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Consumption Footprint and Domestic Footprint: Assessing the environmental impacts of EU consumption and production

Life cycle assessment to support the European Green Deal

Sanyé Mengual E., Sala S.

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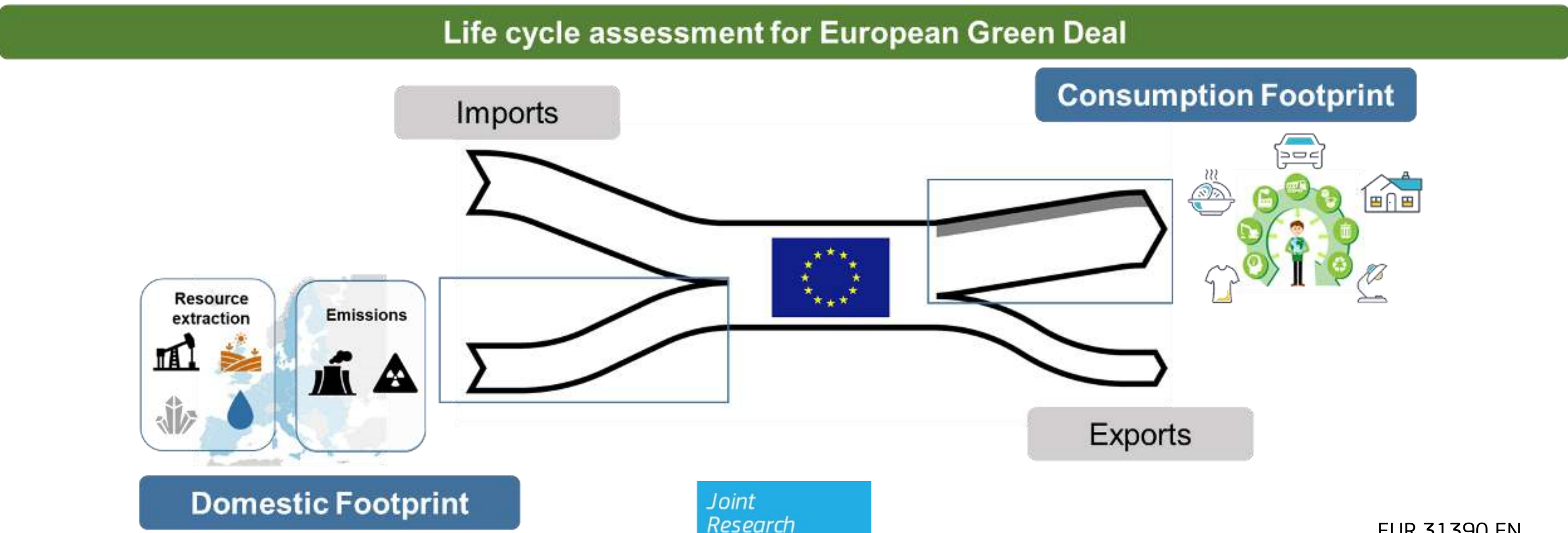

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Contents

Abstract

The Consumption Footprint is a life cycle assessment (LCA)-based set of indicators to assess the environmental impacts of EU production and consumption. LCA allows assessing supply chains and modelling drivers of pressures on the environment and the associated environmental impacts. This report presents the assessment framework relying on two different indicators: the **Domestic Footprint** (production/territorial perspective) and the **Consumption Footprint** (consumption perspective including trade). The Consumption footprint indicators cover 5 areas of consumption: food, mobility, housing, household goods, and appliances. The indicators are calculated by summing the environmental impacts of representative products in each area of consumption multiplied by their consumption intensity. The indicators address 16 environmental impact categories. By applying weighting, both the domestic and the consumption footprint indicators can be presented as well as a single score. The overall EU Consumption Footprint has increased by 4% from 2010 to 2021 (as a single score) with a peak of 10% increase in 2019 that has been curbed with the change of patterns during the COVID pandemic. **Food consumption emerges as the main driver of impacts**, followed by housing (especially for space heating) and mobility (especially due to the use of private cars). On the contrary, **domestic environmental impacts** in EU-27 have decreased (-12% as single score) highlighting the role of the **EU-27 as a** "**net importer of environmental impacts**".

Acknowledgements

This science for policy report is summarising the key results of the project "Application of the consumption footprint indicators in policy analysis", an administrative agreement between DG Environment and the JRC. The project has been developed over time thanks to the contribution of a number of DG Environment colleagues, JRC colleagues, and external experts. The authors of the report want to thank for their precious support:

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This Science for Policy Report is complemented by a JRC technical report detailing the methodology[1] and a series[2] of technical reports and scientific publications presenting the results of the Consumption Footprint project, where methodological details and assumptions as well as comparisons with other available studies are reported. The role of contributors to the work performed in the Consumption Footprint project is fully detailed in these publications.

[1] https://publications.jrc.ec.europa.eu/repository/handle/JRC132734

[2] Publications are available in the project website: https://eplca.jrc.ec.europa.eu/sustainableConsumption.html

Executive summary

This report provides an overview of the Life Cycle Assessment (LCA)-based framework applied to the assessment of the environmental impacts of production and consumption at the EU and Member State levels as a basis to support several EU policies and the assessment of their impacts and benefits. Two sets of indicators are calculated: the Domestic Footprint and the Consumption Footprint. The latter is assessing impacts due to five areas of consumption (Food, Mobility, Housing, Household goods and Appliances).The indicators have been designed to support policies by:

