the period 2010-2022, paying attention to the observed trends in this period (section 5.1), the role of the different areas of consumption (section 5.2) and the geographical variability (section 5.3).

5.1 Evolution of the Consumption Footprint over time from 2010 to 2022

During the period 2010-2022, **the EU total CF increased by 9%** when represented as a single weighted score. Figure 11 shows the distribution of trends by impact category of the EF impact assessment method, alongside the single weighed score (top left graph). The impacts which show greater concerns, since they are growing more than the average rate, are those linked to particulate matter, ozone depletion, and acidification (related to transport and mobility), freshwater ecotoxicity, land use, water use, as well as terrestrial and marine eutrophication, which are related to the impacts from agriculture.

Figure 11. Evolution of the Consumption Footprint in EU-27 over time from 2010 to 2022 and trend by impact categories of the Environmental Footprint (index 2010=100%).

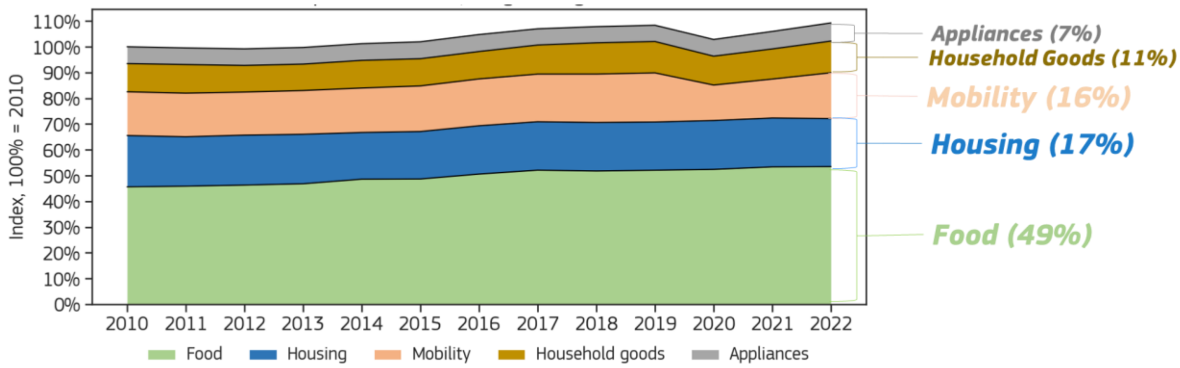


Source: Consumption Footprint Platform (EC-JRC 2024c). Note: Results for 2000 are reported as 100%, and results for the other years are rescaled accordingly. All of the 16 EF categories are highly interdependent among each other, and the split in five chart is intended as being solely illustrative to support visualization and comparability of trend data.

5.2 The EU Consumption Footprint by area of consumption

Figure 12 shows the trend in the EU CF distributed by area of consumption (i.e., product group). The CF increased by 8% from 2010 to 2019, and decreased between 2019 and 2020 due to the effects of the COVID pandemic. This is followed by a slow trend increase (although it was still limited due to a decrease in air mobility, i.e., aeroplane travel), surpassing pre-pandemic levels up to a +9% raise in 2022 compared to 2010. Apart from the variability of mobility during the COVID pandemic, no relevant changes in the role of the different areas of consumption have been observed over this period.

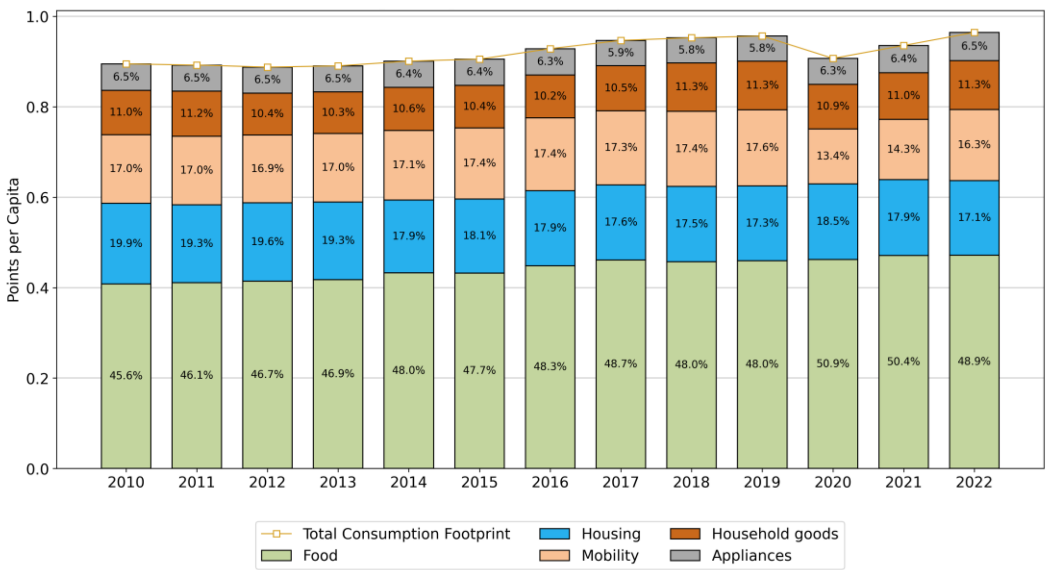
Figure 12. Evolution of the Consumption Footprint in EU-27 over time from 2010 to 2022 and the contribution of the areas of consumption to the Consumption Footprint (index= 2010).



Source: Own elaboration. Note that some datasets underpinning the calculation of the consumption intensities from FAOSTAT and Eurostat are still not public for 2022 and data were extrapolated from previous trends.

The increase can be partly attributed to population growth (about 1.5% increase, Eurostat 2024d), and can be mostly explained by increases in consumption patterns per citizen (Figure 13).

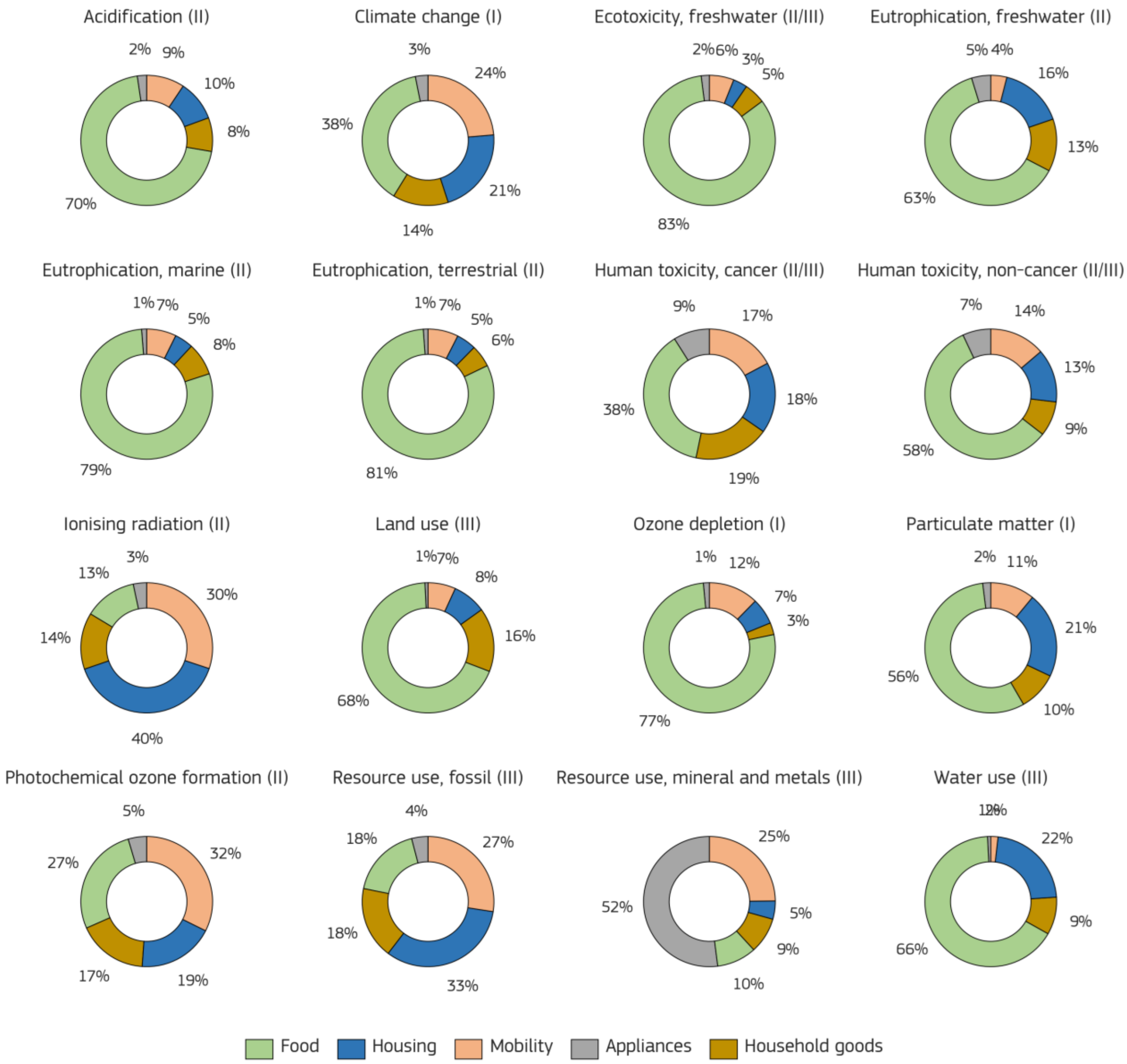
Figure 13. Evolution of the EU Consumption Footprint per capita, expressed as single weighted score, highlighting the contribution by area of consumption.



Source: Own elaboration.

EU citizens seem to keep increasing their annual consumption (i.e., the number of products consumed per person) and, particularly of product groups that have a high impact per product (e.g., animal-based products). Food has the largest share (49%), followed by housing and mobility, with a share of 17% and 16%, respectively. Appliances and household goods had the lowest impact contribution of 6% and 11%, respectively. Figure 14 disaggregates these impacts between the 16 impact categories of the EF. Food represents the greatest number of policy hotspots among the five areas of consumption: for 11 out of 16 impact categories. These include toxicity-related impacts (i.e., 83% for freshwater ecotoxicity, 38% and 58% for cancer and non-cancer human toxicity respectively), eutrophication (i.e., 63% freshwater, 79% marine, and 81% terrestrial), acidification (70%), and resources use (i.e., 68% for land use, 66% for water use), air pollution (i.e., particulate matter for 56% and 77% for ozone depletion), and climate change (38% of total). With regard to the other consumption areas, mobility and appliances are the greatest hotspot for mineral resource use (above 75%, when taken together), housing for ionising radiation (40%) and fossil fuel resource use (33%), and mobility for photochemical ozone formation (32% of total).

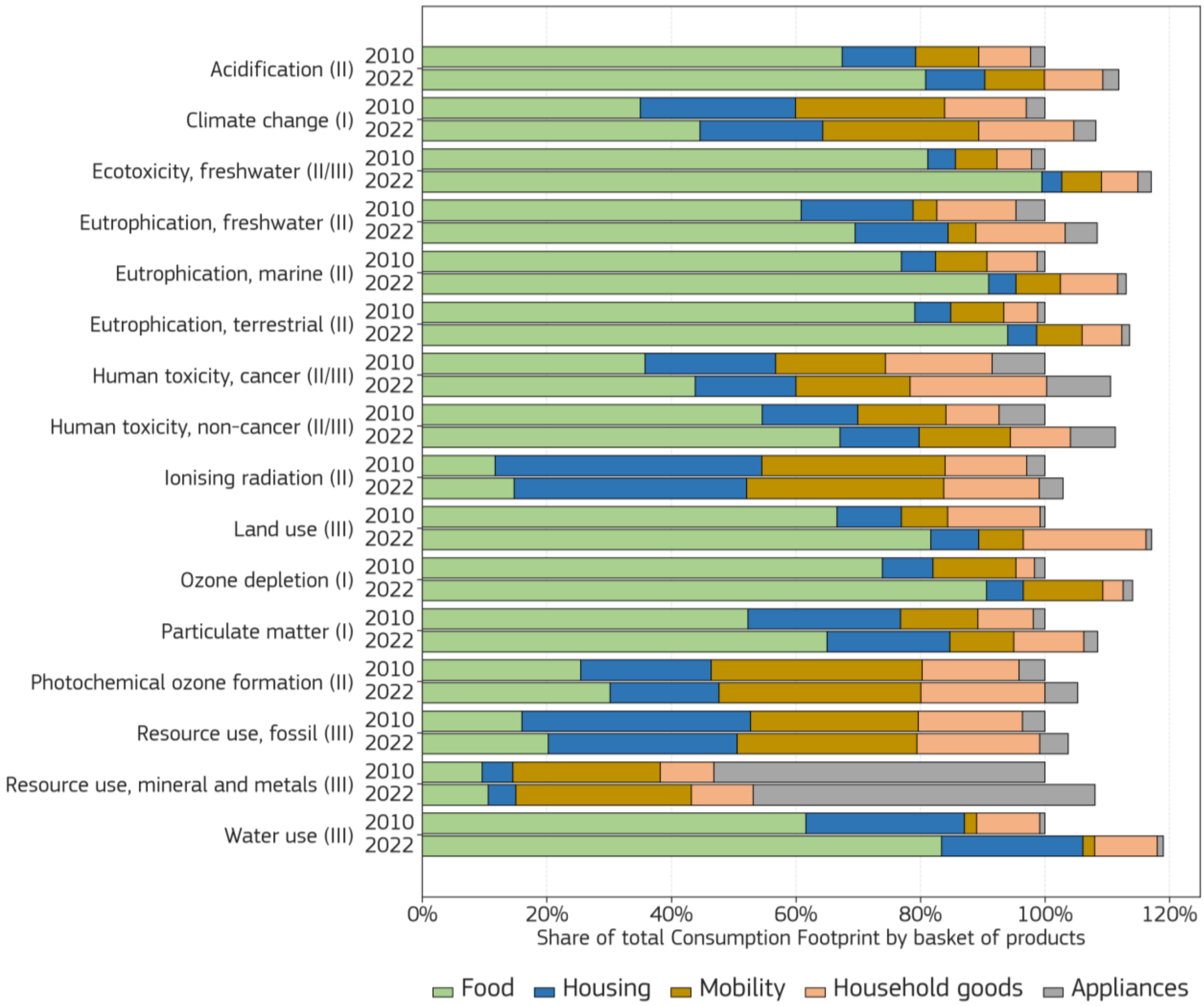
Figure 14. Environmental impacts contribution of the different areas of consumption for EU-27 expressed as in the 16 impact categories of the environmental footprint (2022).



Source: JRC elaboration.

Figure 15 compares the EU CF between 2010 and 2022 by impact category, and by highlighting the relative increase by area of consumption. The area of consumption with the highest increase overtime is food (see Figure 16), dominating all the other areas. Housing shows a decreasing trend in the analysed period (2010-2022), mainly resulting from introducing energy efficiency regulations in 2010 (EPC (2022) (see also Figure 20). Notwithstanding the effects of the COVID pandemic, the area of consumption of mobility (see also Figure 18) shows an increasing trend highlighting that the benefits of policies targeting sustainable mobility, such as the gradual reduction of car emissions (EC, 2008), seem to be counterbalanced by the heightened usage of cars, a phenomenon known as the "rebound effect". This highlights the necessity of implementing strategies that promote more responsible consumption behaviour patterns. The most substantial increase is observed in ozone depletion, land use, eutrophication marine, and ecotoxicity freshwater, primarily due to food consumption. Conversely, a decrease in ionising radiation is noted, attributed to changes in the electricity mix over time.

Figure 15. Evolution of the Consumption Footprint of the EU-27 from 2010 to 2022, and contribution of various areas of consumption to the Consumption Footprint, by impact category (index = 2010).



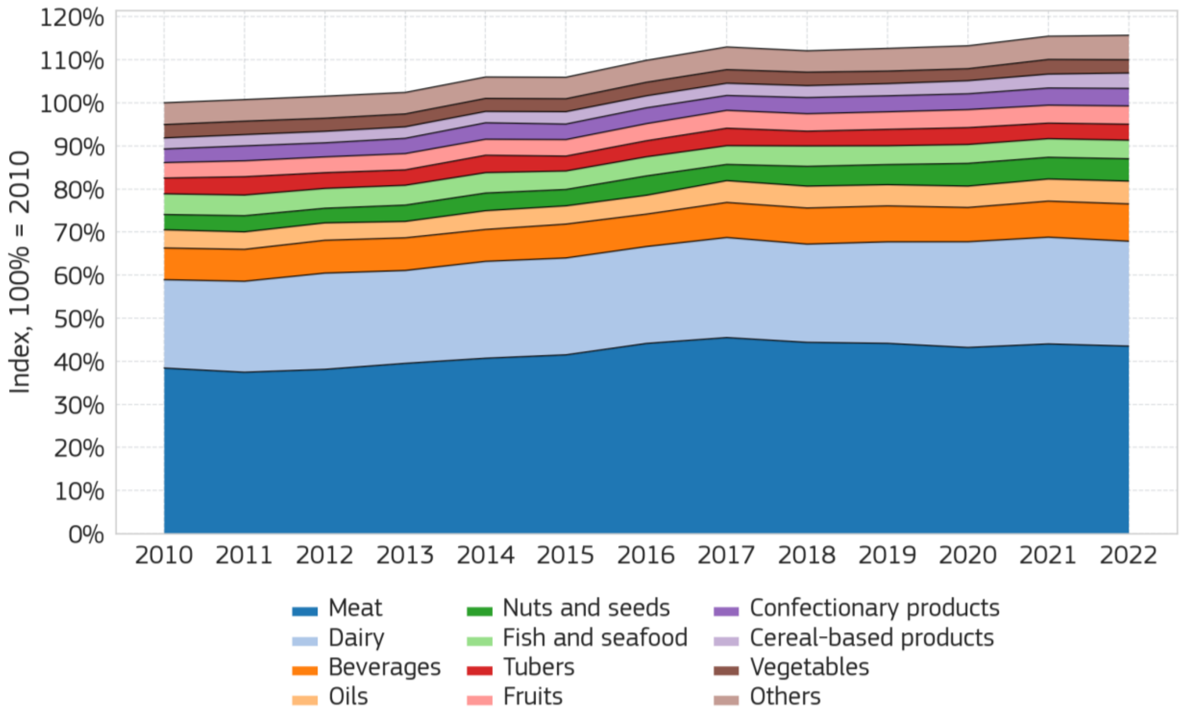
Source: JRC elaboration.

5.2.1 Food

The environmental impacts of food consumption (Figure 16) shows a high increase between 2010 and 2022[8]. The consumption of animal-based products (particularly meat and dairy) is the major contributor to the overall impact during this period, accounting for around 40% and 20% of the total impacts of food, respectively.

The environmental impacts between 2010 and 2022, expressed as a single weighted score, increased for the several food products, owing to higher levels of consumption: beef (+7%), poultry (+12%), pork (12%) and cheese (+36%).

Figure 16. Evolution of the food area of consumption for EU-27 between 2010 and 2022 (index 100% = 2010).

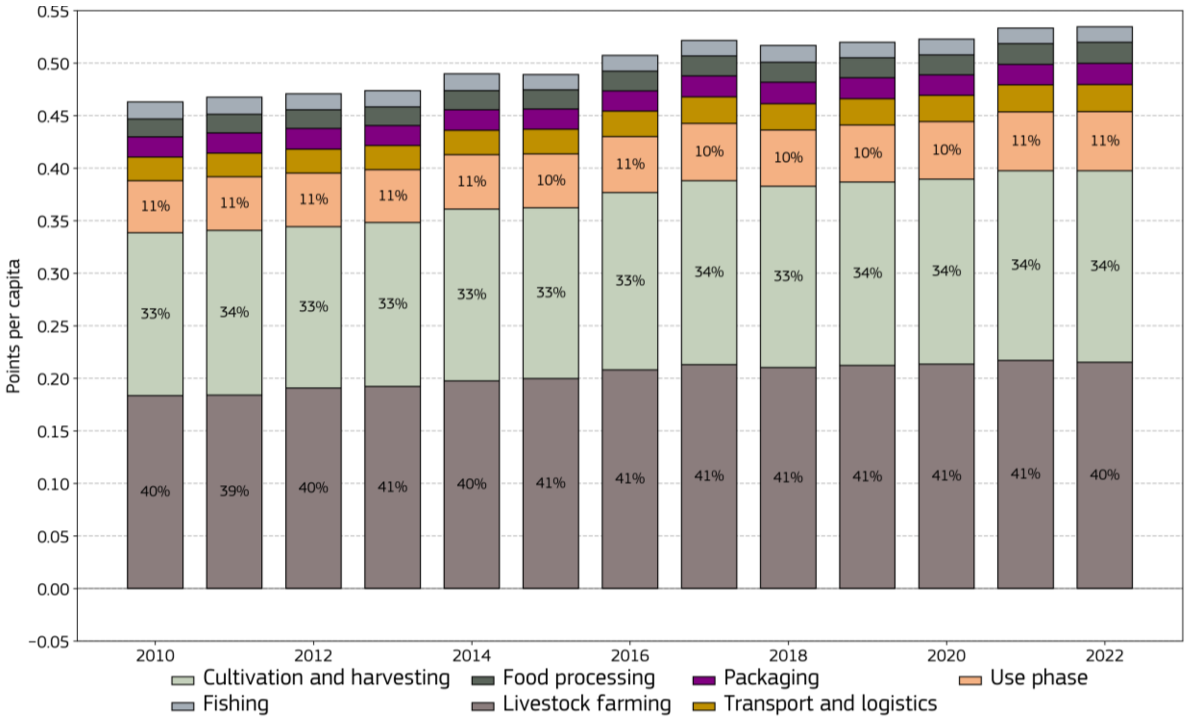


Source: JRC elaboration.

[8] The environmental impact in the food area of consumption are calculated accounting for environmental impacts that occur for processes which are in common with other areas of consumption. Further details are available in Annex 8.

Figure 17 shows the environmental impact of the food area of consumption, in terms of a single weighted score and highlighting the share by life cycle stages). The areas of greatest concern are linked to the primary production of food. In 2022, the 40% of impact of food consumption was due to livestock farming, followed by 34% for the cultivation of fruit and vegetables, as well as feed for animals. An additional 11% of the impact is due to the use phase, mainly linked to energy consumption in housing with activities which link to food storage and processing, such as cooking or refrigeration.

Figure 17. Evolution of the food area of consumption for EU-27 between 2010 and 2022 by life cycle stages (points per capita).

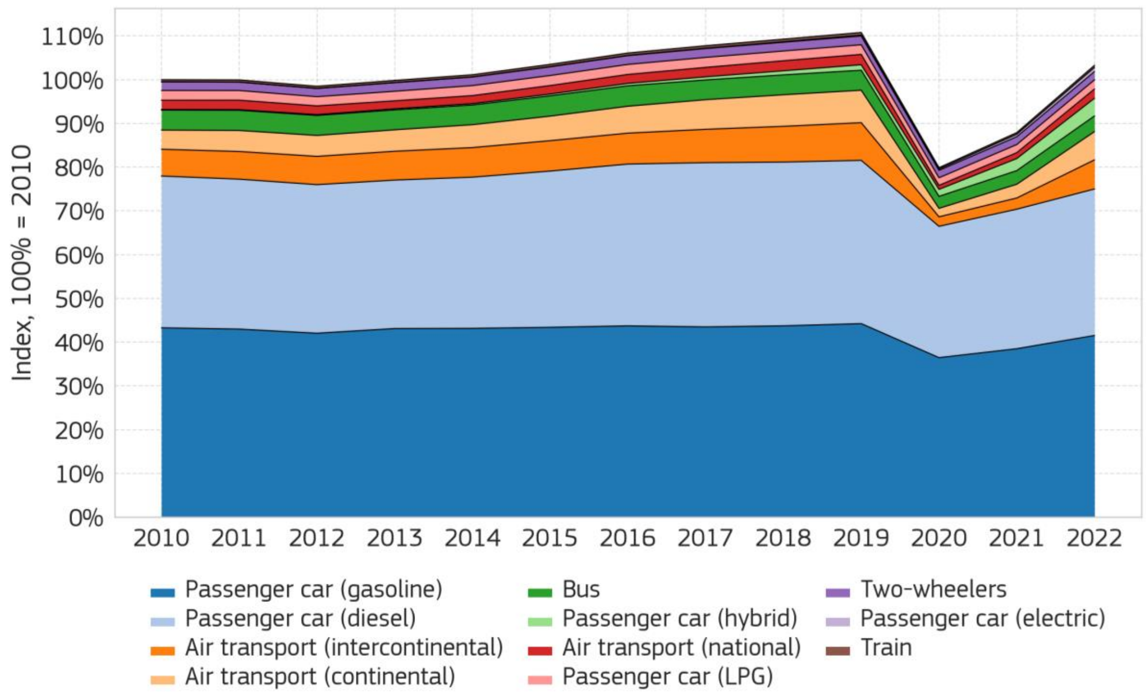


Source: JRC elaboration.

5.2.2 Mobility

The environmental impacts associated with the mobility area of consumption shows an increasing trend in the analysed period (see Figure 18). The mobility of electric and hybrid cars showed the largest increase during this period, being respectively 222 and 32 times higher in 2022 than in 2010. This high increase shows a progressive shift in consumers' behaviour to greener and more sustainable vehicles. Regarding air mobility, continental air transport increased by 49%, and intercontinental by 10%. Mobility via buses saw a decrease in trend by 21%. For passenger cars, LPG cars decreased by 5%, diesel cars increased by 1%, and gasoline cars decreased by 3%. Mobility via train remained relatively stable, while that of two-wheelers decreased by 3%.

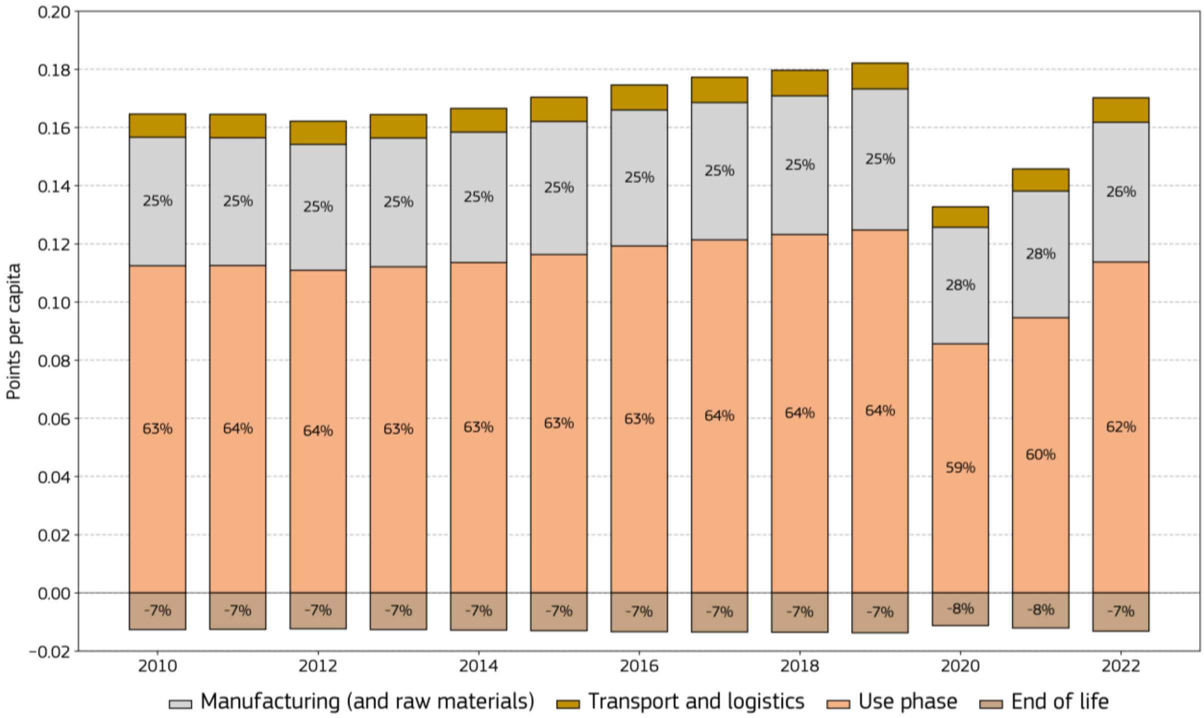
Figure 18. Evolution of the mobility area of consumption for EU-27 between 2010 and 2022 (index 100% = 2010).



Source: JRC elaboration.

Figure 19 shows how the greatest area of concern in the mobility sector is that related to the use phase, because of fuel consumption, infrastructure and repair/ maintenance of vehicles. The use phase accounts for a 62% of total impact in terms of single weighted score in 2022, increasing since the drop between 2019 and 2020 due to COVID which reduced the impact of the use phase to 59% of total. A significant portion is still due to manufacturing of vehicles, accounting for 26% of total impact in 2022. A positive note can be seen on the contribution of circular economy measures, linked to recycling of materials, which, in this area of consumption, accounts for about 7% to 8% reduction in environmental impact across the time period considered.

Figure 19. Evolution of the mobility area of consumption for EU-27 between 2010 and 2022 by life cycle stage (points per capita)

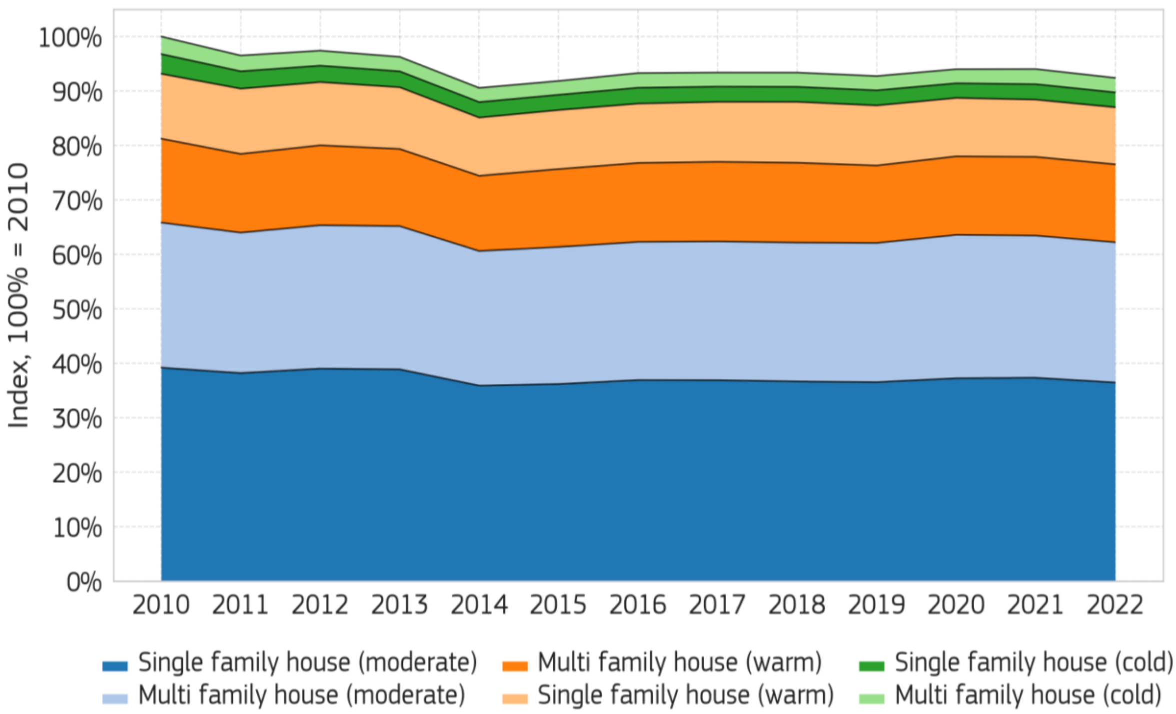


Source: JRC elaboration.

5.2.3 Housing

The **environmental impacts associated with the housing area of consumption** (Figure 20) **highlights a decreasing trend in the period analysed.** The building stock has been partly renovated, with older buildings replaced by those constructed or renovated after 2010. The highest population density in EU countries is found in a moderate climate. As a result, this climate area contributes the most to the overall EU CF for housing. Energy and water consumption per dwelling has reduced, which can mainly be attributed to EU policies that have been designed to make buildings more energy-efficient. The energy utilised for space heating, cooking, water consumption, and lighting decreased amongst all the housing groups. The differences in energy usage for appliances and domestic hot water depend on the climatic region (cold, moderate, and warm) and building type (single and multi-family housing).

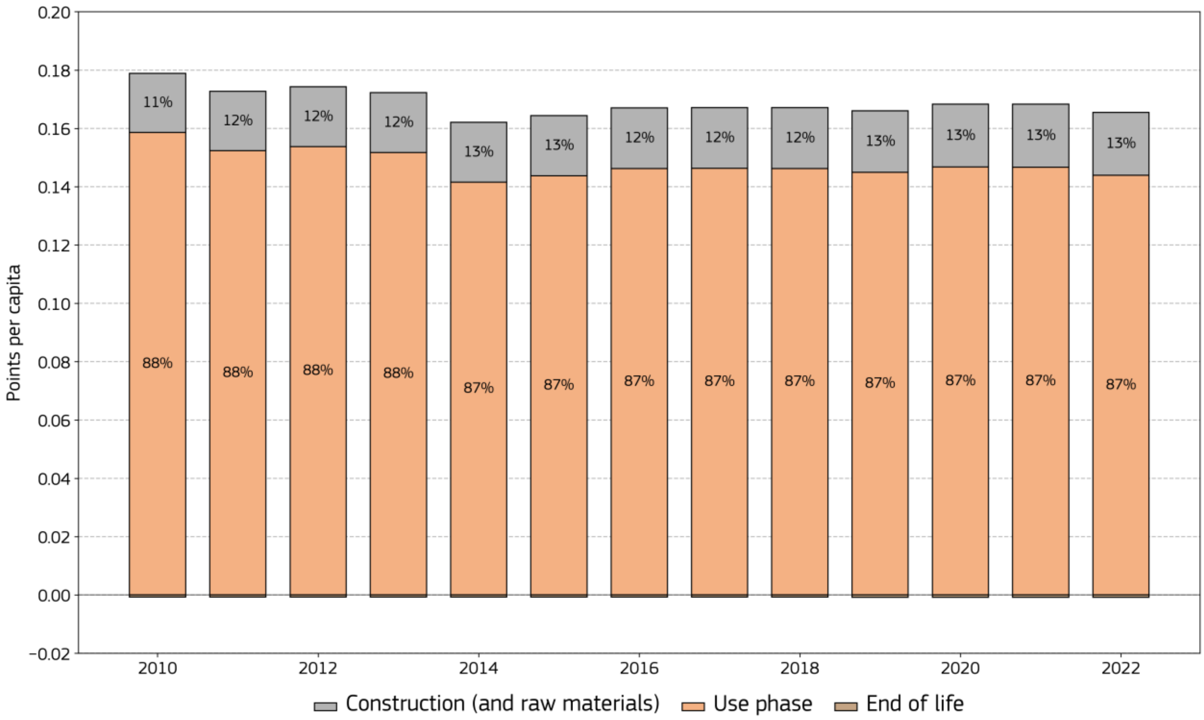
Figure 20. Evolution of the housing area of consumption for EU-27 between 2010 and 2022 (index 100%= 2010)



Source: JRC elaboration.

Figure 21 highlights the impacts by life cycle stages in housing, giving emphasis to the Construction (including extraction of raw materials), Use phase, and End of Life of a building. The vast majority of the impacts (87% of total housing impact in 2022) occur in the use phase, meaning the use of energy for heating and cooling, as well as water use, demonstrating the high importance of energy policy in the housing sector with initiatives such as the Renovation Wave (EC, 2020f). A relatively limited fraction is devoted to the construction phase (13% of total impact in housing in 2020), and marginal influence for the waste treatment.

Figure 21. Evolution of the Housing area of consumption for EU-27 between 2010 and 2022 by life cycle stage (points per capita).

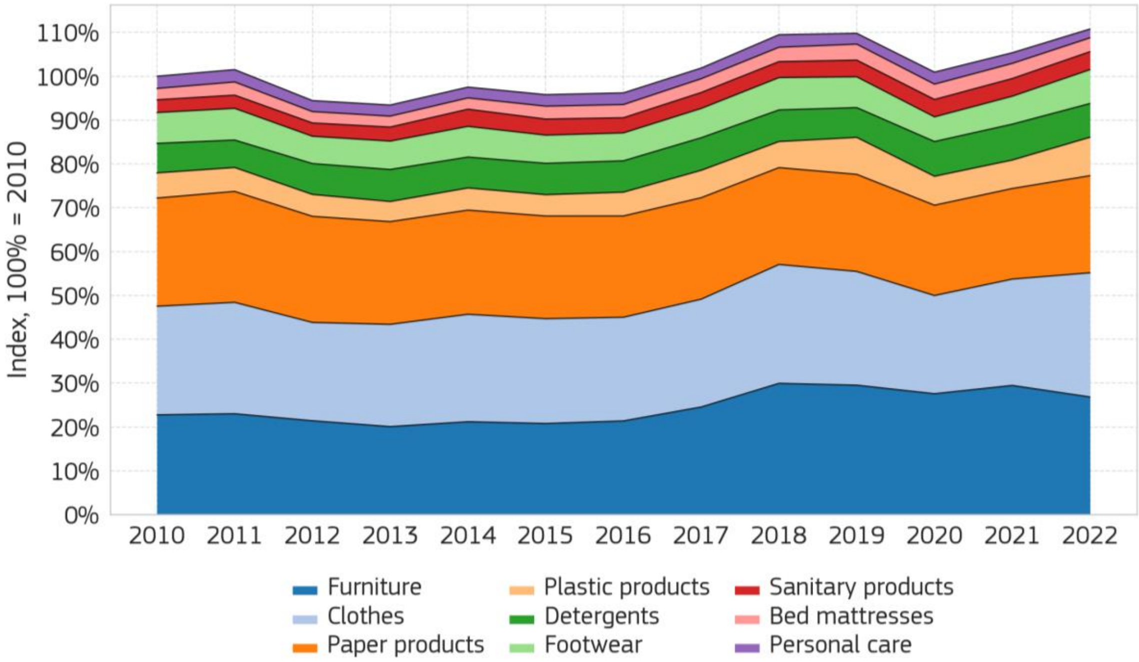


Source: JRC elaboration.

5.2.4 Household goods

The **environmental impacts associated with the area of consumption related to household goods** (Figure 22) **show an increasing trend between 2010 and 2022[9].** The environmental impacts tend to increase in the groups of clothes (textile industry), plastic products and footwear. This is mainly due to increased annual consumption of the underlying products, which comprise such impacts related to hair-related products (+117% increase between 2010 and 2022), wooden tables (+106%), plastic household articles (+99%), liquid soap (+85%), work&waterproof (W&W) footwear (+77%), sleeping bags (+75%), and toilet paper (+61%). On the other hand, the product groups with the most notable decrease include shampoo (-48%), newsprint (-38%), and plastic furniture (-20%).