- Identifying **environmental hotspots**: the granularity of the indicators can provide information at different levels (environmental issues with the highest relevance, areas of consumption, product groups and products, life cycle stages of products, and of most relevant resource used or emissions to the environment). The indicators could be presented as 16 different environmental impact categories or as a single score. Biodiversity footprint and human health footprint could be assessed as well.
- **Monitoring**: yearly updates of the indicators allow tracking the evolution of impacts associated with changes in production and consumption patterns. This may be strategic for monitoring e.g. how much EU is decoupling environmental impacts from economic growth, the benefits of transition towards circular economy, the ability of EU to remain within planetary boundaries as well as progress related to the SDGs (especially SDG12 on responsible consumption and production). The Consumption Footprint is currently one of the headline indicators of the 8th Environment Action Pogramme monitoring framework[3], the EC Resilience Dashboards[4], and the Circular Economy monitoring framework[5].
- Setting a baseline against which **testing policy options and scenarios**: the modularity of the indicators 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.
- **Evaluating lifestyles and consumption patterns**, which can be compared to EU and Member State average lifestyles, as in the Consumer Footprint Calculator (Sala et al., 2022).
- Identifying **transboundary and spillovers effects**, since the indicators could unveil the trade footprint, namely the amount of impacts embodied in imported goods (Sanyé-Mengual & Sala, 2021).

Moreover, since the **Better Regulation** (EC, 2021a) foresees the enhanced application of Life Cycle Analysis for the purpose of supporting policy impact assessments, this report is offering an overview of possible uses of LCA for supporting policies. The Consumption Footprint has been employed in the Impact Assessment of EU policies[6] and is part of the Modelling Inventory and Knowledge Management System of the European Commission (MIDAS)[7]. The Consumption Footprint can also be used to develop future scenarios and calculate expected impacts, as in the analysis performed for the Zero Pollution Outlook (EC-JRC, 2022).

The consumption footprint assessment is systematically documented. This Science for Policy Report is complemented by a series of technical reports[8], where methodological details and assumptions as well as comparisons with other available studies in relation to environmental impacts of consumption are reported.

The domestic footprint and the consumption footprint indicators, their results and time-trends, are available in a dedicated platform, at: https://eplca.jrc.ec.europa.eu/ConsumptionFootprintPlatform.html.

[3] https://environment.ec.europa.eu/publications/monitoring-framework-8th-environment-action-programme_en
[4] https://ec.europa.eu/info/strategy/strategic-planning/strategic-foresight/2020-strategic-foresight-report/resilience-dashboards_en
[5] https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en
[6] For example, the Consumption Footprint has been used to model the climate impacts of circular economy in the IA of the 2030 climate target plan https://climate.ec.europa.eu/eu-action/european-green-deal/2030-climate-target-plan_en
[7] https://web.jrc.ec.europa.eu/policy-model-inventory/
[8] Available reports are listed in the project website: https://eplca.jrc.ec.europa.eu/sustainableConsumption.html

Policy context

As part of its commitment towards more sustainable production and consumption, the European Commission developed a LCA-based framework, which allows assessing the environmental impacts related to EU consumption and production. The framework includes two different indicators: the **Domestic Footprint**, to quantify the overall impacts of domestic production and consumption happening within EU or Member States boundaries (territorial perspective) and the **Consumption Footprint,** to assess the environmental impacts of the consumption at EU and at Member States level, including embodied impacts due to trade (consumption perspective).

These indicators are complementary and are relevant in the context of:

- Achieving the Sustainable Development Goal (SDG) on **Responsible consumption and production (SDG 12) and on Sustainable economic growth (SDG 8)**, adopted in the **2030 Agenda for Sustainable Development** (UN, 2015) and contributing to other SDGs.
- Measuring to which extent Europe is ensuring "**living well within the limits of our Planet"**, including assessing the appropriateness of the inclusion of a lead indicator and targets, as foreseen in the 7th as well as in the **8th Environment Action Programme** (European Parliament and Council, 2022).
- Monitoring progress towards the **8th Environment Action Programme** and the **European Green Deal** (EC, 2019) ambitions, such as those in the **Farm to Fork Strategy** (EC, 2020a), the **New Circular Economy Action Plan** (EC, 2020b), the **Biodiversity Strategy** (EC, 2020c), the **Chemical Strategy for Sustainability** (EC, 2020d) and the **Zero Pollution Action Plan** (EC, 2021a).
- Contributing to **EU product policy** towards making sustainable products the norm (EC, 2022a).
- Contributing to the **Better Regulation initiative** (EC, 2021a), unveiling the potential role of LCA for defining baseline scenarios to be used in policy impact assessment.
- Contributing to the implementation of the **Beyond GDP Roadmap** (EC, 2009).
- Contributing to the transition towards **Bioeconomy** (EC, 2018), through the identification of the environmental hotspots and the monitoring of progress towards their objectives over time.

Key conclusions and main findings

Adopting LCA as reference method, the environmental impacts of EU consumption is assessed for 16 impacts (e.g. climate change, ecotoxicity, land use related impacts, water use related impacts, etc.). Adopting normalisation and weighting, a single headline indicator is calculated as well. Modelling production and consumption in the EU, the calculated environmental impacts are basically the impacts of the production and consumption system (aiming at achieving SDG12 ambitions on responsible production and consumption) to SDGs (3, 6, 13, 14, and 15, addressing environmental sustainability and promoting human health) (Figure 1). Results are reported at different scales, at the overall EU level, at Member States level, per areas of consumption, per single products, per environmental impact category. The indicators could be presented as individual impacts per impact category or as a single score/ single headline indicator.

Which are the main areas of consumption and which are the main products driving the impacts across the 16 impact categories considered?

Five areas of consumption (Food, Mobility, Housing, Household goods and Appliances) have been assessed by means of assessing more than 160 representative products. **Consumption of food emerged as the main driver of impacts** generated by an average EU citizen, followed by housing (especially for space heating) and mobility (especially due to the use of private cars). The Consumption Footprint in the five areas of consumption increased by 4% from 2010 to 2021 (as a single score) with a peak of 10% increase in 2019 that has been curbed with the change of patterns during the COVID pandemic.

Which is the environmental impact of consumption at EU and country scales?

The **EU-27 can be considered a** "**net importer of environmental impacts**" taking place in other world regions. This implies that the Consumption Footprint (overall impacts related to consumption of good and services) is higher than the Domestic Footprint (impacts generated in the EU-27 area).

Is there a decoupling of environmental impact from economic growth?

Between 2010 and 2018, **domestic environmental impacts** in EU-27 have decreased (-12% as single score[9]) while GDP has increased of 23%, showing an **absolute decoupling**. Yet accounting for trade, a more **limited relative decoupling is observed for the Consumption Footprint** (increase by 6% for the same period, relative decoupling). Moreover, a number of impacts cannot be fully captured so far, indicating the need of including in future more aspects to depict comprehensively the decoupling (e.g., biodiversity loss, overexploitation).

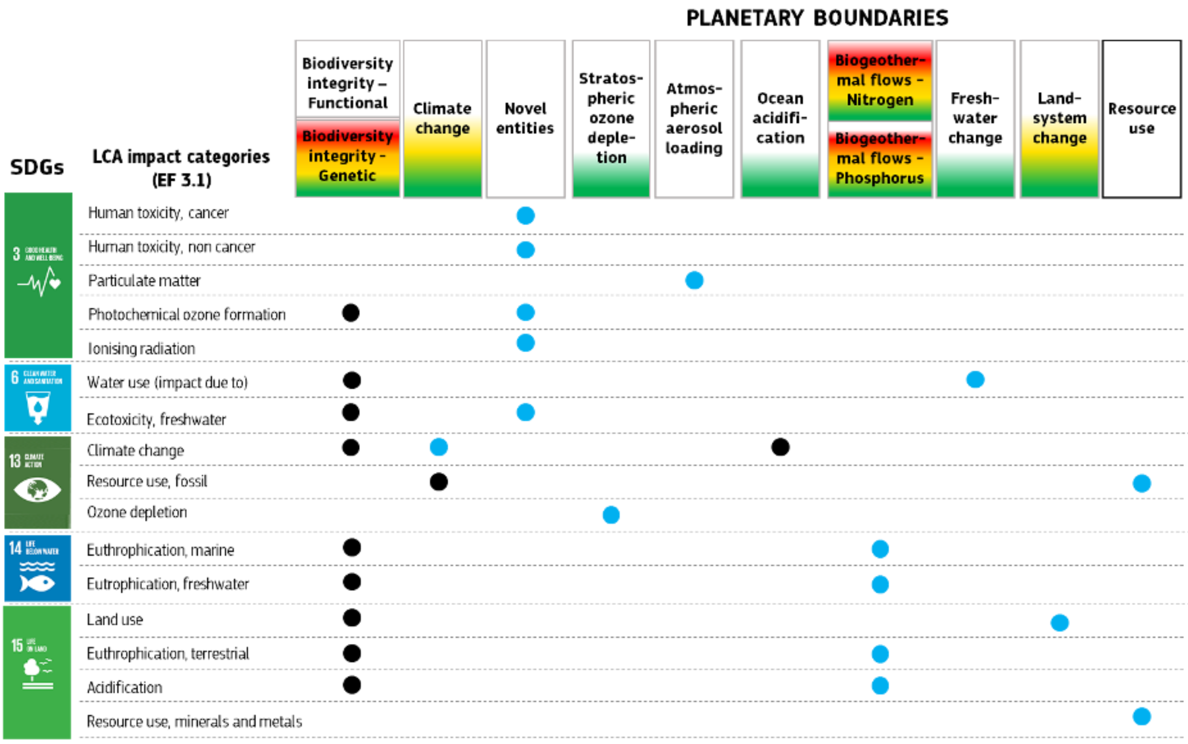
Is consumption in Europe environmentally sustainable and within planetary boundaries?

Results show that the environmental impact of the **consumption of an average EU citizen is outside the safe operating space for humanity** for several impacts, namely climate change, particulate matter, freshwater ecotoxicity, and resource use (fossils fuels, minerals and metals).

Is it possible to evaluate in a systemic manner solutions and green transitions, towards SDGs goals?

The Consumption Footprint in a certain year could be considered a baseline scenario against which different policy options could be tested, from substituting a raw material, to changing a consumer behaviour or a product waste management option. Adopting LCA, trade-offs of green transitions emerge clearly. More than 50 scenarios to foster green transitions in the different areas of consumption have been tested. Overall, results showed that **only an integrated action combining several interventions may ensure reducing significantly the environmental impacts**.

Figure 1. Overview of the links between the (midpoint) impact categories adopted in Life Cycle Impact Assessment, the Sustainable Development Goals and the planetary boundaries (Blue – category with direct correspondence between life cycle impact categories of the consumption footprint and planetary boundaries, Black – category indirectly addressed by the consumption footprint.



[9] The decreasing trend is different for each impact category and can be explored in the consumption footprint platform https://eplca.jrc.ec.europa.eu/ConsumptionFootprintPlatform.html

Quick guide

The report presents the results of the two indicators (the Domestic Footprint and the Consumption Footprint), analysing the results for EU-27 and the individual Member States. Each chapter addresses a specific question.