Figure 22. Evolution of the household goods area of consumption for EU-27 between 2010 and 2022 (index 100%= 2010)

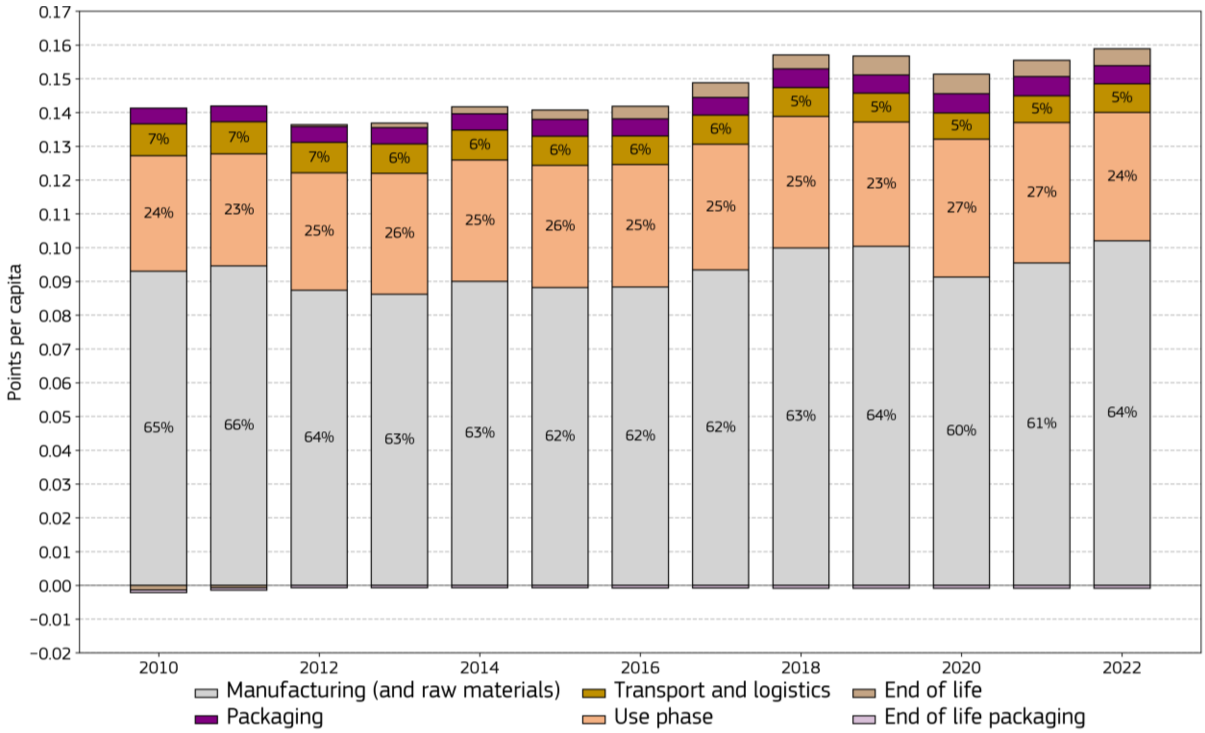


Source: JRC elaboration.

[9] The environmental impact in the household goods area of consumption are calculated accounting for environmental impacts that occur for processes which are in common with other areas of consumption. Further details are available in Annex 8.

The life cycle stages that generate most impacts in housing goods are the manufacturing (including raw material extraction, and in particular for textiles) (64% of total impact in 2022), and use phases, due to the consumption of detergents in dishwashers and washing machines (mostly due to electricity and water consumption) (24% of total impact of goods in 2022), and 5% due to the logistics in the supply chain (Figure 23). Although the housing good market is a less stable market, characterised by fluctuations, the shares or impacts have been generally stable over the period in consideration.

Figure 23. Evolution of the Household goods area of consumption for EU-27 between 2010 and 2022 by life cycle stage (points per capita)

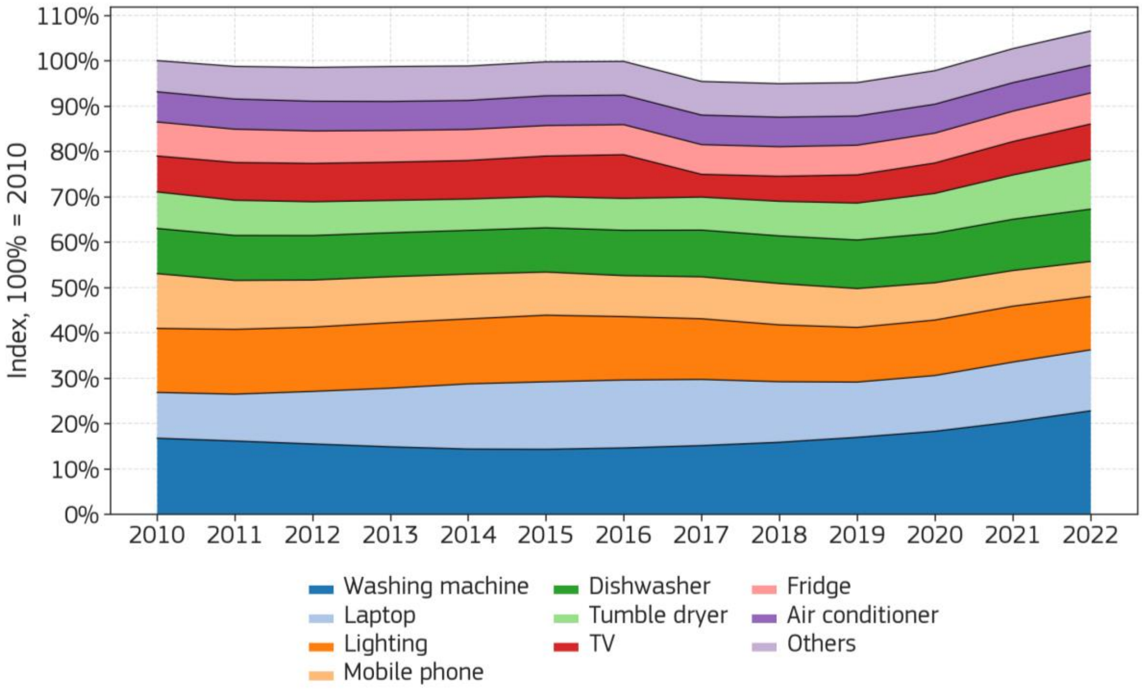


Source: JRC elaboration.

5.2.5 Appliances

The **environmental impacts associated with the appliances area of consumption** (Figure 24) **show an increasing trend over the analysed period[10].** The post-COVID pandemic shift towards hybrid modes of working contributed to an increase in the consumption of laptops (+35%). The appliances with the most notable increase include washing machines (+37%), tumble dryers (+37%), and coffee makers (+22%). On the other hand, the appliances with the most notable decrease in consumption include incandescent bulbs (-87%), halogen lamps [both low voltage (-81%), and main voltage (-78%)].

Figure 24. Evolution of the appliances area of consumption for EU-27 between 2010 and 2022 (index 100%= 2010).

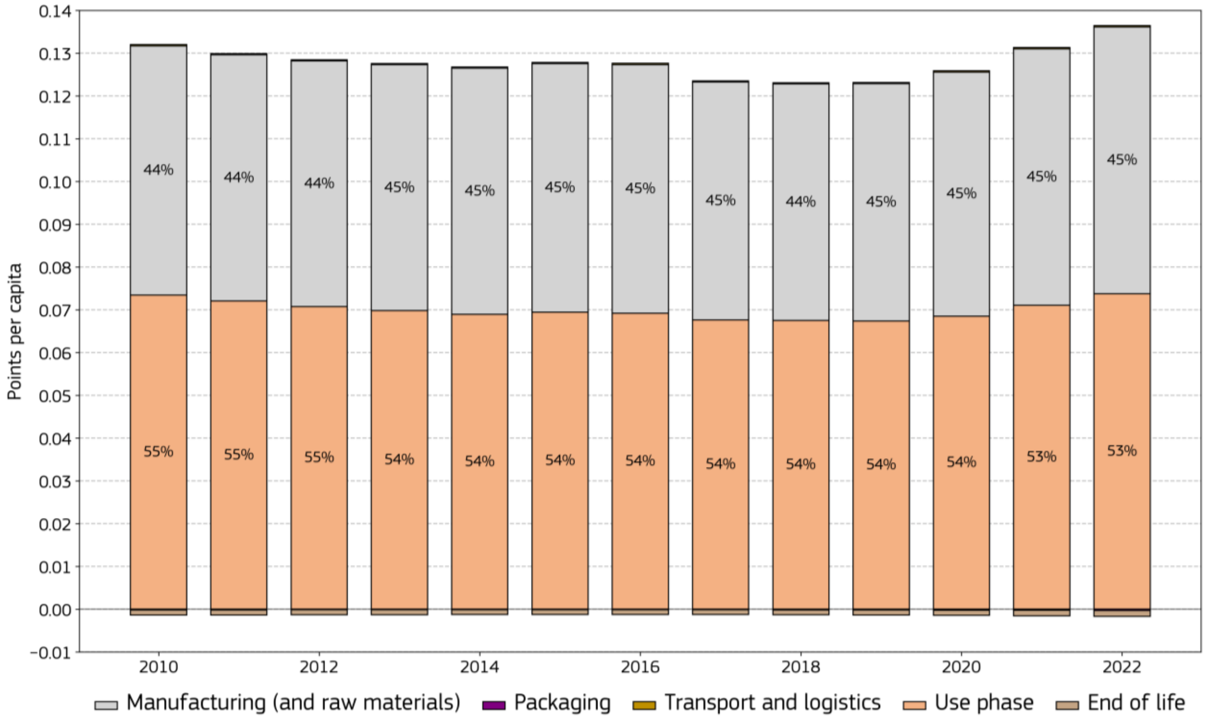


Source: JRC elaboration.

[10] The environmental impact in the appliances area of consumption are calculated accounting for environmental impacts that occur for processes which are in common with other areas of consumption. Further details are available in Annex 8.

As shown in Figure 25, the two main life cycle stages of the appliances area of consumption are Manufacturing (including raw materials extraction) representing 45% of the total impact, and the Use phase due to energy use, and water use for operating appliances. End of life and recycling represent limited potential for decreasing impact in the model.

Figure 25. Evolution of the appliances area of consumption for EU-27 between 2010 and 2022 by life cycle stage (points per capita)



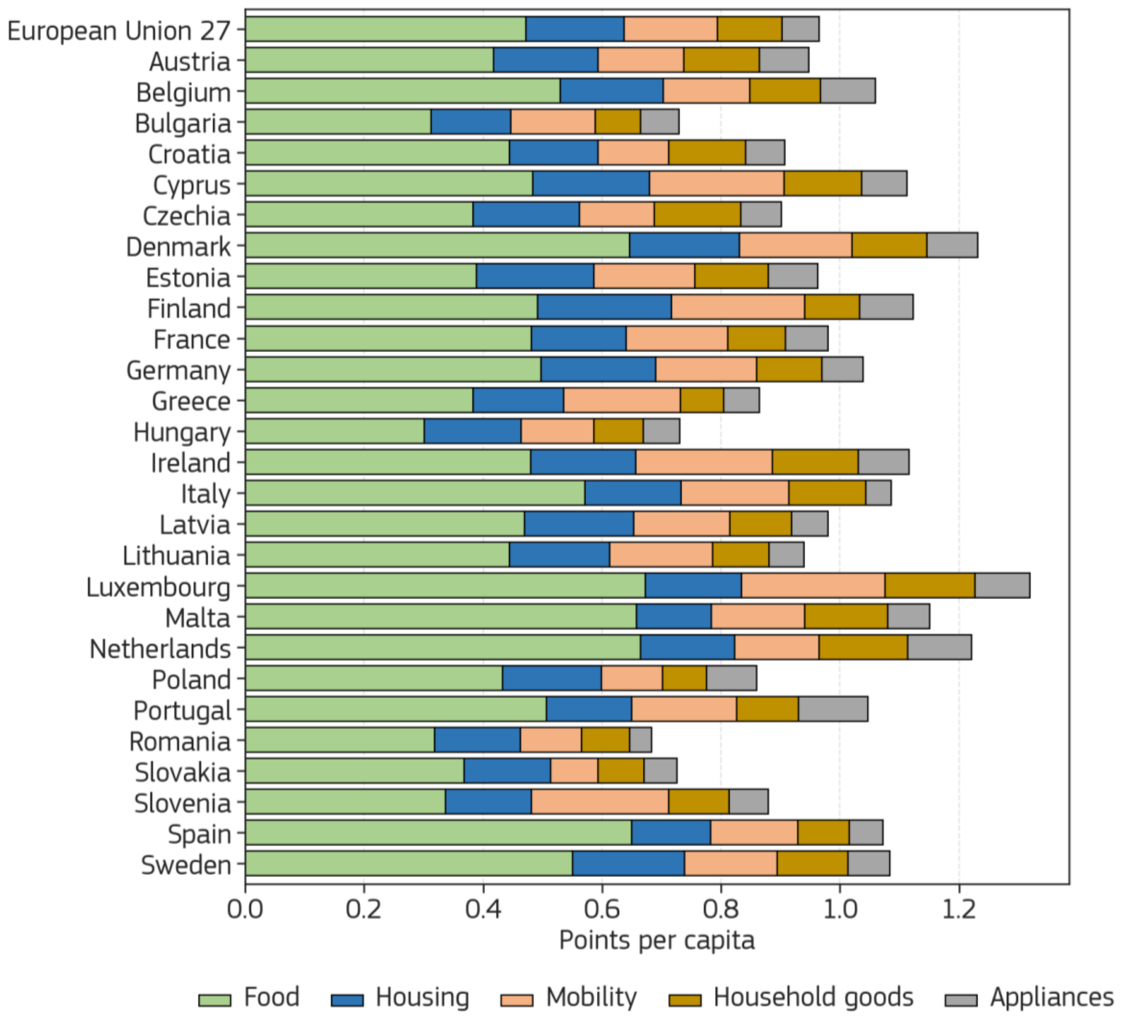
Source: JRC elaboration.

5.3. The Consumption Footprint per capita in the different countries (2010-2022)

Figure 26 shows the CF per capita of the EU-27 and EU countries in 2022 by area of consumption in terms of a single weighted score. Luxembourg, Denmark and Malta have the highest CF per capita. On the other hand, Romania, Hungary and Slovakia have the lowest CF per capita. Differences rely on contrasting consumption patterns (e.g., diet), geographical constraints (e.g., dependency on trade, isolated location), and income (e.g., high consumption per capita levels).

Across the EU countries, food consumption emerges as the primary contributor to the CF. Housing, particularly in moderate and cold countries, gains relevance due to the higher level of energy consumption utilized for heating purposes. The environmental impacts of household goods consumption vary, influenced by specific consumption patterns and lifestyles. Mobility, especially in countries with high air mobility needs like Malta, also plays a relevant role. It's worth noting that appliances generally have the lowest contribution. It is worth noting that, in the combined calculation of the impacts of all areas of consumption together, it is necessary to prevent double-counting, i.e., that environmental impacts are accounted in more than one area. For example, electricity consumption by appliances is counted where it occurs in the housing BOP, and likewise the consumption of soap detergent by appliances. The mapping of these interdependences is shown is available in Annex 8 and further details can be found in Sanyé-Mengual et al. (2023a).

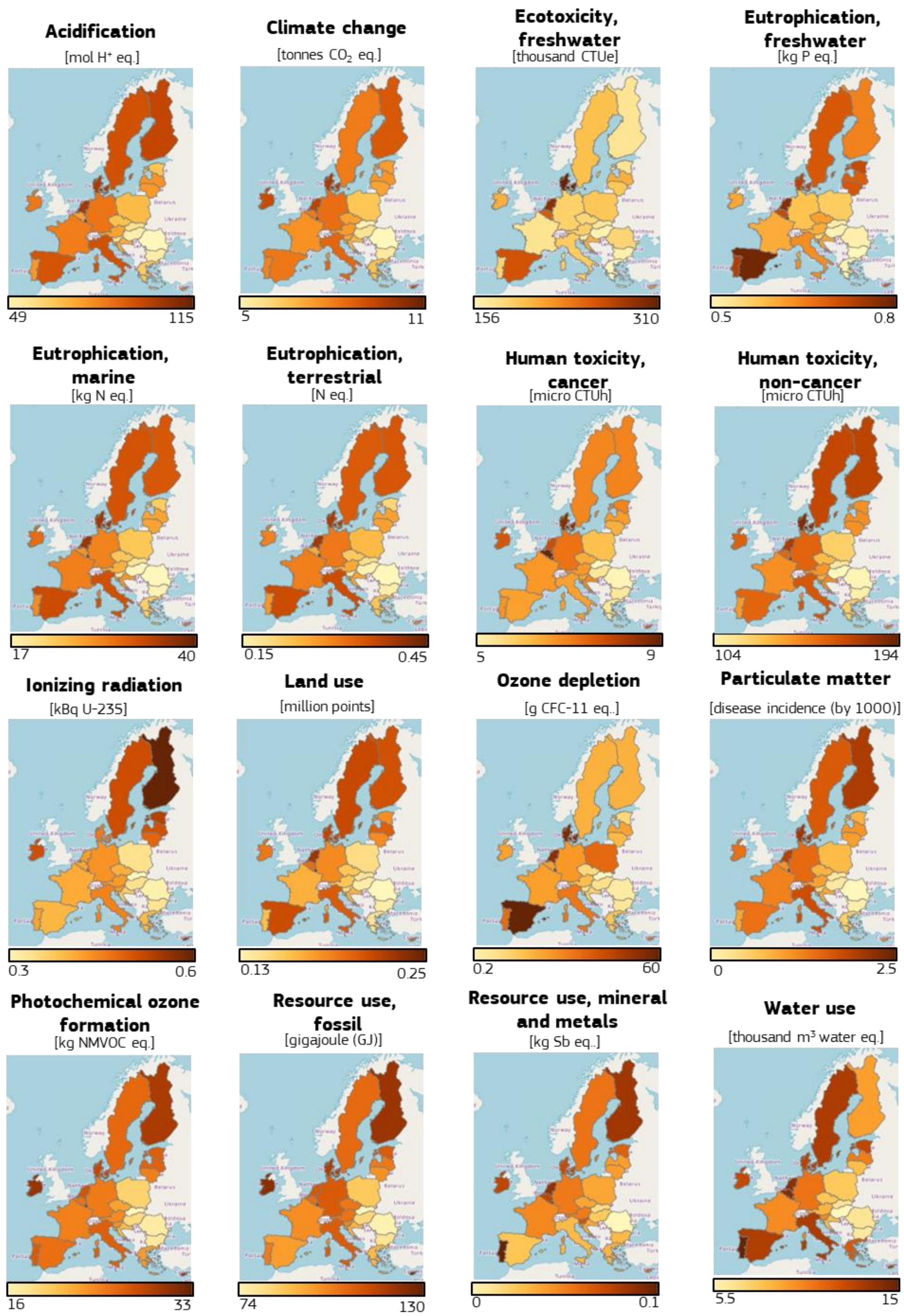
Figure 26. Consumption Footprint per capita and per area of consumption, by EU Member State (2022).



Source: JRC elaboration.

The CF per capita of each EU country is illustrated per EF impact category in Figure 27. EU countries with a high GDP per citizen, such as Luxembourg, Netherlands, Denmark, Finland, Sweden, and Belgium, usually exhibit a high impact per citizen. Southern EU countries tend to show a lower impact intensity per citizen, with the exception of water use.

Figure 27. Consumption Footprint per citizen of the EU countries, with respect to the 16 impact categories (2022).



Source: Consumption Footprint Platform (EC-JRC 2024c).

6. Analysing relative sustainability: environmental decoupling of the EU Domestic Footprint and Consumption Footprint

The CF and the DF models are powerful tools for assessing 16 environmental impact categories, which can be analysed in the context of both absolute and relative sustainability (Bjørn and Hauschild, 2013). In terms of relative sustainability, observing the evolution over time enables assessing whether progress is taking place. For example, progress can be evaluated by comparing the evolution of the environmental impact against that of economic growth. This specific analysis of progress is an **assessment of the decoupling**, which can be classified as absolute, relative or absent (see Box 2). Chapter 7 explores the assessment from an absolute sustainability perspective that, in a nutshell, aims to ensure that the environmental impacts of economic activities are within the limits of the planet.

Box 2. Definition of relative sustainability, absolute sustainability, and decoupling

Absolute sustainability: Economic activities **are performed within their relative share of natural limits of the planet**.

Relative sustainability: Economic activities **are performed better than in the past** but are not within the limits of the regenerative capacity of the planet.

Decoupling is a concept that allows us to compare the evolution of the environmental impact and the economic growth over the same time period. It can be classified as follows:

— **Absolute decoupling**: when the environmental impacts decrease over time in contrast to increasing economic growth.

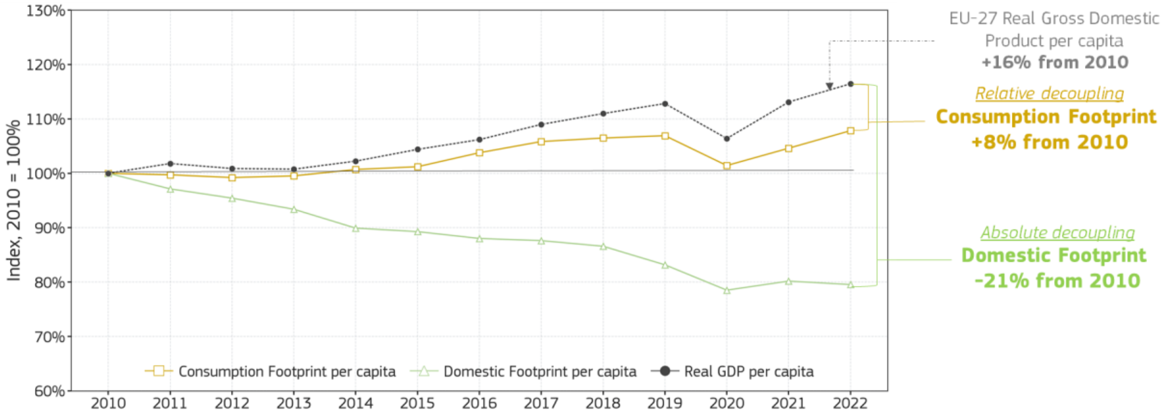
— **Relative decoupling**: when the environmental impacts increase over time but at a slower pace than the economic growth.

— **No decoupling**: when the environmental impact increases at a higher rate than the economic growth.

6.1. Overview decoupling of EU production and consumption

Gross Domestic Product (GDP) [see Box 3] is the sum of agricultural, industrial, and service output in a country in one year. It partially overlaps with our definitions of production (in the DF model) and consumption (in the CF model). This section describes how the impacts of production (DF) and consumption (CF) trends decouple from the evolution of GDP. Figure 28 shows the trend in DF and CF (in terms of single weighted score indicators) per capita compared with real GDP per capita (Eurostat 2024e). The figure shows that both DF and CF are decoupling from the evolution of GDP in per capita terms (+16% growth from 2010 to 2022). Still, only the DF shows an absolute decoupling (i.e., the impacts decrease over time, -21%). When considering the trade balance in the CF, the impacts still increase over time (+8% from 2010 to 2022), leading to solely relative decoupling.

Figure 28. Environmental impact decoupling of the Consumption Footprint and Domestic Footprint per capita from economic growth (i.e., real GDP per capita) (EU27, 2010-2022)



Source: Consumption Footprint Platform (EC-JRC 2024c), Eurostat (2024e)

Box 3. Different definitions of GDP and relationship with DF and CF datasets

Understanding the **various methods of calculating GDP** is crucial for understanding the intricacies of economic measurements. One such method involves summing up the value added by agricultural, industrial, and service output produced within a country's domestic territory. Alternatively, GDP can be calculated using the formula **GDP = Consumption + Private Investments + Government Expenditure + (Export – Imports).**

In this study, we use the definition of **Apparent Consumption = Domestic Production + Imports – Exports** to calculate the consumption intensity (or annual consumption) of products within the CF model. As a result, our definitions of domestic production and consumption partially overlap with the broader definition of GDP, but remain different concepts.

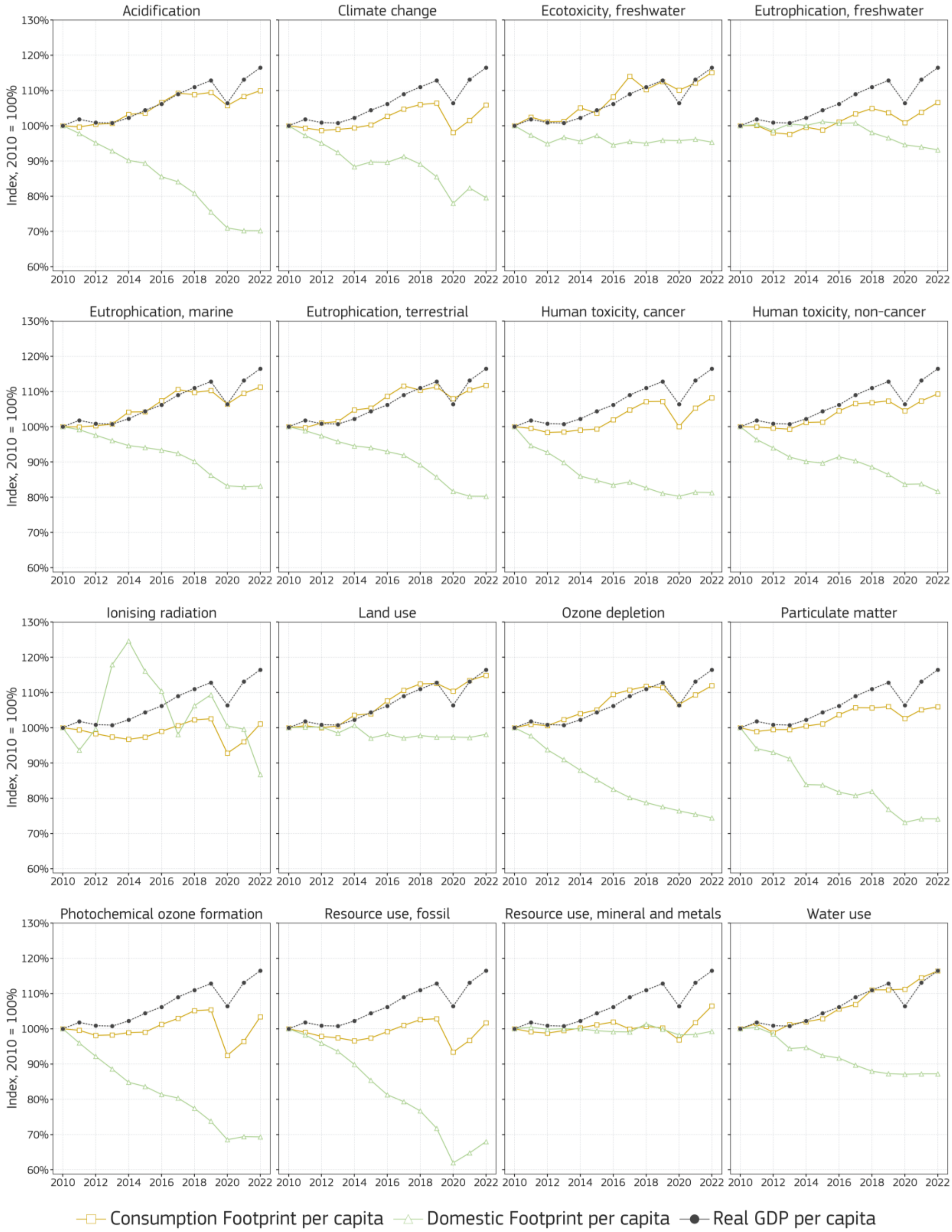
6.2. Zooming in to environmental decoupling by impact category

Since the calculation of the DF and the CF as a single weighted score may obscure the actual environmental impacts that comprise the two footprints, this section provides a breakdown of the environmental decoupling assessment of the DF and CF by impact category, via the EF method.

In the case of the DF, Figure 29 shows that all impact categories are below the GDP per capita curve and therefore, show some degree of decoupling, thereby leading to improved environmental performance. Most impact categories, as well as the single weighted score, decreased during the 2000-2022 period. Only two impact categories increased during this period (land use and resource use, minerals and metals), leading to a relative decoupling.

Decoupling results are different for the CF. The disaggregation of the single weighted score in its impact categories highlights that the CF does not decouple from economic growth for 7 of the impact categories (e.g., acidification, freshwater ecotoxicity, marine and terrestrial eutrophication, ozone depletion, land and water use). It is not possible to consider any impact category to show absolute decoupling.

Figure 29. Trend in the Domestic Footprint and Consumption Footprint impact categories, and decoupling against real GDP per capita from 2000 to 2022.

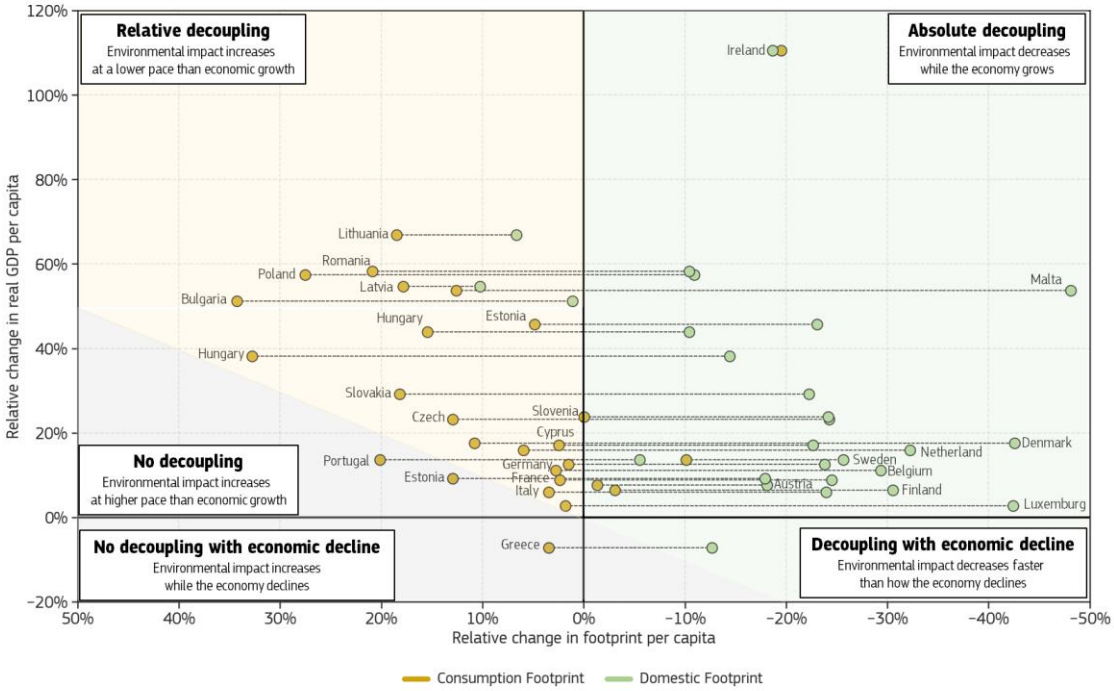


Source: Consumption Footprint Platform (EC-JRC 2024c)..

When comparing the performance of each EU country from 2010 to 2022 (Figure 30), positive trends are observed in the DF for most of the EU countries which are located in the absolute decoupling area, i.e. at the top right quadrant in the figure, where countries showed economic growth while at the same time decreasing their environmental footprint in terms of domestic production. The only country outside this quadrant is Greece, which showed negative economic growth but still improved performance in terms of environmental impact.

Looking at the CF results, most EU countries are in the top left quadrant, and yellow zone, i.e. relative decoupling with good progress in economic growth but less in environmental performance. The only countries that do not follow this trend are Portugal, Estonia, (both showing GDP growth) and Greece (showing decline in GDP), showing an increase of CF impact relative to the economic performance, and thus showing no-decoupling at all.

Figure 30. Mapping EU-27 countries in terms of how the gap in DF and CF per capita differs (x axis), compared with the gap in real GDP per capita (y axis), and highlighting decoupling areas (2010 vs 2022 data).

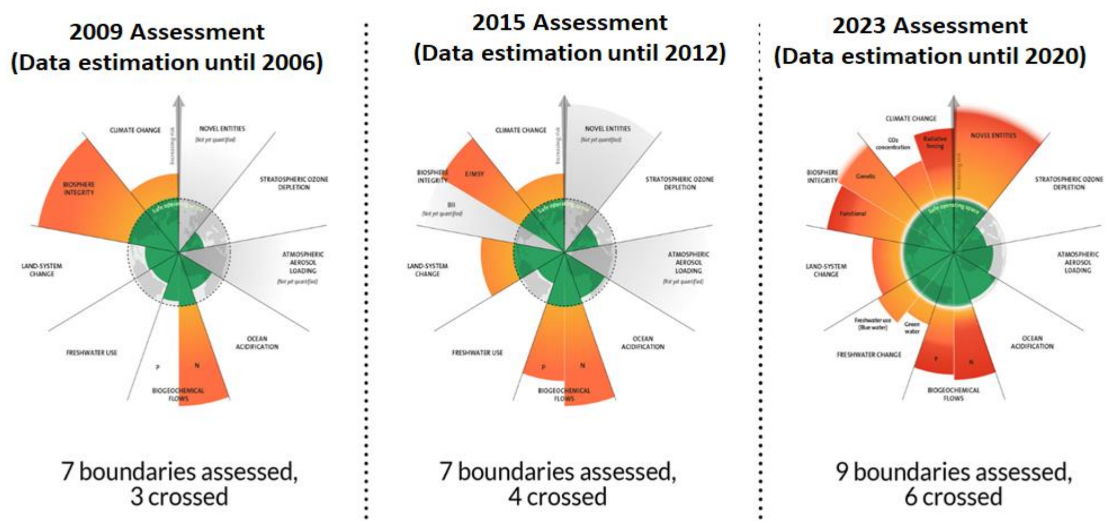


Source: Consumption Footprint Platform (EC-JRC 2024c)..

7. Assessing absolute sustainability: the EU Domestic Footprint and Consumption Footprint with respect to the Planetary Boundaries

Absolute sustainability is gaining momentum in scientific and policy-making communities, which pursue economic development that lies within the limits of the planet. A crucial step to operationalise absolute sustainability is to be able to define the thresholds which determine such limits. For this purpose, Rockström and colleagues presented in 2009 the planetary boundaries (PBs) framework, which identifies nine ecological processes and associated control variables. Figure 31 presents the evolution of the PBs framework from 2009 to 2023 (Rockström et al. 2009; Steffen et al. 2015; Richardson et al. 2023). The power of the PB framework is to give a reference for absolute sustainability by control variable for nine ecological processes with two threshold levels (we may call them 'safety' and 'risky'). At the global level, 'risky' thresholds have been crossed for six out of nine ecological processes (i.e., climate change impact, biodiversity, land & freshwater system, along the biochemical flows of the two nutrients phosphorus and nitrogen as well as novel entities) with other three worsening off between an assessment and the next (i.e., stratospheric ozone depletion, atmospheric aerosol loading and ocean acidification) (Richardson et al. 2023).

Figure 31. Evolution of Planetary boundaries (PBs) reference framework from 2009 to 2023.



Source: Rockström et al. 2009; Steffen et al. 2015; Richardson et al. 2023.

In line with the EU's long-term vision to 2050 of living well within planetary limits of the 8th EAP (EEA 2024, EEAa 2025) and the SDGs (in particular SDG 3, 6, 13, 14 and 15) (UN 2015), this section assesses the impact of EU DF and CF against the PB framework. The assessment is achieved by normalizing the impact categories of the EF method with a set of LCA-based PB framework in the context of the CF model. Figure 32 shows the mapping between PB and EF indicators grouped by relevant SDGs.

Figure 32. Overview of the link between the midpoint impact adopted in Life Cycle Impact Assessment, the Sustainable Development Goals and the planetary boundaries.

= Safe operating space
= Boundaries crossed
= Not considered in PB

SDGs

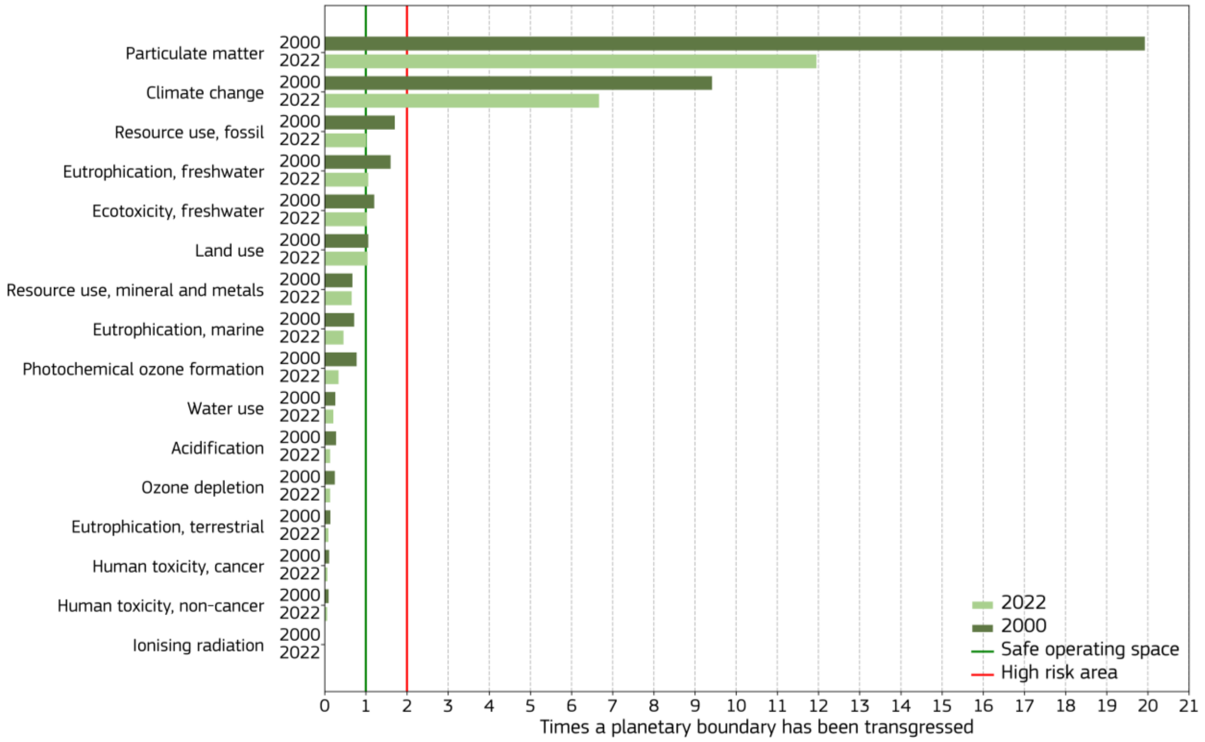
LCA environmental impact categories (EF 3.1) / Planetary Boundaries (Richardson 2023)

LCA environmental impact categories (EF 3.1)	Biosphere integrity - Functional	Biosphere integrity - Genetic	Climate change - CO_2 concentration	Climate change - Radioactive forcing	Novel entities	Stratospheric ozone depletion	Atmospheric aerosol loading	Ocean acidification	Biogeothermal flows - Nitrogen	Biogeothermal flows - Phosphorus	Freshwater use - Blue water	Freshwater use - Green water	Land-system change	Resource use
Human toxicity, cancer					•									
Human toxicity, non-cancer					•									
Particulate matter							•							
Photochemical ozone formation		•			•									
Ionising radiation					•									
Water Use		•										•		
Ecotoxicity, freshwater		•			•									
Climate change		•	•	•				•						
Resource use, fossil			•	•										•
Ozone depletion						•								
Eutrophication, marine		•							•	•				
Eutrophication, freshwater		•							•	•				
Land use		•											•	
Eutrophication, terrestrial		•							•	•				
Acidification		•							•	•				
Resource use, minerals and metals			•	•										•