Section 1	Introduction: An integrated approach to the assessment of the environmental impacts of European Union consumption
Section 2	Why to rely on life cycle assessment to evaluate the environmental impacts of consumption?
Section 3	How to assess the environmental impacts of consumption?
Section 4	Domestic Footprint: which are the impacts generated within the EU territory?
Section 5	Consumption Footprint: which are the impacts of an average EU citizen?
Section 6	What is the temporal evolution and geographical distribution of the EU Consumption Footprint?
Section 7	Are the consumption patterns of EU citizens sustainable?
Section 8	What are the applications of the developed framework?
Section 9	A regionalized Consumption Footprint
Section 10	Conclusions

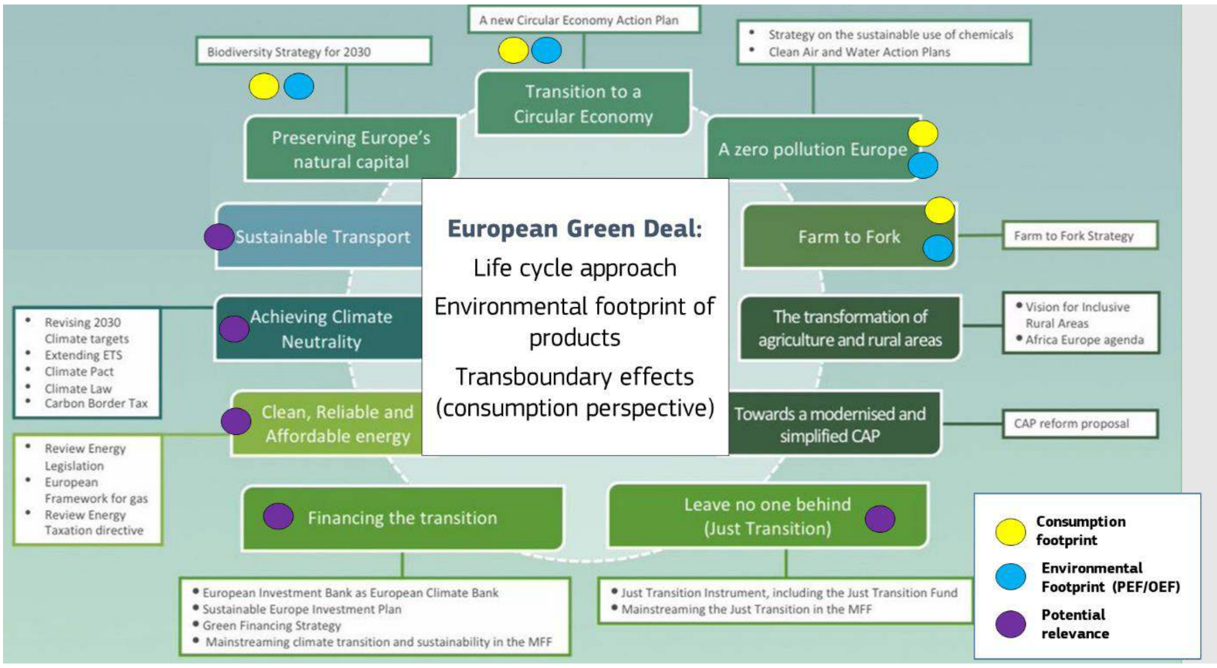
1 Introduction: An integrated approach to the assessment of the environmental impacts of EU consumption

The protection of the environment is one of the core principles of the European Union (EU) and has been integrated in an increasing number of policies. Within the activities impacting on the global environment, consumption patterns of goods and services is recognised as one of the main drivers. **Addressing the environmental impacts of consumption is therefore of utmost importance to meet environmental objectives and targets set by EU**.

The Agenda 2030, with its 17 **Sustainable Development Goals (SDGs)**, is the global key reference in the way towards sustainable development (EC, 2016). Responsible production and consumption are the core of the SDG12, and are as well addressed by other SDGs such as the SDG 11 on sustainable cities and communities, and the SDG 9 on industry, innovation and infrastructure. Furthermore, environmental impacts generated by consumption have an impact on a number of SDGs, e.g., on the SDG 3 on good health and well-being, the SDG 6 related to clear water on sanitation, the SDG 13 dealing with climate action, the SDG 14 and the SDG 15 respectively related to life below water and on land. Sustainability of consumption is central in many EU environmental policies. The **8th Environment Action Programme** (8th EAP) (European Parliament and Council, 2022), which will be guiding EU environmental policies until 2030, reiterates EU's long-term vision to 2050 of living well, within planetary boundaries (Rockström et al., 2009, Steffen et al., 2015). In order to do so, resource efficiency needs to be improved and a decoupling of economic growth and wellbeing from environmental impacts is needed (EC, 2011; Sala et al., 2014). Measuring environmental impacts over time and the extent to which the impacts of consumption are decoupling from economic growth is key to assess the success of the abovementioned environmental policies (European Parliament and Council, 2022).

Moreover, the **"Beyond GDP" initiative** highlights the importance of developing indicators as clear and appealing as Gross Domestic Product (GDP), but more inclusive of environmental and social aspects of progress (EC, 2009). The Single Market for Green Products Initiative (EC, 2013) aims at removing market barriers which may limit the uptake of green products. The **European Green Deal** (EGD) (EC, 2019) aims at making Europe the first climate-neutral continent with a set of ambitions targeting climate change, environmental degradation and resource efficiency while ensure economic competitiveness. The EGD policy initiatives mention the transboundary effects (Figure 2) and the need of adequate methodological frameworks that assess both production and consumption at the macro-scale (Sanyé-Mengual & Sala, 2022).

Figure 2. Contribution of the Consumption Footprint, the Environmental Footprint for products (PEF) and organisations (OEF) and to the ambitions of the European Green Deal.