Source: adapted from Sanyé Mengual and Sala (2023), Richardson et al. 2023

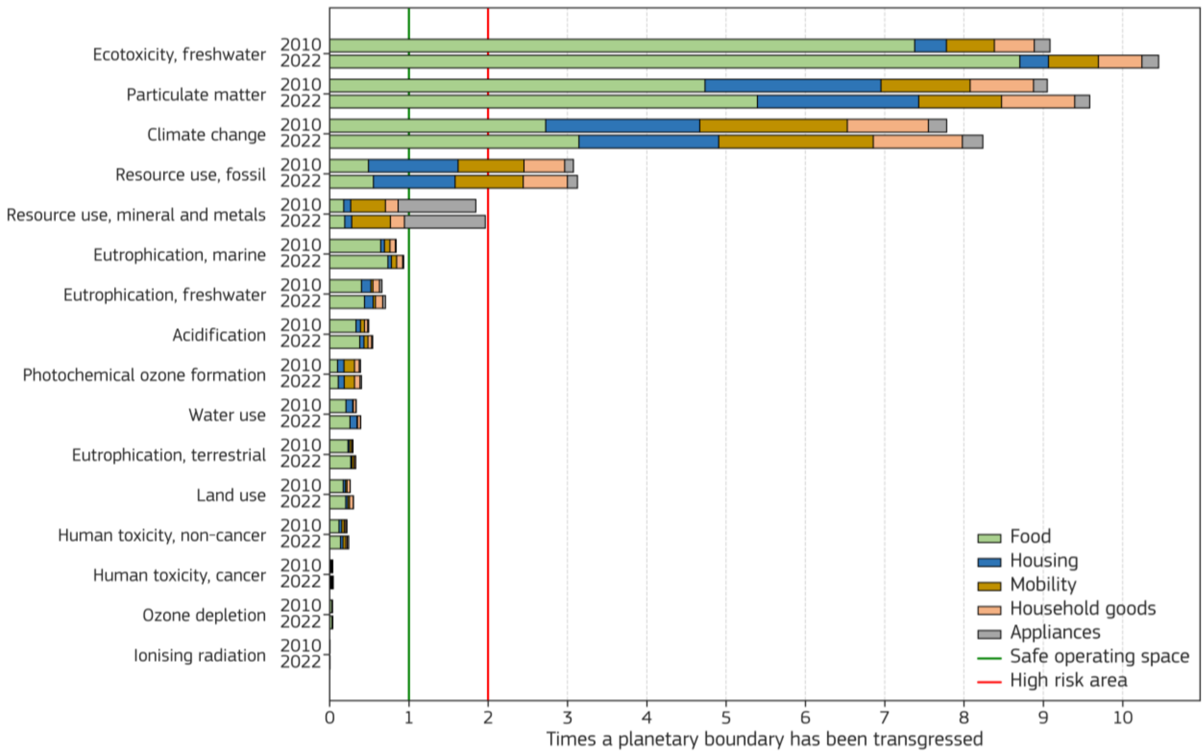
The DF (Figure 33) and the CF (Figure 34) transgress the limits of the planet for several impact categories. With each individual PB being crucial to ensure the conditions for a safe operating space for humanity, even only transgressing one PB can be considered as being unsustainable. In this sense, current EU production and consumption activities are unsustainable. As observed in previous chapter, impacts are higher in the CF than in the DF. The Consumption Footprint transgresses three of these indicators that are over eight times the safety threshold of PB (climate change, particulate matter and ecotoxicity freshwater). In addition to this, natural resources are being exploited (i.e. fossil fuels and minerals) by a factor of two to three times above known available resources; this is mostly due to consumption patterns, rather than production factors. EU consumption and production may be considered in within the safety area for 11 of the impact indicators.

Figure 33. Comparison of the EU Domestic Footprint per capita and planetary boundaries between 2010 and 2022.



Source: Consumption Footprint Platform (EC-JRC 2024c).

Figure 34. Comparison of the EU Consumption Footprint per capita and planetary boundaries between 2010 and 2022.



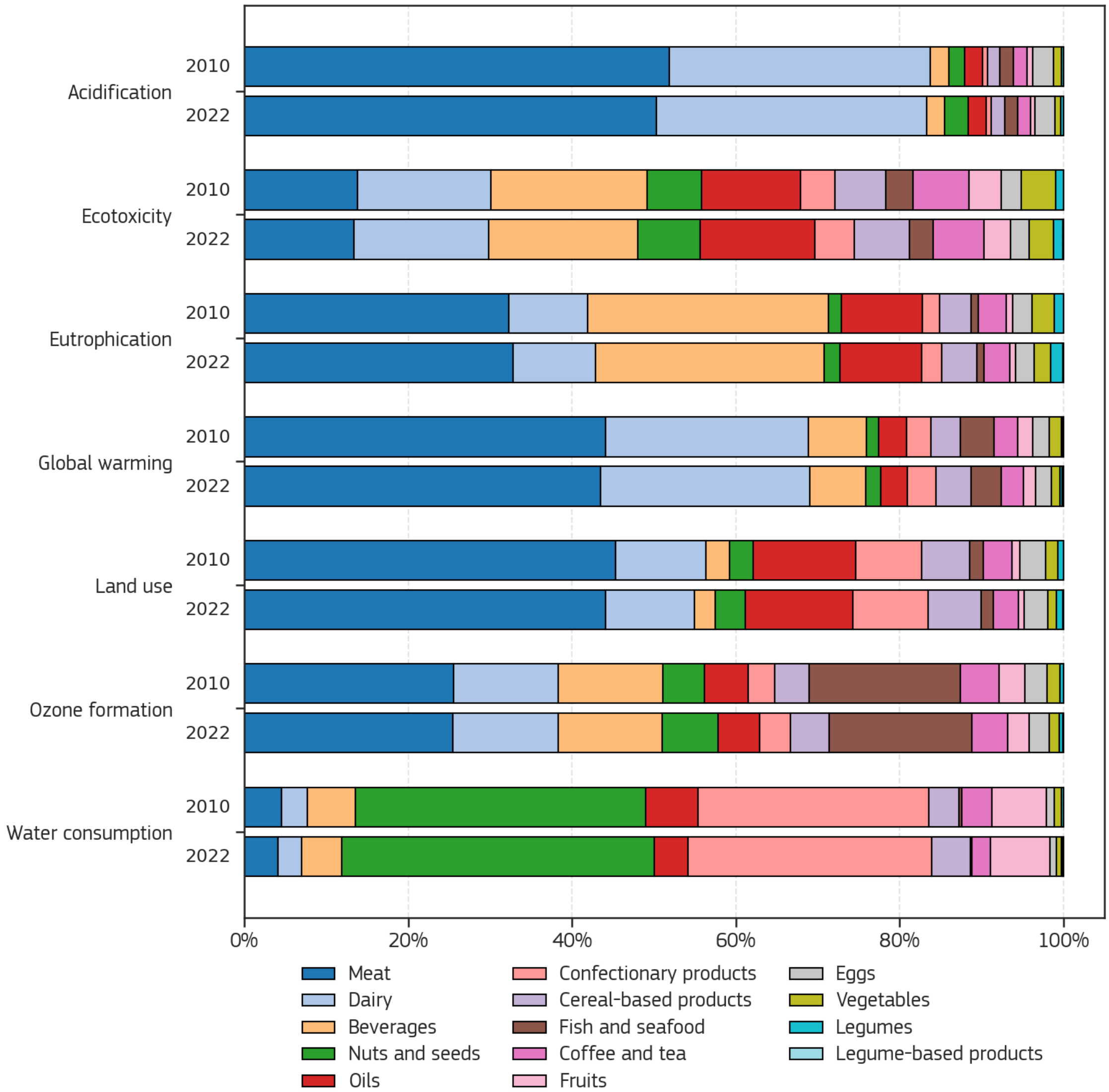
Source: Consumption Footprint Platform (EC-JRC 2024c).

8. Introducing the Biodiversity Footprint of EU food consumption

The biodiversity footprint of EU food consumption has been assessed following the ReCiPe 2016 impact assessment method at the endpoint level (Hujibregts et al., 2017) for the years 2010 to 2022 (further details are explained in Chapter 2, describing the method, and Annex 6 for analysis at the EU and Member State levels).

The product contribution to each category of biodiversity impact is shown in Figure 35. Meat and dairy have by far the greatest impact on terrestrial acidification and global warming with 80% and 65%, respectively, and are major contributors to the remaining impact categories, apart from water use. For water use, nuts and confectionary are consuming most of the water, with almonds and cashews requiring most of the water at farming. Comparing the impact and product group contribution to the total biodiversity impact in 2010 and 2022, the trend share of the product groups to the impact categories is similar, with only negligible changes.

Figure 35. Biodiversity impact by share of product group at Member State and EU level for 2010 and 2022



Source: JRC elaboration.

9. Available platforms and tools

The research leading to the CF and DF models has resulted in three online platforms and tools developed for different purposes and targeting different stakeholder groups (Table 4), and available in EC-JRC (2024d).

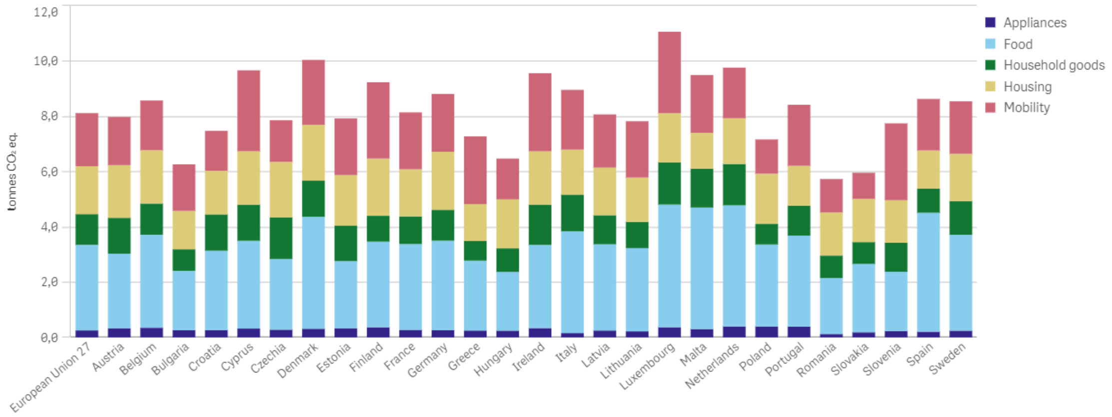
Table 4. Available Consumption Footprint-based tools, targeted stakeholders and main goal.

Online tool	**Targeted stakeholders**	**Main goal**
Consumption Footprint Platform	Policymakers Researchers Stakeholders	— Explore Consumption Footprint and Domestic Footprint data — Access and download data
Consumer Footprint Calculator	Citizens	— Assess the individual Consumption Footprint — Identify hotspots of impacts and potential sustainable lifestyle tips
Member States – Consumption Footprint Tool	Member States	— Explore the underpinning consumption intensity data of the Consumption Footprint — Assess alternative data sources for consumption intensity data and effect on Consumption Footprint

Source: Sanyé Mengual & Sala (2023).

Through the **Consumption Footprint Platform**[11] (EC-JRC, 2024c) it is possible to explore the results of the CF for the period 2010-2022, and of the DF for the period 2000-2022. Both indicators are available at EU and Member State level with data per country (Figure 36), per capita and per km^2.

Figure 36. Example of chart provided in the Consumption Footprint Platform regarding the Consumption Footprint per Member State.



Source: Consumption Footprint Platform (EC-JRC 2024c).

[11] Access to the platform: https://eplca.jrc.ec.europa.eu/ConsumptionFootprintPlatform.html

The platform includes:

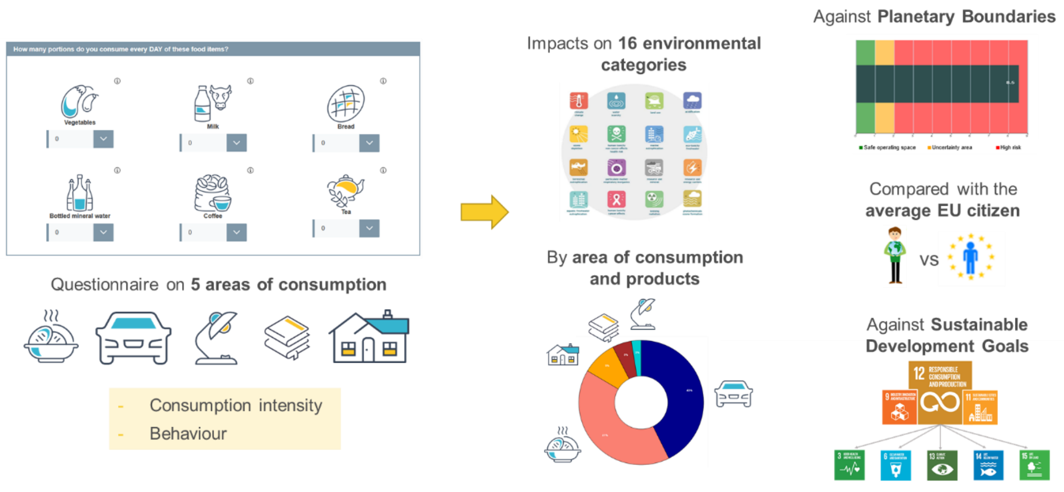
- The assessment of decoupling, against Planetary Boundaries and against Sustainable Development Goals,
- a comparison of production and consumption impacts,
- the possibility to explore the contribution by product,
- a page devoted to assessing the environmental and biodiversity impacts of EU food system,
- the access to regionalised Consumption Footprint data.

The **Consumer Footprint Calculator**[12] allows EU citizens to calculate the environmental impacts of their consumption patterns and to evaluate how changes in their lifestyle may affect their personal footprint (Sala et al., 2022, EC-JRC, 2024e). The calculator has been recently updated to be available in **all 24 EU official languages.**

The Calculator allows citizens to explore the impacts of their lifestyles (Figure 37):

- through 16 environmental impact categories and a single weighted score
- by displaying the impact by area of consumption and product
- via assessing the results against the planetary boundaries and the Sustainable Development Goals
- by comparing the impacts against the average EU citizen
- by providing the user links to sustainability tips with the aim of promoting alternative lifestyle choice that might encourage changing consumption patterns and reduce their footprint.

Figure 37. Overview of the structure of the Consumer Footprint Calculator: questionnaire and results visualization options.

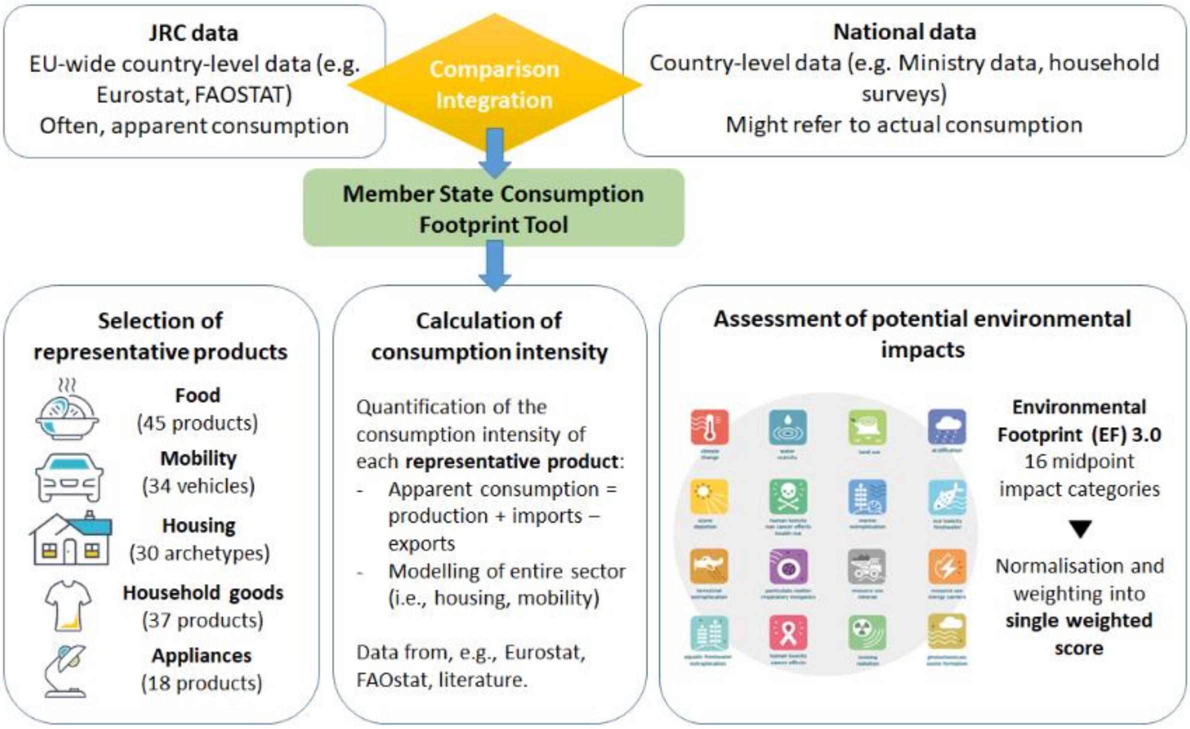


Source: Consumer Footprint Calculator, EC-JRC, 2024e

[12] Link to the Consumer Footprint Calculator: https://knowsdgs.jrc.ec.europa.eu/cfc

The **Member States – Consumption Footprint Tool**[13] (EC-JRC, 2024f; Sanye Mengual et al., 2023c) allows Member States to explore the results at Member State level of the Consumption Footprint. In particular, the tool includes a specific module to support Member States in introducing their own data on consumption intensity, e.g. stemming from local household consumption surveys or other data they might have at national level on consumption (Figure 38).

Figure 38. Overview of the Member States – Consumption Footprint Tool.



Source: Sanyé Mengual et al. (2023c).

[13] Link to the Member States Consumption Footprint Tool: https://eplca.jrc.ec.europa.eu/MSConsumptionFootprint.html

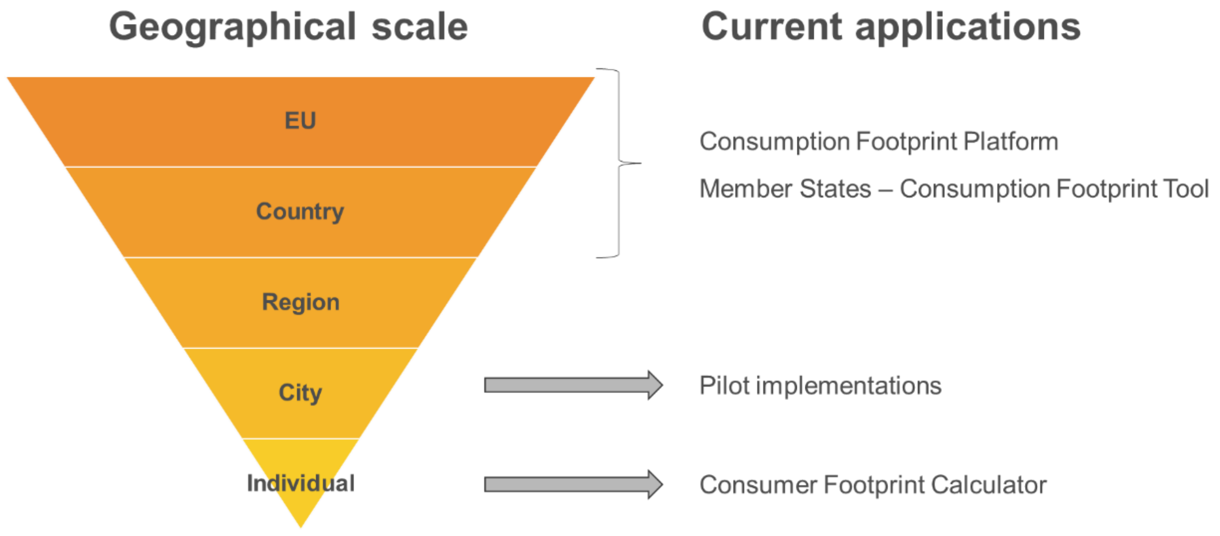
10. Spatial resolution of the Domestic and Consumption Footprints

The Consumption Footprint can be applied at different geographical scales and at different levels of granularity, from the EU to the individual consumer (Figure 39):

- The **Consumption Footprint Platform** (EC-JRC, 2024c) provides data at EU and country level. At the country level, the **Spanish Ministry of Consumer Affairs** has employed the data from the platform to analyse the case of Spain in collaboration with the JRC (MdC and EC-JRC, 2022). Member States can also use the Member States – Consumption footprint Tool (EC-JRC, 2024f) to calculate their CF with national data sources.
- The indicator can be calculated at regional or urban scale, by using consumption statistics at higher granularity. A **case study was run at city level** in collaboration with the Politecnico of Turin for the city of Turin (Italy) (Genta et al., 2022). In this application, household consumption surveys were combined with other data sources, such as geographic information systems on residential buildings, and data on urban public transportation.
- At the individual level, the **Consumer Footprint Calculator** (Sala et al., 2022) can be used to calculate the environmental impacts of specific consumption patterns and behaviours.