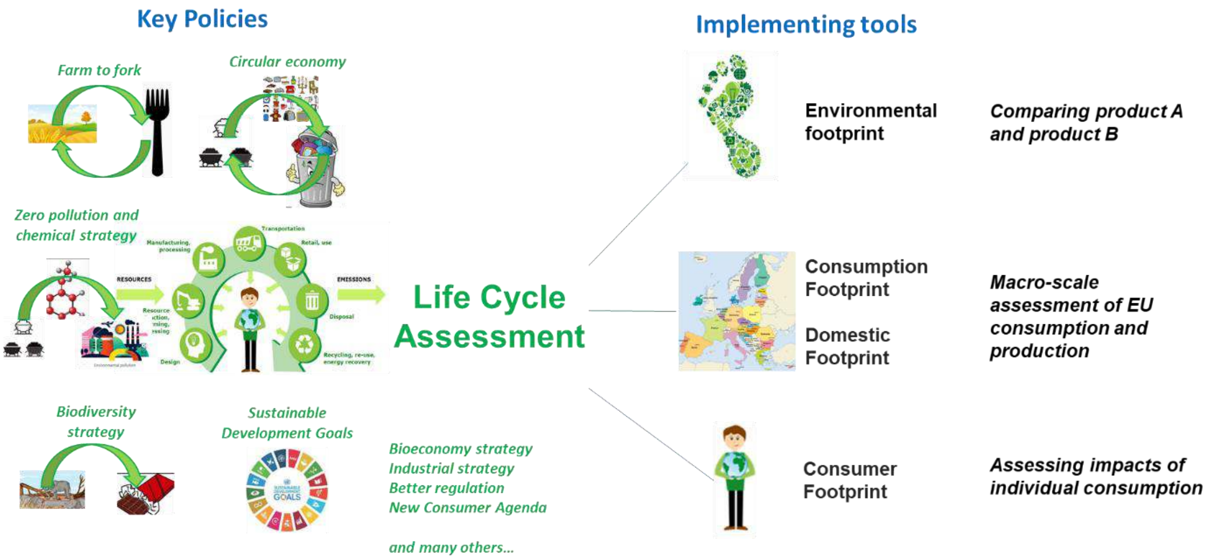
Note: ETS: Emission Trading System; CAP: Common Agricultural Policy; MFF: Multiannual Financial Framework.

The **Farm to Fork Strategy** (EC, 2020a), the **Circular Economy Action Plan**[10] (EC, 2020b), the **Biodiversity Strategy** for 2030 (EC, 2020c), the **Chemical Strategy for Sustainability** (EC, 2020d) and the **Zero Pollution Action Plan** (EC, 2021b) adopt a value chain perspective as key element to enable green transitions (Sanyé-Mengual & Sala, 2022). These aspects are closely linked to a life cycle thinking, which have progressively been used in EU policy (Sala et al., 2021). The **Better Regulation** with its tool n.66 foresees the enhanced application of life cycle analysis for the purpose of supporting policy impact assessments (EC, 2021a)[11]. As well, the **New Consumer Agenda** (EC, 2020e) pursues empowering citizens on the sustainable recovery.

As part of its commitment towards more sustainable production and consumption, the European Commission has developed a Life Cycle Assessment (LCA)-based method that have a life cycle thinking at the core. Beyond the EC recommendation to use the **Environmental Footprint** (EC, 2021c) to assess the life cycle of products to allow a harmonized, robust and systematic comparison among products, the JRC and DG Environment have worked on the development of an **LCA-based framework** to monitor the evolution of environmental impacts associated to consumption in EU. Indicators are based on LCA (ISO, 2006a, 2006b), a methodology to assess the environmental impacts of products and services along their life cycle. The main advantage of LCA is that, thanks to its comprehensiveness, it allows assessing key environmental impacts (i.e. 16 in the Environmental Footprint) highlighting possible trade-offs and burden shifting. The aim is to assess impact comprehensively and holistically, avoiding that impacts are transferred from a life cycle stage to another, or from an environmental compartment to another. A more in-depth description of LCA is reported in Section 2.

The LCA based framework to **assess the environmental impacts of consumption and production** may serve policy-makers both in analysing the effects of existing policies, and in identifying hotspots in terms of the most critical areas of consumption and life cycle stages which should be prioritised by future policies. The indicator framework has been developed between DG Environment and the JRC. The present report summarises the main outcomes and more detailed results are described in a series of reports available at the project website[12].

Figure 3. Key policies and implementing LCA-based approaches to support EU policy.



[10] Within the Circular Economy Action Plan, the Ecodesign for Sustainable Products Regulation aims at making sustainable products the norm (EC, 2022a).

[11] The **Better Regulation** foresees the enhanced application of Life Cycle Analysis for the purpose of supporting policy impact assessments. The Consumption Footprint has been employed in the Impact Assessment of EU policies and is part of the Modelling Inventory and Knowledge Management System of the European Commission (MIDAS). The Consumption Footprint can also be projected to assess expected trends, such as in the analysis performed for the Zero Pollution Outlook (EC-JRC, 2022).

[12] Available reports are listed in the project website: https://eplca.jrc.ec.europa.eu/sustainableConsumption.html

2 Why to rely on life cycle assessment to evaluate the environmental impacts of consumption?

Life cycle thinking is a basic concept referring to the need of assessing burden and benefits associated to products, sectors, and projects adopting a life-cycle perspective, i.e., from raw material extraction to end of life. Life cycle thinking can be applied to assess environmental, economic and social pillars. The environmental pillar of life cycle thinking is primarily supported by the LCA methodology.

Compared to other methodologies with a more limited perspective, **LCA has the advantage of accounting for potential burdens shifting among life cycle stages and among environmental impacts, allowing a comprehensive and systematic assessment**.

According to ISO (2006a,b), LCA entails four main steps (Figure 4).

1. *Definition of goal and scope*. This step includes the overall design of the study, e.g. the definition of the specific objectives of the study, the description of the modelling assumptions, the identification of the intended audience, etc.
2. *Compilation of the life cycle inventory (LCI)*. In this step, data on inputs, i.e. use of resources, and outputs, i.e. emissions to the environmental compartments (air, water, soil), entering and leaving the system under study should be collected.
3. *Life cycle impact assessment (LCIA)*. In this step, the environmental impacts due to resources use and emissions reported in the LCI are calculated through the use of impact assessment models. Sixteen indicators referred to different impacts are considered, such as climate change, eutrophication of water bodies, use of fossil, mineral and metal resources (EC, 2021c). Furthermore, endpoint assessment models can be applied to assess effects of these 16 impacts on 3 areas of protection, i.e. human health, ecosystem health, and natural resources. These 16 indicators may be normalised by global impacts and weighted to be summarised in one "single score" indicator. Compared to the 16 indicators, the single score indicator has the advantage of being more effective for communication and for supporting the selection of alternatives, but at the same time "hides" part of the complexity of the different environmental impacts, and introduce a subjective element, i.e. weighting, which may affect the results.
4. *Interpretation of the results*. This step is aimed at fulfilling the goal and scope of the study. Typical questions which may be answered at this stage are "which are the most impacting stages of the supply chain?", "which are the effects on the environment of a certain policy?". LCA results are characterised by different sources of uncertainty which should be considered in the interpretation of the results. The definition of the LCI is subject to the availability of average information describing the system. In addition, impact assessment models are characterised by uncertainties, which to different extent influence the robustness of the 16 indicators (details on the robustness of each indicator are given in Annex 1).

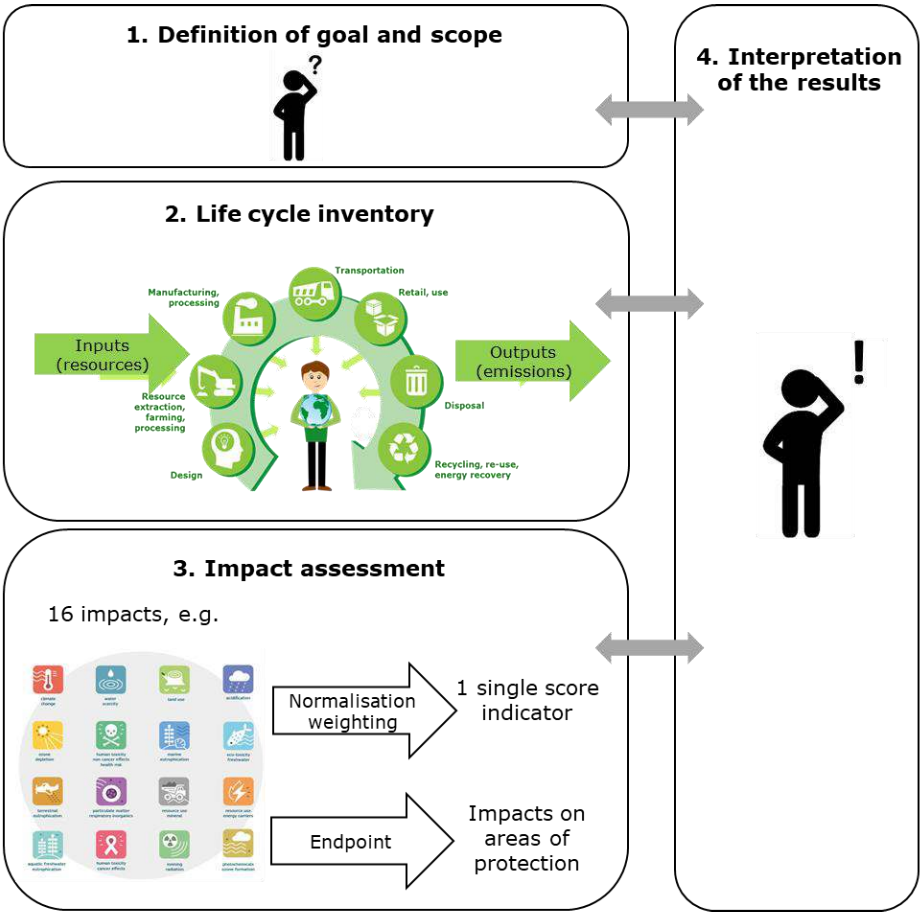
The EU Environmental Footprint

Performing a LCA implies making assumptions on the modelling of the analysed system, choosing sources for inventory data, and selecting the most suitable impact assessment models among the ones available. All these elements may affect LCA results and its comparability with other LCA results, thus limiting the effectiveness of environmental communication.

To enhance the comparability of LCA and remove potential market barriers due to the existence of different environmental communication schemes, the European Commission has proposed the Product Environmental Footprint (PEF) and the Organisation Environmental Footprint (OEF) methods (EC, 2021c). The methodological approach was tested between 2013-2018 together with more than 280 volunteering companies and organisations. The current transition phase is further developing category rules for 5 product groups.

The Consumption Footprint follows the Environmental Footprint when possible: (a) when modelling the individual products PEF requirements are followed when possible, (b) data on representative products from the PEF pilot are used for representative products, and (c) the Environmental Footprint method is employed for the impact assessment step.

Figure 4. Steps of life cycle assessment



LCA and the "Driver Pressure State Impact Response" framework (DPSIR)

The underpinning logic of LCA is linked with the framework "Drivers, Pressure, State, Impact and Response" (DPSIR) for reporting environmental issues (Smeets and Weterings, 1999). When defining the LCI of a product, sector or project, drivers of environmental issues should be identified and resulting pressures should be quantified. Impacts on the environment are then calculated through the use of impact assessment models. Finally, the interpretation of the results allows to test the effects of responses, such as policies, on the environmental impacts of products, sectors and services.