An advantage of the potential use at different scales is the possibility to compare the environmental impacts of consumption at different levels in a consistent manner, such as allowing the comparison of the footprint of citizen living in a specific urban area against the footprint of a person representing the average consumer of a nation of even the entire EU (Genta et al., 2022).

Figure 39. Potential applications of the Consumption Footprint at different geographical scales.



Source: Sanyé Mengual and Sala (2023).

11. Conclusions

This technical report presents the **latest updates of the EC-JRC LCA-based framework to assess the environmental impacts of EU production and consumption**. The Domestic Footprint and Consumption Footprint models have been updated to provide data for the year 2022. This report provides an overview of the updated results as well as details the methodological updates compared to the 2023 version (Sanyé-Mengual and Sala 2023), and forms the basis for companion publication using the DF and CF models for running scenario outlook analysis in the frame of the Zero Pollution Action Plan, as proposed in Pasqualino et al (2025)

New data from 2022 confirms pre-existing trends and insights of the framework:

- The **EU Domestic Footprint shows a decreasing trend** over time, resulting from the effects of EU environmental policy largely within the EU's borders
- The **EU Consumption Footprint has increased since 2010,** with consumption patterns (quantity and diversity) back to pre-COVID levels
- The analysis of decoupling highlights the role of the EU as a **'net importer' of environmental impacts which occur beyond EU borders** through imported raw materials, intermediary products and final products, and highlights greater concern for environmental impacts linked to agriculture production, such as land and water use.
- The areas of greatest concern in 2022 in terms of the Consumption Footprint shares of impacts are **food (49%), housing (17%) and mobility (16%);** this highlights that further measures are potentially needed regarding both production and consumption with respect to these value chains.
- When **compared with the planetary boundaries, the environmental impacts of current consumption patterns are transgressing many limits of the planet**. These include particulate matter by a factor of 9 times (high data confidence) and freshwater ecotoxicity by a factor of ten times (medium data confidence), fossil fuels and mineral resource use by 2 to 3 times (low data confidence), both being a driver for pollution. Finally, climate change transgresses planetary boundaries by a factor of eight times (high data confidence).

With an increasing relevance of the impacts of EU consumption on third countries in EU policy-making, the Consumption Footprint indicator is currently an **official indicator for the following EU monitoring frameworks**:

- Headline indicator for the **8th Environment Action Programme** (EC 2022b)
- Headline indicator for the **Circular Economy** (Eurostat 2024b),
- Indicator of the environmental resilience of the **Resilience Dashboards** (EC 2023b)
- Indicator of the **SDG monitoring framework** (Eurostat 2024c),
- Indicator for both monitoring and outlook analysis for **Zero Pollution Action Plan** (EC 2021b)
- Indicator for the **EU Food System Monitoring Dashboard**, regarding the area of consumption food for consumption footprint and biodiversity footprint (EC-JRC, 2024b)

Further, the Consumption Footprint is included in the EU Food System Monitoring Dashboard[1].

Recent **methodological updates** included the extension of data up to 2022, the revision of data sources, and the identification and management of outliers in data sources, as explained in detail in the annexes.

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List of abbreviations

BoP	Basket of representative Products
CF	Consumption Footprint
CFC	Chlorofluorocarbons
CTU	Comparative Toxic Unit
DF	Domestic Footprint
EF	Environmental Footprint
ESPR	Eco-design for Sustainable Product Regulation
EU	European Union
GDP	Gross Domestic Product
GJ	Gigajoule
HCFC	Hydrochlorofluorocarbon
HDI	Human Development Index
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LCA	Life Cycle Assessment
LPG	Liquefied petroleum gas
MIDAS	Modelling Inventory and Knowledge Management System
MJ	Megajoule
NMVOC	Non-methane volatile organic compounds
PB	Planetary boundary
SDG	Sustainable Development Goal
TV	Television
W&W	Work & waterproof

Abbreviations for impact categories

AC	Acidification
CC	Climate change
ECOTOX	Ecotoxicity, freshwater
FEU	Eutrophication, freshwater
FRD	Resource use, fossils (impacts due to)
HTOX_c	Human toxicity, cancer

HTOX_nc	Human toxicity, non-cancer
IR	Ionising radiation
LU	Land use (impacts due to)
MEU	Eutrophication, marine
MRD	Resource use, minerals and metals (impacts due to)
ODP	Ozone depletion
PM	Particulate matter
POF	Photochemical ozone formation
TEU	Eutrophication, terrestrial
WU	Water use (impacts due to)

Annexes

Annex 1. Impact categories, underpinning models, and robustness of the impact assessment models (Environmental Footprint 3.1).

Impact category	Unit	Model adopted as in EF (Model robustness[a])	Global normalisation factors[b]	Planetary Boundaries	Weighting factors[c] (%)
Climate change (GWP)	kg CO_2 eq	Bern model - Global warming potentials (GWP) over a 100-year time horizon (based on Forster et al., 2021) (I)	7.55E+03	6.81E+12	21.06
Ozone depletion (ODP)	kg CFC-11 eq	EDIP model based on the ODPs of the World Meteorological Organisation (WMO) over an infinite time horizon (WMO 2014 + integrations) (I)	5.23E-02	5.39E+08	6.31
Particulate matter (PM)	Disease incidence	PM model (Fantke et al., 2016 in UNEP 2016) (I)	5.95E-04	5.16E+05	8.96
Ionising radiation (IR)	kBq U-235 eq.	Human health effect model as developed by Dreicer et al. 1995 (Frischknecht et al, 2000) (II)	4.22E+01	5.27E+14	5.01
Photochemical ozone formation (POF)	kg NMVOC eq.	LOTOS-EUROS model (Van Zelm et al, 2008) as applied in ReCiPe 2008 (II)	4.09E+01	4.07E+11	4.78
Acidification (AC)	mol H^+ eq	Accumulated exceedance (Seppälä et al. 2006, Posch et al, 2008) (II)	5.56E+01	1.00E+12	6.2
Eutrophication, terrestrial (TEU)	mol N eq		1.77E+02	6.11E+12	3.71
Eutrophication, freshwater (FEU)	kg P eq	EUTREND model (Struijs et al, 2009) as applied in ReCiPe (II)	1.61E+00	5.81E+09	2.8
Eutrophication, marine (MEU)	kg N eq		1.95E+01	2.01E+11	2.96
Freshwater ecotoxicity (ECOTOX)	CTUe	based on USEtox2.1 model (Fantke et al. 2017), adapted as in Andreasi Bassi et al. 2023 (III)	5.67E+04	1.31E+14	1.92
Human toxicity, non-cancer (HTOX_nc)	CTUh		1.29E-04	4.10E+06	2.13
Human toxicity, cancer (HTOX_c)	CTUh		1.73E-05	9.62E+05	1.84
Land use (LU)	Pt	Soil quality index based on LANCA model (De Laurentiis et al. 2019) and on the LANCA CF version 2.5 (Horn and Maier, 2018) (III)	8.19E+05	3.98E+15	7.94
Water use (WU)	m^3 water eq	Available WAter REmaining (AWARE) model (Boulay et al., 2018; UNEP 2016) (III)	1.15E+04	1.82E+14	8.51
Resource use, fossils (FRD)	MJ	ADP fossils (van Oers et al., 2002) (III)	6.50+04	2.24E+14	8.32
Resource use, minerals and metals (MRD)	kg Sb eq	ADP ultimate reserve (van Oers et al., 2002) (III)	6.36E-02	2.19E+08	7.55

[a]European Commission (2021); [b] Andreasi Bassi et al. (2023); [c] Sala et al. (2018).

The 16 impact categories can be aggregated in a single score following a normalization and weighting process:

$$Single\ score = \sum_{n=1}^{16} \left(\frac{Impact\ value}{Global\ normalization\ factor}\ x\ Weighting\ factor \right)$$

Annex 2. Domestic Footprint: Overview of environmental pressures and data sources per impact category

The overview of the data sources used in the Domestic Footprint is reported in the following table, 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 (2024)
	CFCs; Hydrochlorofluorocarbons (HCFCs)	- Sala et al. (2014) - EDGAR (EC-JRC&PBL, 2024)
Ozone Depletion (ODP)	CFCs; HCFCs	- Sala et al. (2014) - EDGAR (EC-JRC&PBL, 2024)
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 methodology proposed by Leclerc et al. (2019), and relying on the following sources: - E-PRTR (2024) - Waterbase (EEAb, 2024) - FAOSTAT (2024a) - Kuczyński et al. (2005) - Hamscher et al. (2005) - EC (2010) - Eurostat (2007) - Fantke et al. (2011)
Particulate matter (PM)	NO_x; NH_3; SO_2; PM_{10}; $PM_{2.5}$; CO	- EMEP/CEIP (2024)
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	- PRIS (2024); - RADD (2024); - EF dataset (EC-JRC, 2017); - Eurostat(2024f) - Eurostat(2024g) - Eurostat (2024h) - OSPAR (2024)
Photochemical ozone formation (POF)	NMVOC as aggregated; NO_X, CH_4; CO	- EMEP/CEIP (2024)
	NMVOC breakdown	- Laurent & Hauschild (2014)
Acidification (AC)	NO_x; SO_2; NH_3	- EMEP/CEIP (2024)

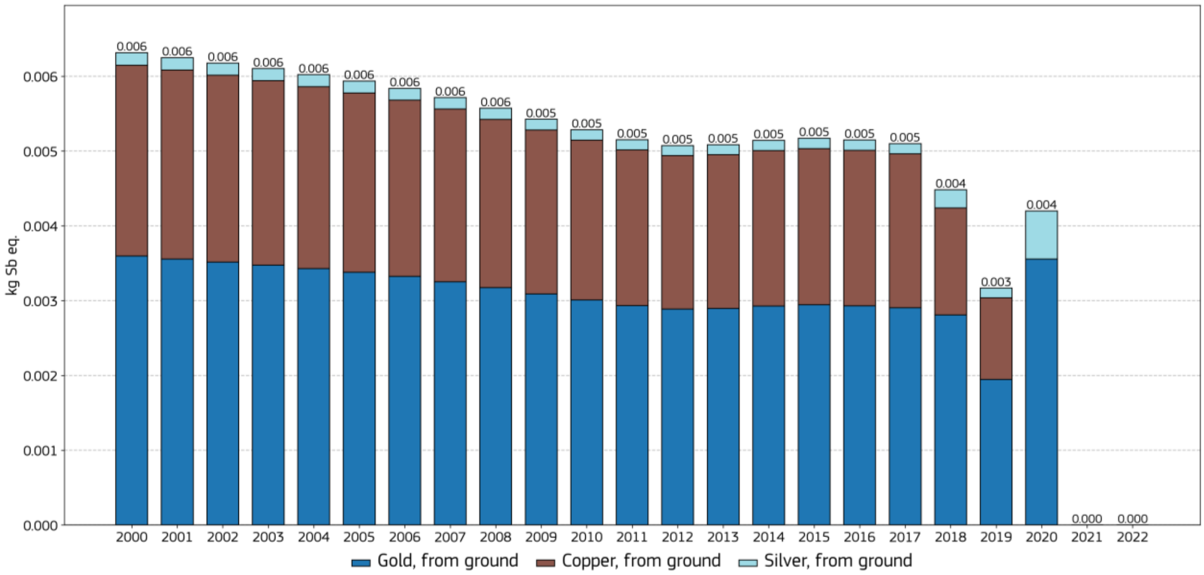
Eutrophication, Terrestrial (TEU)	NO_x; NH_3	- EMEP/CEIP (2024)
Eutrophication, freshwater (FEU)	Phosphorous (total) to soil and water, from agriculture	- Eurostat (2024i) for phosphorous input and output data; - UNFCCC (2024) for nitrogen input; - Bouwman et al. (2009) 10% loss of phosphorous to water 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 (2024j): Share of people connected to wastewater treatment plants (WWTPs)
Eutrophication, marine (MEU)	NO_x; NH_3	- EMEP/CEIP (2024)
	Nitrogen (total) to water, from agriculture	- UNFCCC (2024): Nitrogen total input data, losses to water and to air, synthetic fertilizers manure - Eurostat (2024i)
	Nitrogen (total) to soil and water, from sewages	- FAOSTAT (2024b): Protein intake - Van Drecht et al. (2009): Removal efficiency of Nitrogen - Eurostat (2020j): Share of people connected to WWTP
Land use (LU)	"Land occupation" and "land transformation": forest, cropland, grassland, settlements, wetlands, unspecified	- UNFCCC (2024)
Water use (WU)	Gross freshwater abstraction & Gross water consumption	- Eurostat (2024k) - WaterGAP: (Müller Schmied et al., 2014)
Resource use	Minerals and metals (MRD)	-BGS (2024); USGS (2024); WMD (2024)
	Fossils (FRD)	- Eurostat (2024l)

Annex 3. Domestic Footprint: Apparent anomalies in some of the Domestic Footprint results, by impact category and their justification

The data update of the DF and CF models requires a step of quality control of these data, as these often present anomalies which needs to be identified as outliers, and secondly proven if the anomaly may be considered as a real data point(s) or not. This annex shows some examples of how this approach is applied in the case of the DF model.

A suspected outlier regarding the resource extraction of minerals and metals in Cyprus was investigated due to changes in the timeline from 2018, as presented in the Figure 40. In particular, the extraction of copper, gold and silver in Cyprus dropped significantly from 2018, reaching a value of 0 tonnes in 2021 and 2022. The reason for the rapid decline was due to the gradual closure of the Skouriotiss mine, first by closing the copper extraction facilities in 2020, and then those linked to gold and silver. Skouriotiss was the last functioning mine in the country [14] [15].

Figure 40. Time-series of mineral and metals resource use impact category showing a significant drop of copper, gold and silver production in Cyprus from 2018 to 2022.



Source: Consumption Footprint Platform (EC-JRC 2024c)

A suspected outlier regarding the emissions leading to acidification impacts in Slovenia (recording a drop in 2005 followed by constant decline) and in Spain (similar behaviour to that observed in Slovenia, but commencing in 2007) is presented in Figure 41 and Figure 42. The 2014 Air Pollution factsheet for the EU-27 by the European Environmental Agency (EEA 2014) confirmed this trend for sulphur dioxide emissions, by pointing at the binding EU on the National Emissions of certain pollutants (EPC 2016, which aimed at supporting a shift in the energy mix of each relevant country, thus decreasing the emissions of sulphur oxide.

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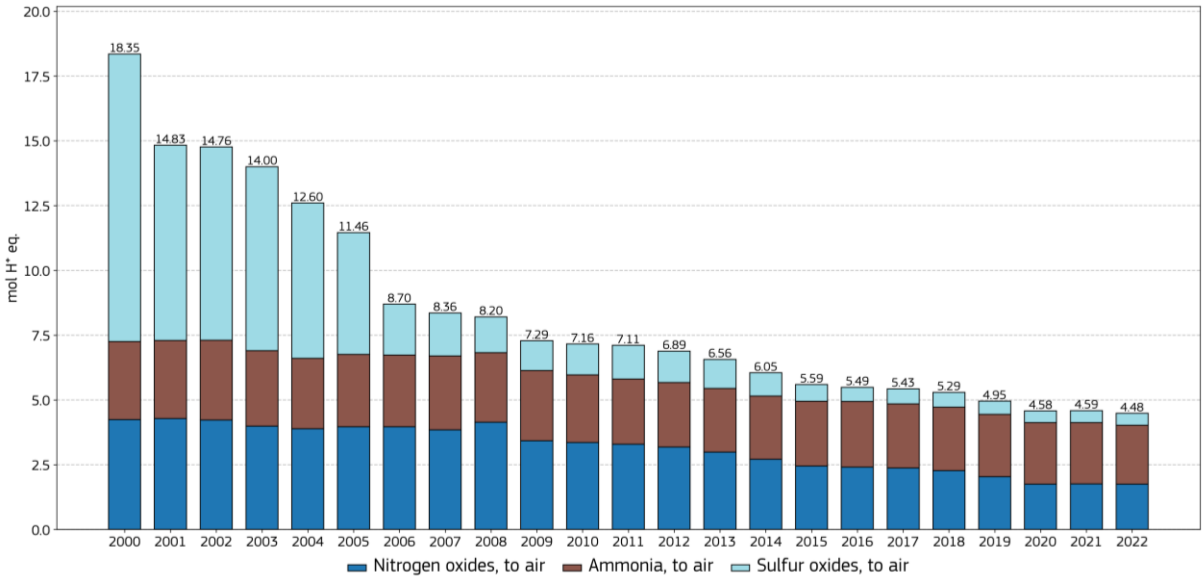
14 https://www.moa.gov.cy/moa/mines/minesSrv.nsf/dmlresources_en/dmlresources_en?OpenDocument#:~:text=The%20ores%20of%20Cyprus%20are,and%20chromite%20and%20asbestos%20ores.

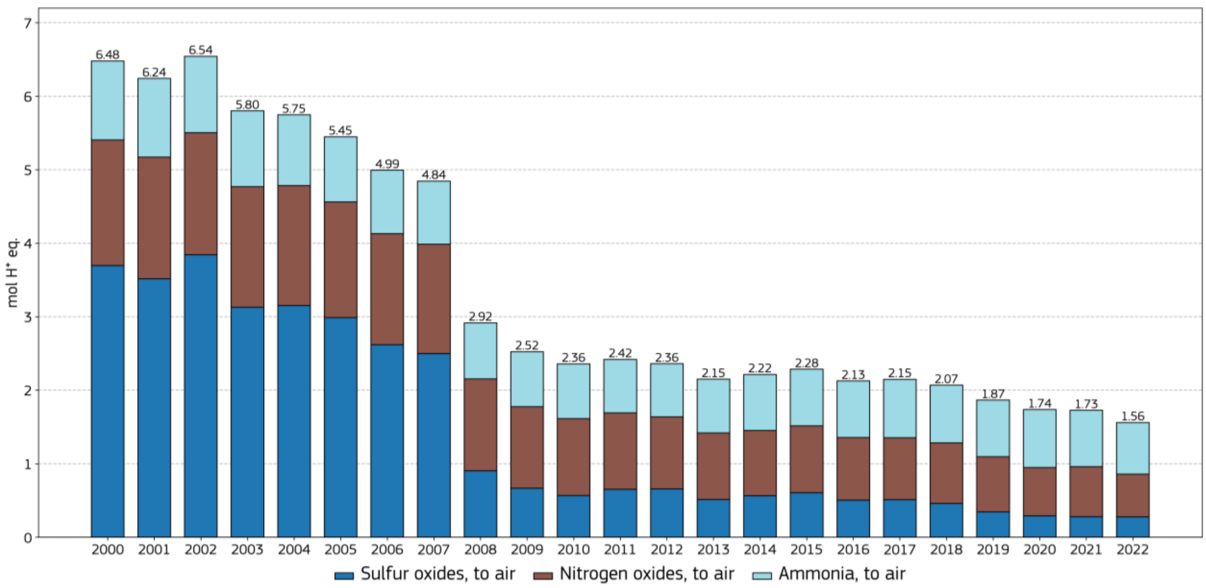
15 https://cyprus-mail.com/2023/01/30/viability-of-gold-mining-in-cyprus-still-open-to-question

Figure 41. Time-series of Acidification impact category showing a significant drop in sulphur oxides emissions in Slovenia after 2005.