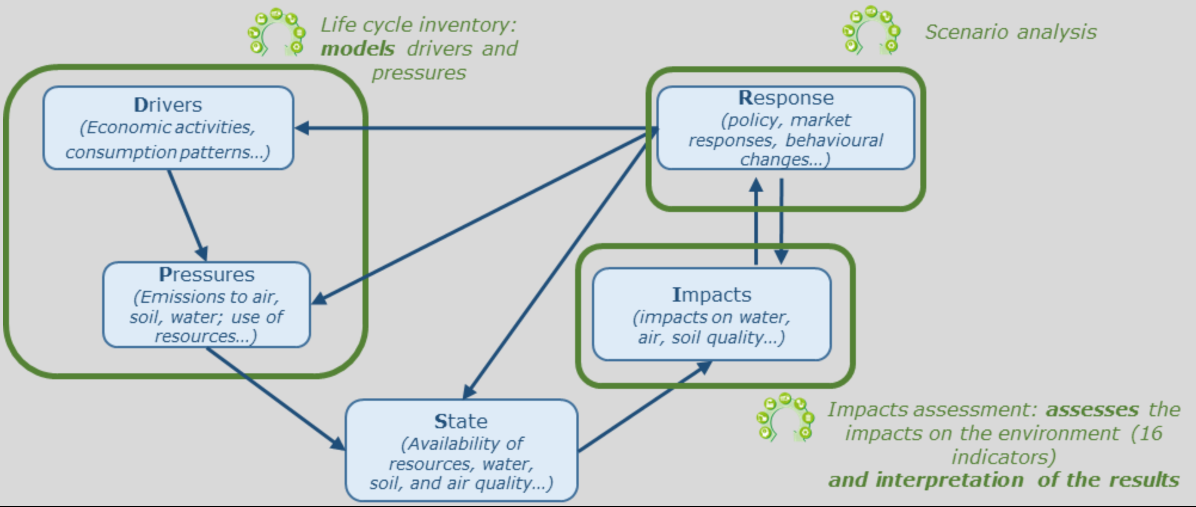


Figure 5. The 16 impact categories of the Environmental Footprint method

Climate change

This indicator refers to the increase in the average global temperatures as result of greenhouse gas (GHG) emissions. The greatest contributor is generally the combustion of fossil fuels such as coal, oil, and natural gas. The global warming potential of all GHG emissions is measured in kilogram of carbon dioxide equivalent (kg CO_2 eq), namely all GHG are compared to the amount of the global warming potential of 1 kg of CO_2.

Particulate Matter

This indicator measures the adverse impacts on human health caused by emissions of Particulate Matter (PM) and its precursors (e.g. NO_x, SO_2). Usually, the smaller the particles, the more dangerous they are, as they can go deeper into the lungs. The potential impact of is measured as the change in mortality due to PM emissions, expressed as disease incidence per kg of $PM_{2.5}$ emitted.

Ionising radiation

The exposure to ionising radiation (radioactivity) can have impacts on human health. The Environmental Footprint only considers emissions under normal operating conditions (no accidents in nuclear plants are considered). The potential impact on human health of different ionising radiations is converted to the equivalent of kilobequerels of Uranium-235 (kg U_{235} eq).

Photochemical ozone formation

Ozone (O_3) on the ground (in the troposphere) is harmful: it attacks organic compounds in animals and plants, it increases the frequency of respiratory problems when photochemical smog ("summer smog") is present in cities. The potential impact of substances contributing to photochemical ozone formation is converted into the equivalent of kilograms of Non-Methane Volatile Organic Compounds (e.g. alcohols, aromatics, etc.; kg NMVOC eq).

Eutrophication, terrestrial

Eutrophication impacts ecosystems due to substances containing nitrogen (N) or phosphorus (P). These nutrients cause a growth of algae or specific plants and limit growth in the original ecosystem. The potential impact of substances contributing to terrestrial eutrophication is converted to the equivalent of moles of nitrogen (mol N eq).

Ozone depletion

The stratospheric ozone (O_3) layer protects us from hazardous ultraviolet radiation (UV-B). Its depletion increases skin cancer cases in humans and damage to plants. The potential impacts of all relevant substances for ozone depletion are converted to their equivalent of kilograms of trichlorofluoromethane (also called Freon-11 and R-11), hence the unit of measurement is in kilogram of CFC-11 equivalent (kg CFC-11 eq).

LCA and environmental impacts

With LCA, different environmental impacts may be assessed.
The Environmental Footprint method allows assessing 16 impact categories.

Acidification

Acidification has contributed to a decline of coniferous forests and an increase in fish mortality. Acidification can be caused by emissions getting into the air, water and soil. The most significant sources are combustion processes in electricity, heating production, and transport. The contribution to acidification is greatest when the fuels contain a high level of sulphur. The potential impact of substances contributing to acidification is converted to the equivalent of moles of hydron (general name for a cationic form of atomic hydrogen, mol H^+ eq).

Eutrophication, freshwater

Eutrophication impacts ecosystems due to substances containing nitrogen (N) or phosphorus (P). If algae grows too rapidly, it can leave water without enough oxygen for fish to survive. Nitrogen emissions into the aquatic environment are caused largely by fertilizers used in agriculture, but also by combustion processes. The most significant sources of phosphorus emissions are sewage treatment plants for urban and industrial effluents and leaching from agricultural land. The potential impact of substances contributing to freshwater eutrophication is converted to the equivalent of kilograms of phosphorus (kg P eq).

Figure 5 (cont.). The 16 impact categories of the Environmental Footprint method

Eutrophication, marine

Eutrophication impacts ecosystems due to substances containing nitrogen (N) or phosphorus (P). As a rule, the availability of one of these nutrients will be a limiting factor for growth in the ecosystem, and if this nutrient is added, the growth of algae or specific plants will be increased. For the marine environment this will be mainly due to an increase of nitrogen (N). Nitrogen emissions are caused largely by the agricultural use of fertilisers, but also by combustion processes. The potential impact of substances contributing to marine eutrophication is converted to the equivalent of kilograms of nitrogen (kg N eq).