Source: Consumption Footprint Platform (EC-JRC 2024c)

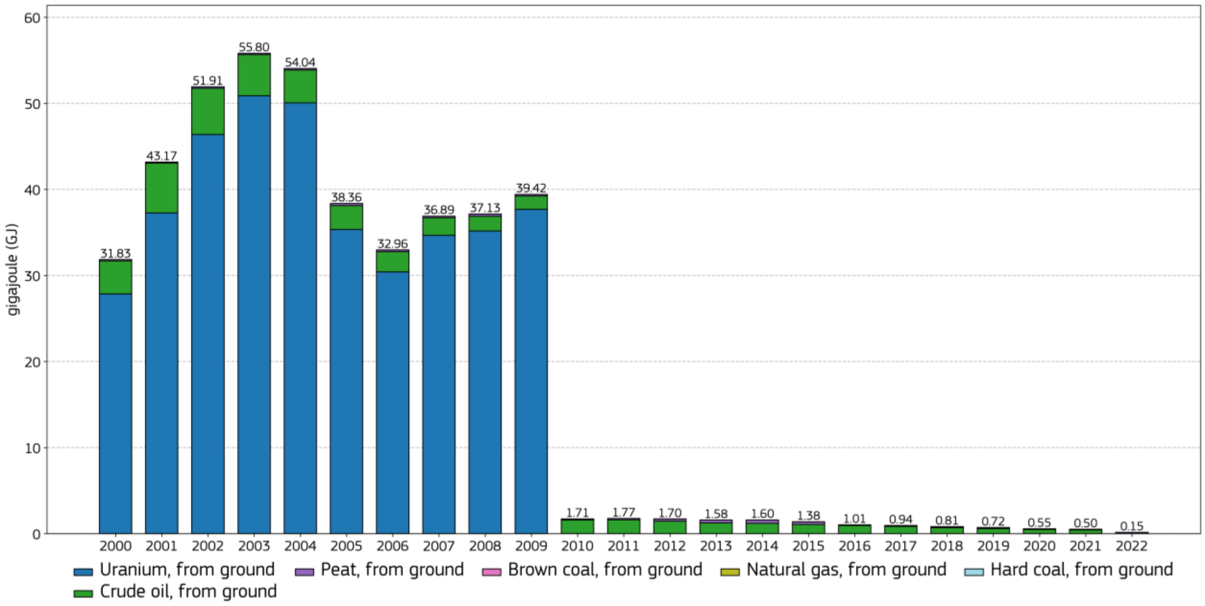
Figure 42. Time-series of the Acidification impact category showing a significant drop in sulphur oxides emissions in Spain after 2007.



Source: Consumption Footprint Platform (EC-JRC 2024c)

A suspected outlier regarding the extraction of fossil resources in Lithuania was investigated due to a significant drop in 2009, as observed in Figure 43. In particular, there was a significant drop in uranium production in Lithuania after 2009. This was revealed to be as a result of the decommissioning of the second nuclear reactor in 2009, the first nuclear reactor was decommissioned in 2004 (EC 2011).

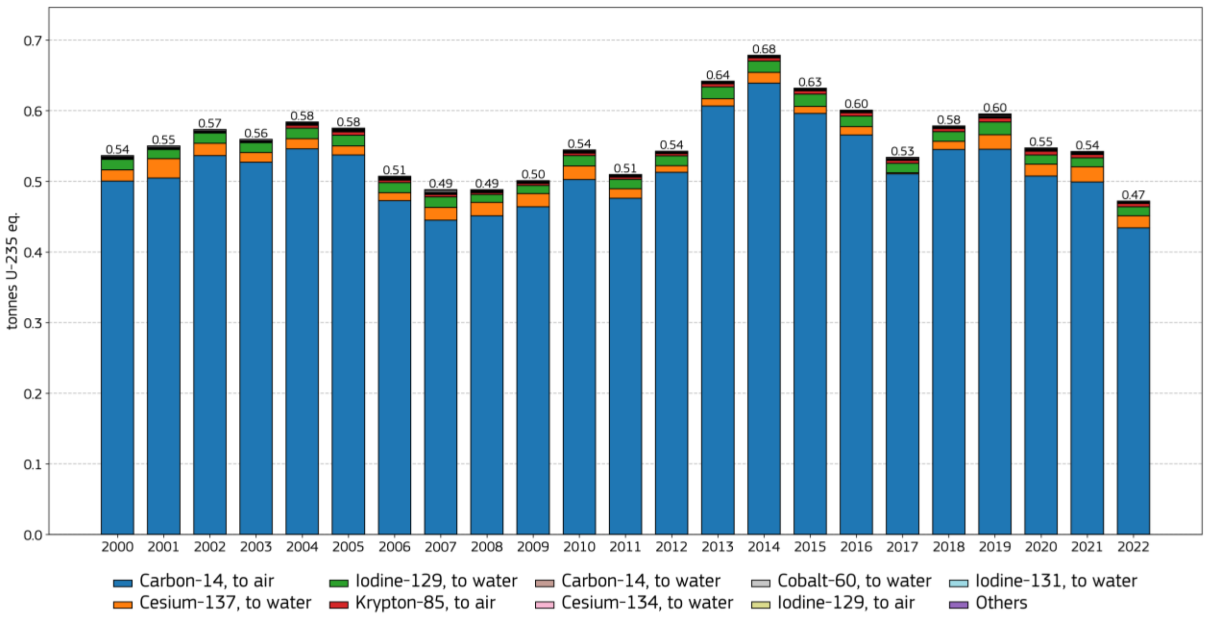
Figure 43. Time-series of Resource use, fossil impact category showing a very significant decrease of uranium in Lithuania after 2009.



Source: Consumption Footprint Platform (EC-JRC 2024c)

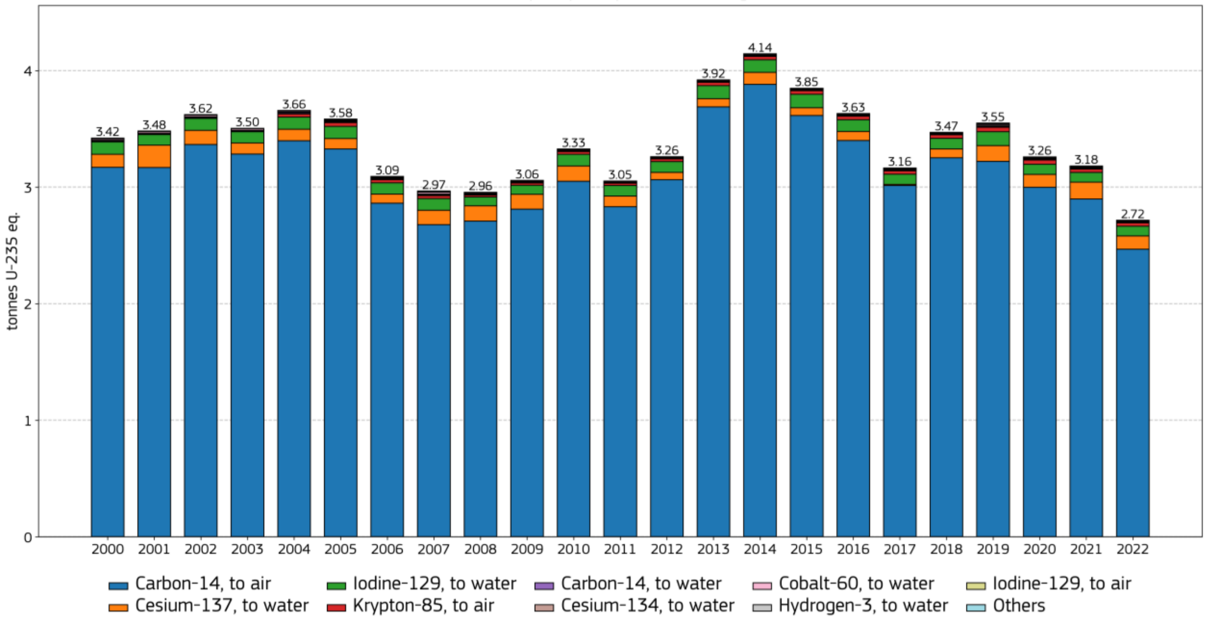
Figure 44 shows the ionising radiation per capita for the EU-27, highlighting a significant decrease from 2021 to 2022, signalling a possible error. Upon further investigation, it was revealed that the decrease was largely due to nuclear reactor maintenance and repairs in France (the EU's largest producer of nuclear power (Eurostat 2024m).) The shape of both curves mirrored each other for the time period considered (Figure 45).

Figure 44. Time-series of ionising radiation for EU-27 showing a suspicious decrease in 2022.



Source: Consumption Footprint Platform (EC-JRC 2024c)

Figure 45. Time-series of ionising radiation for France showing a suspicious decrease in 2022.



Source: Consumption Footprint Platform (EC-JRC 2024c)

Annex 4. Consumption Footprint: Representative products per area of consumption

This annex details the representative products covered in the Consumption Footprint by area of consumption and product group (Sanyé Mengual & Sala, 2023).

FOOD 	**Product group**	**Representative product**
	MEAT	Pork meat
		Beef meat
		Poultry meat
	FISH & SEAFOOD	Salmon
		Cod
		Shrimps
		Tuna
	DAIRY	Milk
		Cheese
		Butter
	EGGS	Eggs
	CEREAL-BASED PRODUCTS	Bread
		Pasta
		Rice
		Quinoa
	SUGAR	Sugar
	OILS	Sunflower oil
		Olive oil
		Rapeseed oil
		Soybean oil
		Palm oil
	LEGUME PRODUCTS	Tofu
		Soy drink

Product group	**Representative product**
BEVERAGES	Beer
	Wine
	Mineral water
CONFECTIONERY PRODUCTS	Biscuits
	Chocolate
TUBERS	Potatoes
FRUITS	Apples
	Oranges
	Bananas
	Avocados
	Strawberries
NUTS & SEEDS	Almonds
	Cashew
COFFEE & TEA	Coffee
	Tea
VEGETABLES	Tomatoes
	Broccoli
	Carrots
LEGUMES	Beans
	Chickpeas
	Lentils
PRE-PREPARED MEALS	Meat-based dishes

APPLICANCES	**Product group**	**Representative product**
	REFRIGERATION	Combined fridge-freezer
	DISHWASHING	Dishwasher (10p)
		Dishwasher (13p)
	WASHING	Washing machine
		Electric condenser tumble dryer
	ELECTRONICS	TV
		Notebook
		Mobile phone
	LIGHTING	Compact fluorescent lamp with integrated ballast (CFLi)
		Halogen lamp, low voltage (model HLLVR)
		Halogen lamp, mains voltage (model HLLME)
		Incandescent lamp (GLS)
		Light Emitting Diodes (LED)
	AIR CONDITIONING	Air conditioner
	DOMESTIC COOKING APPLIANCES	Electric oven
		Coffee maker
	CLEANING APPLIANCES	Vacuum cleaner
	BATHROOM APPLIANCES	Hair dryer

HOUSEHOLD GOODS	**Product group**	**Representative product**
	DETERGENTS	All-purpose cleaners
		Detergent for dishwashers
		Hand dishwashing detergents
		Laundry detergents liquid
		Laundry detergents powder
	SANITARY PRODUCTS	Baby diapers
		Sanitary pads
		Tampons
		Breast pads
	PERSONAL CARE PRODUCTS	Bar soap
		Liquid soap
		Shampoo
		Hair conditioner
	FURNITURE	Bedroom wooden furniture
		Kitchen furniture
		Upholstered seat
		Non-upholstered seat
		Dining room table
	BED MATRESSES	Mattress

Product group	**Representative product**
CLOTHING	T-shirt
	Women blouse
	Men trousers
	Jeans
PAPER PRODUCTS	Newspaper
	Book
	Toilet paper
PLASTIC PRODUCTS	Toys
	Plastic articles of apparel and clothing
	Hair-related products
	Sandals
	Household plastic articles
	Furniture of plastic
	Sleeping bags
FOOTWEAR	Work and waterproof
	Sport
	Leisure
	Fashion

HOUSING 	Type of building	Climate zone	Construction period	Representative product (reference dwelling)
	Multifamily house (MFH)	Cold	< 1945	MFHcold_45
			1945 - 1969	MFHcold_4569
			1970 - 1989	MFHcold_7089
			1990 - 2010	MFHcold_9010
			> 2010	MFHcold_10
		Moderate	< 1945	MFHmoderate_45
			1945 - 1969	MFHmoderate_4569
			1970 - 1989	MFHmoderate_7089
			1990 - 2010	MFHmoderate_9010
			> 2010	MFHmoderate_10
		Warm	< 1945	MFHwarm_45
			1945 - 1969	MFHwarm_4569
			1970 - 1989	MFHwarm_7089
			1990 - 2010	MFHwarm_9010
			> 2010	MFHwarm_10
	Single family house (SFH)	Cold	< 1945	SFHcold_45
			1945 - 1969	SFHcold_4569
			1970 - 1989	SFHcold_7089
			1990 - 2010	SFHcold_9010
			> 2010	SFHcold_10
		Moderate	< 1945	SFHmoderate_45
			1945 - 1969	SFHmoderate_4569
			1970 - 1989	SFHmoderate_7089
			1990 - 2010	SFHmoderate_9010
			> 2010	SFHmoderate_10
		Warm	< 1945	SFHwarm_45
			1945 - 1969	SFHwarm_4569
			1970 - 1989	SFHwarm_7089
			1990 - 2010	SFHwarm_9010
			> 2010	SFHwarm_10

MOBILITY	Transport type	Vehicle type	Vehicle subtype	Technology
	Road transport	Passenger car	Gasoline <1.4 L	Conventional; Euro_1; Euro_2; Euro_3
			Gasoline <1.4 L	Euro_4
			Gasoline <1.4 L	Euro_5
			Gasoline <1.4 L	Euro_6
			Gasoline 1.4 - 2.0 L	Conventional; Euro_1; Euro_2; Euro_3
			Gasoline 1.4 - 2.0 L	Euro_4
			Gasoline 1.4 - 2.0 L	Euro_5
			Gasoline 1.4 - 2.0 L	Euro_6
			Gasoline >2.0 L	Conventional; Euro_1; Euro_2; Euro_3
			Gasoline >2.0 L	Euro_4
			Gasoline >2.0 L	Euro_5
			Gasoline >2.0 L	Euro_6
			Diesel 1.4 - 2.0 L	Conventional; Euro_1; Euro_2; Euro_3
			Diesel 1.4 - 2.0 L	Euro_4
			Diesel 1,4 - 2.0 L	Euro_5
			Diesel 1,4 - 2.0 L	Euro_6
			Diesel >2.0 L	Conventional; Euro_1; Euro_2; Euro_3
			Diesel >2.0 L	Euro_4
			Diesel >2.0 L	Euro_5
			Diesel >2.0 L	Euro_6
			LPG	Conventional; Euro_1; Euro_2; Euro_3; Euro_4; Euro_5
			Electric	Total
			Hybrid	Total
		2-wheelers	Mopeds <50 cm^3	Conventional; Euro_1; Euro_2; Euro_3
			Motorcycles <125cm^3	Conventional
			Motorcycles >125 cm^3	Conventional;Euro_1; Euro_2; Euro_3
		Bus	Urban Buses Standard 15 - 18 t	Conventional; Euro_1; Euro_2; Euro_3; Euro_4; Euro_5
			Coaches Standard <=18 t	C Conventional; Euro_1; Euro_2; Euro_3; Euro_4; Euro_5onventional;Euro_1; Euro_2;Euro_3; Euro_4;Euro_5
			Urban CNG Buses	Euro_1; Euro_2; Euro_3
	Rail transport	Train	Electric	Total
			Diesel	Total
	Air transport	Plane	National	Total
			Intra EU	Total
			Extra EU	Total

Annex 5. Consumption Footprint data sources in updated version

BoP	Variables	Source
MOBILITY 	Distance travelled per vehicle for: bus, coach, cars, rail	EC-DG_MOVE (2024) - Statistical pocketbook of mobility and transport
	International extra-EU air passenger transport by reporting country and partner world region and countries	Eurostat (2024n)
	International intra-EU air passenger transport by reporting country and partner world region and countries	Eurostat (2024o)
	National air passenger transport by reporting country	Eurostat (2024p)
	Train traffic performance by train category and source of energy	Eurostat (2024q)
	Motor coaches, buses and trolley buses, by type of motor energy	Eurostat (2024r)
	Passenger cars by age	Eurostat (2024s)
	Passenger cars, by type of motor energy and size of engine	Eurostat (2024t)
	Passenger cars, by type of motor energy	Eurostat (2024u)
	Mopeds and motorcycles, by type of motor energy	Eurostat (2024v)
	Motorcycles by engine size	Eurostat (2024w)
	National passenger road transport performance by type of vehicles registered in the reporting country	Eurostat (2024x)
	National road traffic performance by type of vehicle and type of road	Eurostat (2024y)
HOUSING 	Share of dwellings per construction period and country	Building stock observatory - DG_ENER (2024)
	Energy consumption values per country and type of energy use	Energy Efficiency Database | Data & Indicators - Odyssee (2024a) -
	Number of dwellings per country and type of dwelling	Energy Efficiency Database | Data & Indicators - Odyssee (2024b) -
	Share of dwellers by country and dwelling type	Eurostat (2024z)
	Energy consumption for space heating per country, dwelling type and construction period	Hotmaps (2024)
	Water use by supply category and economical sector	Eurostat (2024aa)
FOOD 	Food balances (2010-)	FAO (2024c)
	Crops and livestock products (production)	Produdction data - FAO (2024d)
	Crops and livestock products (trade)	Trade data - FAO (2024e).
	Import, export and production by product	PRODCOM Eurostat (2024ab)
	Food Consumption (for soya drink and tofu)	FoodEx – Food consumption Statistics - EFSA (2024)
	Matching data between PRODCOM and COMEXT data	Eurostat (2024ac)- RAMON data classification
	Detailed trade data	Eurostat (2024ad) - COMEXT

	Energy consumption shares	Eurostat (2024ae)
HOUSEHOLD GOODS 	Import, export and production by product	PRODCOM Eurostat (2024ab)
	Matching data between PRODCOM and COMEXT data	Eurostat (2024ac) - RAMON data classification
	Detailed trade data	Eurostat (2024ad) - COMEXT
APPLIANCES	Import, export and production by product	PRODCOM Eurostat (2024ab)
	Matching data between PRODCOM and COMEXT data	Eurostat (2024ac) - RAMON data classification
	Detailed trade data	Eurostat (2024ad) - COMEXT

Annex 6. Consumption Footprint updates in data gap filling procedures

The data cleaning and gap filling procedure is a hybrid human-machine data analysis approach designed to fill data gaps and correct possible data errors that may be found in available public data sources used to monitoring the annual consumption (or consumption intensity) of products used in the CF model. Specifically, when new data are downloaded, these often include empty values as well as possible outliers, which needs to be checked and investigated to assure data quality for the CF model and associated platform. The procedure consists in 3 iterative steps:

1. Firstly, checking the quality of data with the help of computer aided algorithms and uncover potential errors in the data. A further investigation on the validity of these data is carried out. Leading to two options:
   - If the outlier is considered as a real data point, then it is kept in the database
   - If the outlier is confirmed as an error, than it is removed from the database, and it will be filled using the data gap filling approach described below in the second step of this procedure.
2. Secondly, substituting every resulting empty data point, with a calculated approximation using an algorithm that applies a combination of eleven heuristics, which uses the related data to the missing value a proxy for calculating the missing one.
3. Thirdly, revising the results of the automatic procedure for filling gaps and checking consistency of the output. When issues arise these are corrected to avoid any possible error. This case may arise for example when using price and trade data as a mean to calculate a missing data point, which may return discontinuous values against past data. In such a case, another heuristic can be used to fill such a data gap.

This section explains in brief the logic of these heuristics, and provides and overview of how these are combined and applied to fill the missing statistics for every product of the CF model.

Algorithms of the data gap filling procedure

The heuristics can be divided in 4 groups, based on the logic in use to determine the data gap filling procedure, and the data source to consider. These are:

(i) **Based on price data**: these approaches use unit prices calculated from pairs of available trade volume and trade nominal value pairs linked to a specific product. When either trade volume or nominal value is missing, that is calculated using price to multiply or divide per the available data. This is applied for ProdCom (**#1**), ComExt (**#2**) and FAO (**#3**) data sources.

(ii) **Based on per capita data:** Calculates indicator per capita using data on population, either at the Member State or at the EU total level. Specifically, this approach fills missing data by multiplying population of a country (**#4**), or total EU-27 (**#5**) by the calculated per capita value.

(iii) **Based on statistical analysis:** When the previous five methods do not return convincing data, then three additional approaches are considered. Linear interpolation (**#6**) is applied to fill data where extremes are present by mean of interpolation. Specifically this approach calculates a new data point by creating a line between any two non-missing data points, and does not work when the missing data point is at the extremes of the times series (either first data point or last most recent one). In these cases, the approach either calculates the final data point as a mean among all possible data (**#7**)**,** adopts linear regression (**#8**), exponential regression (**#9**) based on past data,

(iv) **Based on market share assumptions:** considering that the Housing BoP uses data linked to the share of energy consumption or dwelling as input to the model, the adoption of the approaches listed above can create partial inconsistencies in data, such as increasing the total consumption above or below 100%. These cases can be fixed by assuming the constant value at the most closer data point to the missing value (**#10**), or correcting the result of a regression adjustment to adjust all market share data to become the required 100% (**#11**).

Table 5. Data gap filling procedure and order of application depending on every Basket of Products in the Consumption Footprint model.

		Data gap filling procedures										
BoP	**Data source**	**#1**	**#2**	**#3**	**#4**	**#5**	**#6**	**#7**	**#8**	**#9**	**#10**	**#11**
Food	FAOSTAT	-	-	1	4	3	-	5	2	-	-	-
Food	PRODCOM	1	2	-	6	5	3	7	4	-	-	-
Food	FOODEX	-	-	-	2	1	-	-	3	-	-	-
Appliances	PRODCOM	1	2	-	6	5	3	7	4	-	-	-
Household Goods	PRODCOM	1	2	-	6	5	3	7	4	-	-	-
Mobility	EUROSTAT	-	-	-	-	-	1	3	2	-	-	-
Mobility (Electric cars)	EUROSTAT	-	-	-	-	-	1	3	-	2		-
Housing (consumption level)	ODYSSEY EUROSTAT	-	-	-	3	2	-	-	1	-	-	-
Housing (shares in energy consumption)	EUROSTAT	-	-	-	-	-	1	3	-	-	2	4
Housing (shares of dwellers)	EUROSTAT	-	-	-	-	-	-	-	1	-	-	2
Housing (shares of dwellings)	DGENER	-	-	-	-	-	1	3	2	-	-	4

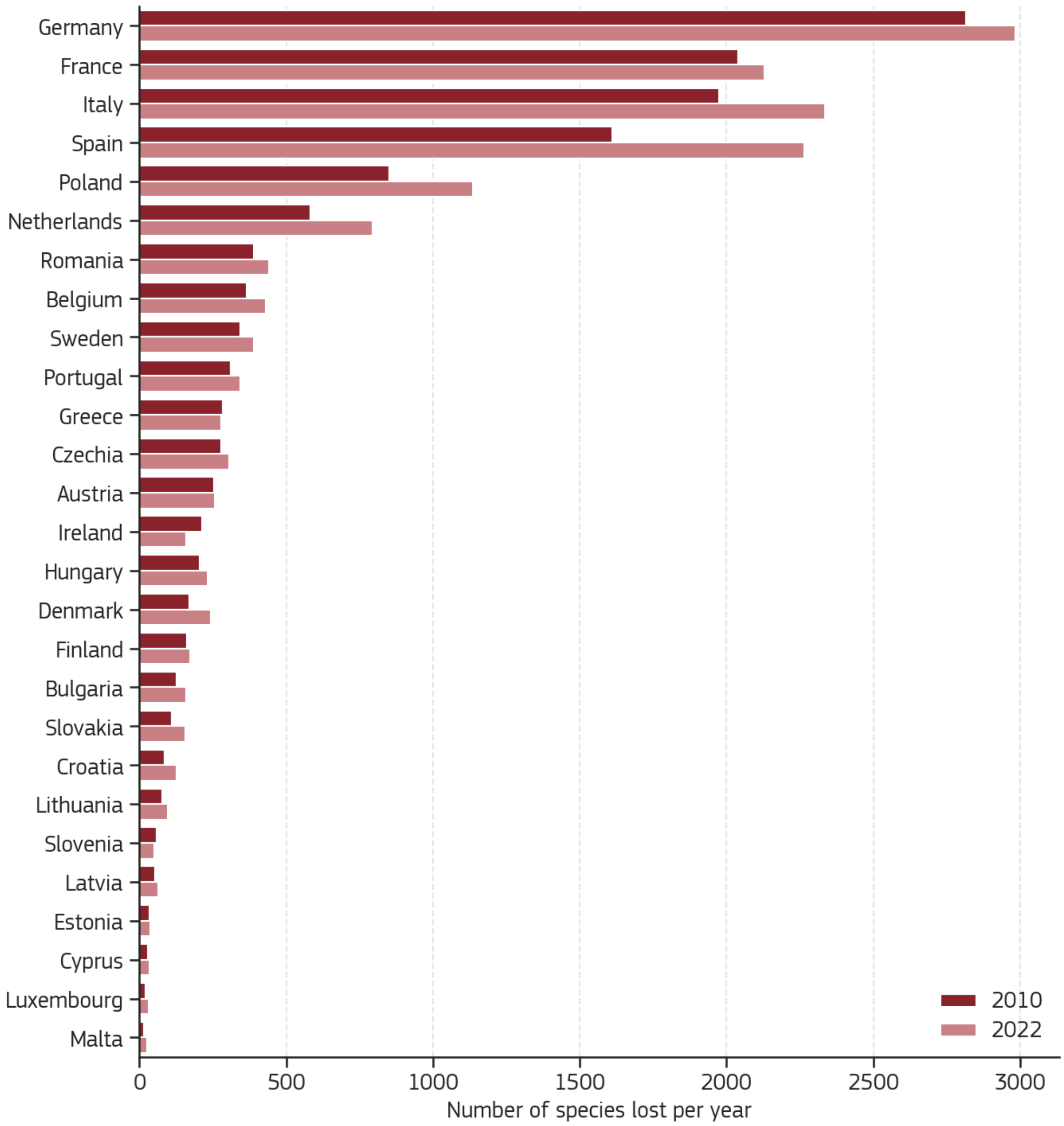
Source: Own elaboration. The number in the table highlight the sequential order of application of every data gap filling approach. All methods which present a value are applied.

Annex 7. Biodiversity footprint of the EU-27 countries

This annex highlights the results, following the ReCiPe 2016 impact assessment method at the endpoint level (Hujibregts et al., 2016) using the food BOP of the CF, and compares the analysis at EU-27 and Member State levels.

Figure 46 presents the biodiversity impact per capita, comparing the different Member States alongside the EU average for 2010 and 2022. Generally, the biodiversity loss in 2022 has increased compared to 2010. On average, species have diminished by 23% at the EU level, with some Member States having a lower impact (Slovakia, Romania, Poland, Hungary, Greece and Bulgaria) than most EU countries. The countries with the greatest species loss in 2022 are Spain, Malta, and Luxembourg. Furthermore, a minority of countries have a similar biodiversity footprint a decade later (Sweden, Greece, France, Finland and Austria), while a few Member States have a lower impact in 2022 compared to 2010 (Austria, Ireland and Slovenia).

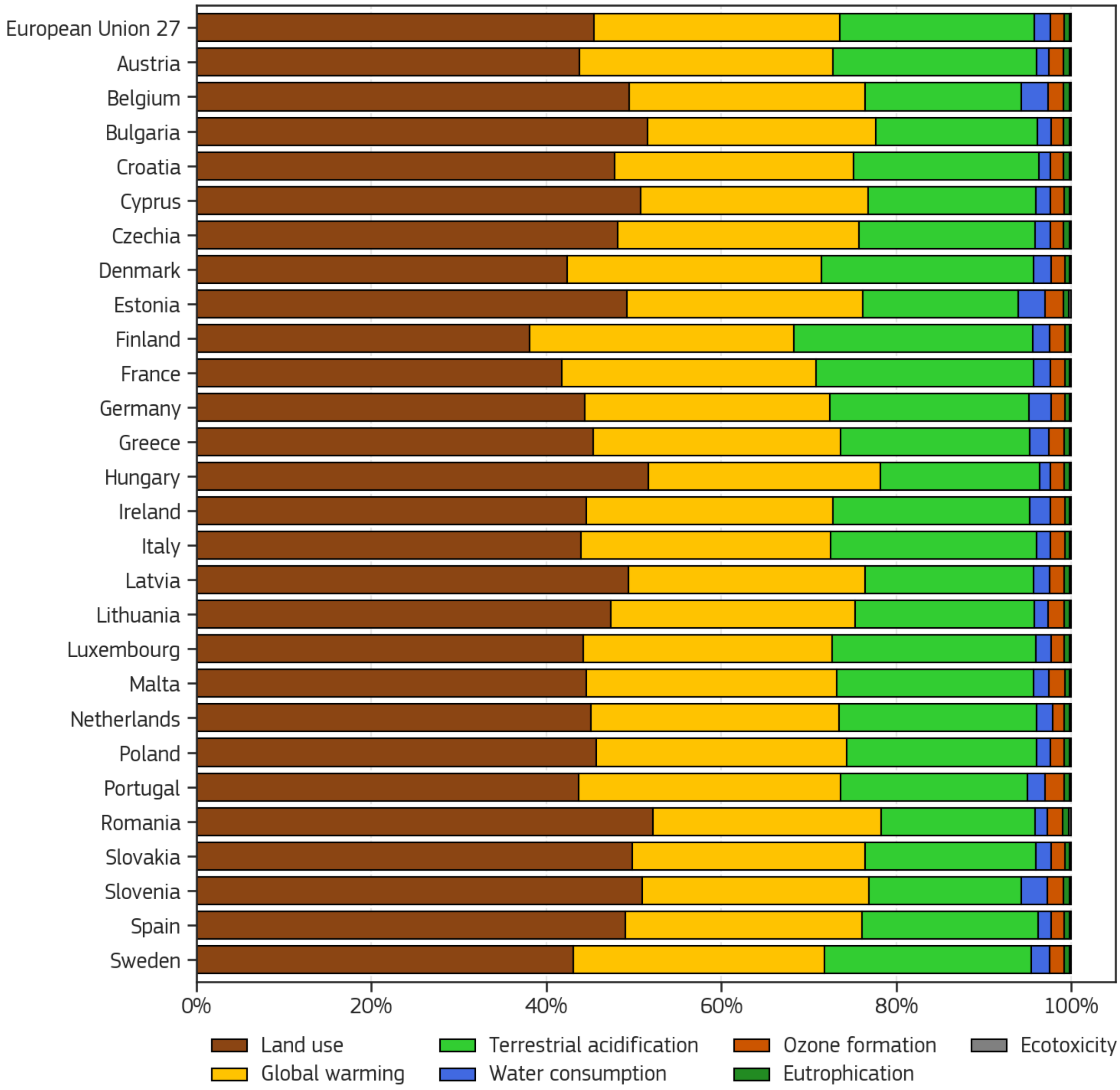
Figure 46. Biodiversity impact per capita of food consumption at EU level and Member State level in 2022



Source: Own elaboration.

The biodiversity impact is mainly caused by land use, global warming, and terrestrial acidification, which contribute 45%, 22%, and 15% to the total biodiversity degradation, respectively. Water consumption and ozone formation account for about 6% of the total biodiversity footprint, with ecotoxicity and eutrophication showing a negligible contribution. The share of the impact categories in the total biodiversity loss is displayed in Figure 47.

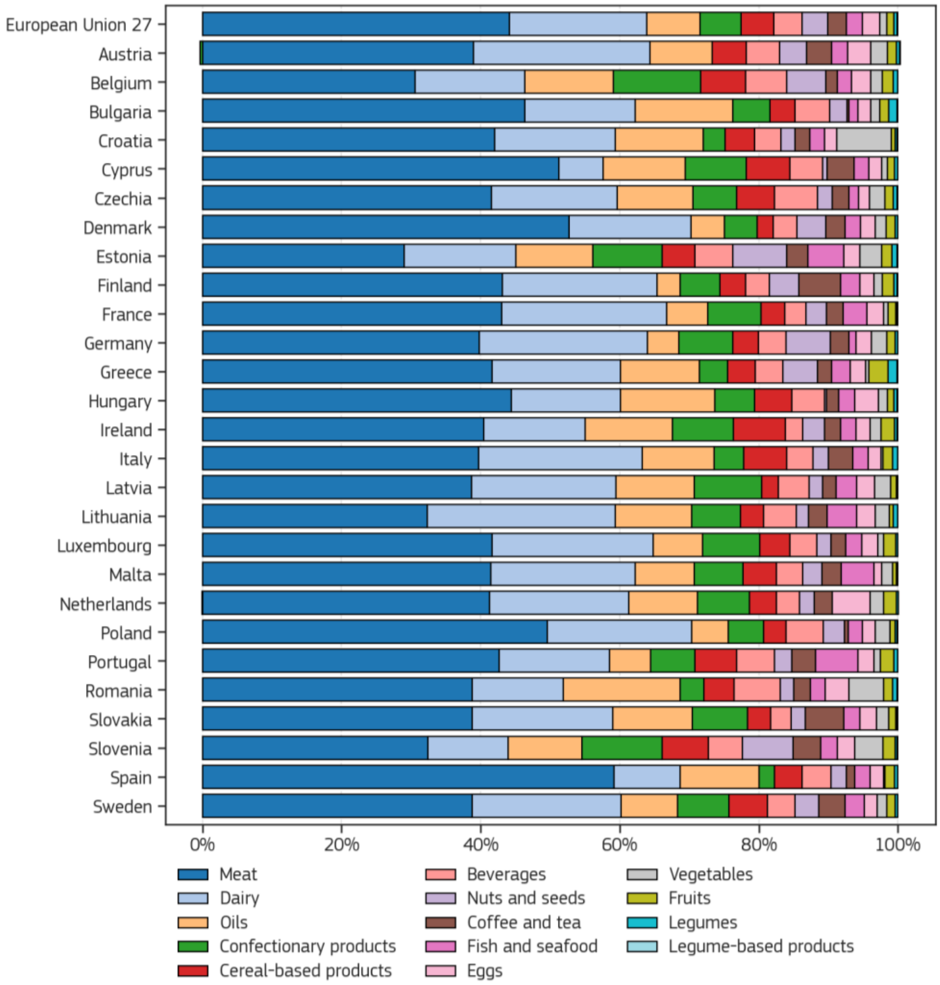
Figure 47. Biodiversity impact by share of impact category at Member State and EU level for 2022



Source: Own elaboration.

In terms of product groups, meat and dairy products account for more than 60% to the biodiversity footprint, followed by vegetable oils and confectionary products with nearly 20% and cereal products and beverages with about 10% (see Figure 48). Pork and poultry meat are responsible for the high land use contribution, followed by beef meat from cattle rearing. Similarly, pork and beef meat have the highest impact on global warming, followed by poultry meat. For terrestrial acidification, beef meat from cattle rearing has the highest impact, with pork meat also contributing considerably. Cheese is the highest impact contributor within the dairy product group, while sunflower and olive oil are the main products responsible for biodiversity loss in the vegetable product group. Beer and wine are the greatest contributors to the impacts of the beverage product group. Pasta and bread are responsible for the highest impact in the cereal-based product group where wheat is causing the highest land use. For global warming, rice production is the main contributor among those products in the cereal-based product group. Chocolate farm production has the highest global warming and land use impact among the products in the confectionary product group.

Figure 48. Biodiversity impact by share of product group at Member State and EU level for 2022



Source: Own elaboration.

Annex 8. Preventing double-counting between areas of consumption

The five areas of consumption of the CF model present processes which environmental impacts are in occur between both in one basket of products and another. For example, the use of detergents can be found both the Household Goods and the Appliances areas of consumption, while the energy consumption in considered in the use phase of Appliances can be also found in the energy consumption of Housing. This aspect has important implications when the environmental impacts of different areas of consumption are considered together, as it is important to prevent double-counting of these overlapping impacts.

For these reasons, the CF model includes a single parameter in the basket of products of food, household goods, and appliances (called "double-counting"), which can have a have a value of either 1 or 0, and allows one to switch on and off, the environmental impact that occurs in more than one area of consumption. Specifically, if the impacts are calculated to focus on a single area of consumption, it is important to include all the elements which comprise such an impact (thus double-counting parameter =1). However, when impacts are analysed together to provide an overview of the evolution of impact of total consumption, then the overlapping impacts will have to be counted only in one of the areas of consumption for all areas of consumption (thus double-counting parameter=0).

Table 6 details the activities that can be found in multiple areas of consumption and in which basket the impact of such activity is allocated when the overall Consumption Footprint is assessed. Additional details can be found in Sanye-Mengual et al. (2023a).

Table 6. Detail of activities that overlap among areas of consumption and basket where the activity is considered, by life cycle stage.

Life Cycle Stages	Activity	Overlapping	Basket in which is kept
Use	Transport to client	Transport to client overlaps among the use phase of the Food, Mobility, Household goods, and lighting of the Appliances basket.	Mobility[16]
	Tap water consumption	Tap water use is overlapped among Food, Housing, and Household goods basket.	Housing[17]
	Heat consumption	Heat consumption overlaps with the use phase of Food and Housing basket.	Housing[6]
	Electricity consumption	Electricity consumption overlaps with the use phase of Food, Housing, Household goods, and Appliances basket.	Housing[6]
	Detergents consumption	Use of detergents overlaps between the basket Appliances and Household goods.	Household goods[18]
Wastewater treatment	Toilet paper	Consumption of toilet paper in the wastewater treatment dataset of Food basket is overlapped with the use phase of the toilet paper in the Household goods basket.	Household goods[7]
	Wastewater	The same amount of water consumed in the use phase goes to wastewater treatment as sewage from residence. Hence, there is an overlapping also for wastewater treatment (as it is for water use)	Housing[19]
	Soap and detergent consumption	Consumption of soap and detergent in the wastewater treatment dataset of basket Food are overlapped with the use phase of the soap and detergent in the Household goods and Appliances basket.	Household goods[7]
	Electricity	Electricity consumption for the hand drying machine, and washing machine in the wastewater treatment dataset in Food basket are overlapped with the electricity consumption of the Housing.	Housing[6]

Source: Sanye-Mengual et al. (2023a).

[16] Since BoP Mobility is more comprehensive as it includes the overall use of passenger car, the activity is kept in that basket, to have the overall footprint of transport in the Mobility sector.

[17] The top-down statistics for Housing are considered to be more comprehensive than the bottom-up numbers in case of Food, Household goods, and Appliances.

[18] The data regarding the consumption of detergents and toilet paper in household goods has a top-down approach and it is more comprehensive than a partial bottom-up estimation in Food and Household Goods.

[19] Wastewater treatment is kept in BoP Housing for consistency with water use in the use phase

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