Human toxicity, non-cancer

This indicator refers to potential impacts on human health caused by absorbing substances through the air, water, and soil. Direct effects of products on humans are currently not measured. The unit of measurement is Comparative Toxic Unit for humans (CTUh). This is based on a model called USEtox.

Water use

The withdrawal of water from lakes, rivers or groundwater can contribute to the 'depletion' of available water. The impact category considers the availability or scarcity of water in the regions where the activity takes place, if this information is known. The potential impact is expressed in cubic metres (m^3) of water use related to the local scarcity of water.

Resource use, minerals and metals

The basic idea behind this impact category is the same as the one behind the impact category resource use, fossils (namely, extracting a high concentration of resources today will force future generations to extract lower concentration or lower value resources). The amount of materials contributing to resource depletion are converted into equivalents of kilograms of antimony (kg Sb eq).

Ecotoxicity, freshwater

This indicator refers to potential toxic impacts on an ecosystem, which may damage individual species as well as the functioning of the ecosystem. Some substances have a tendency to accumulate in living organisms. The unit of measurement is Comparative Toxic Unit for ecosystems (CTUe). This is based on a model called USEtox.

Human toxicity, cancer

This indicator refers to potential impacts on human health caused by absorbing substances through the air, water and soil. Direct effects of products on humans are currently not measured. The unit of measurement is Comparative Toxic Unit for humans (CTUh). This is based on a model called USEtox.

Land Use

Use and transformation of land for agriculture, roads, housing, mining or other purposes. The impacts can vary and include loss of species, of the organic matter content of soil, or loss of the soil itself (erosion). This is a composite indicator measuring impacts on four soil properties (biotic production, erosion resistance, groundwater regeneration and mechanical filtration), expressed in points (Pts).

Resource use, fossils

The earth contains a finite amount of non-renewable resources, such as fossil fuels like coal, oil and gas. The basic idea behind this impact category is that extracting resources today will force future generations to extract less or different resources. For example, the depletion of fossil fuels may lead to the non-availability of fossil fuels for future generations. The amount of materials contributing to resource use, fossils, are converted into MJ.

Impact affecting the environment on a global scale

Impact affecting the environment mainly at local/regional scale

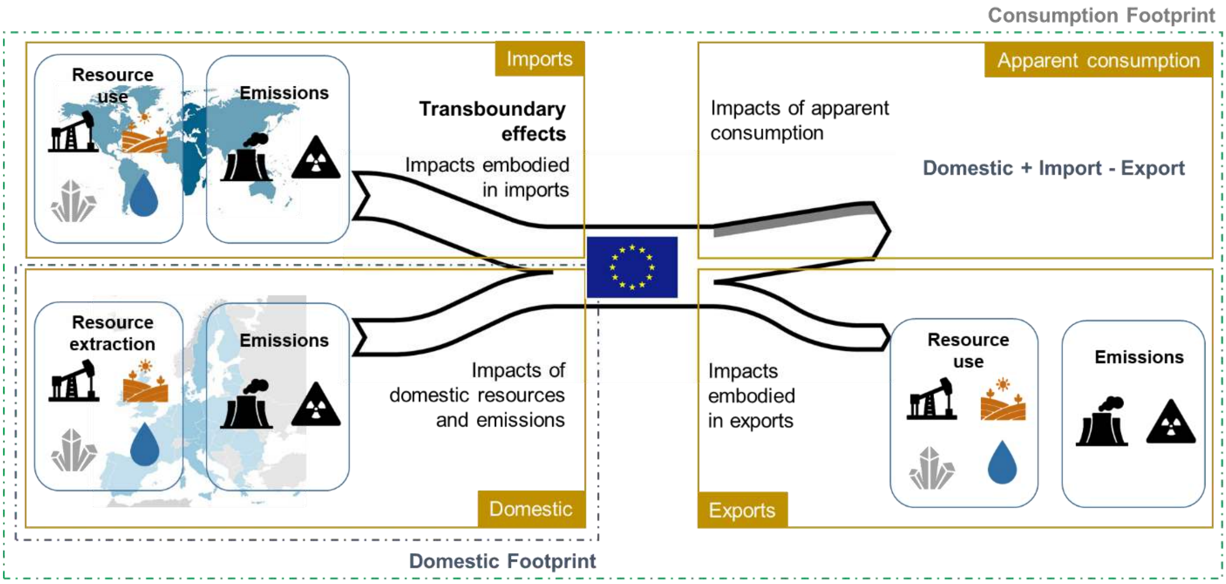
3 How to assess the environmental impacts of consumption?

Understanding the environmental impacts of consumption and production activities requires the combination of different approaches. Environmental impacts generated by consumption and, more generally, by people's lifestyle, is a growing topic in the scientific literature. Carbon, water, land, material and other footprints adopt a **consumption-based approach**, i.e. they consider the full life cycle of products and they allocate the impacts to the final consumer. They differ from the **production-based approach**, which instead allocates the impacts to the producer of goods (Hertwich and Peters, 2009; Davis and Caldeira, 2010; Wiedmann et al., 2013).

In this study, an LCA-based framework (Figure 6) to assess the environmental impacts of consumption and production at the macro-scale (EU level) and meso-scale (countries, regions and cities) was developed combining:

- A **production-based approach**: The Domestic Footprint aims to quantify the environmental impacts due to domestic activities, hence limiting the scope to emissions (as well as resources extracted) within the EU territory. The resource use and the emissions are multiplied by impact factors (characterisation factors) to estimate environmental impacts, following the EF method. Domestic activities include production and domestic consumption (e.g., consumption of domestically produced products, direct emissions during consumption such as those due to combustion).
- A **consumption-based approach**: The Consumption Footprint aims to quantify the environmental impacts of consumption at EU and Member State level, thereby considering not only impacts taking place within the EU territory but also the embedded impacts in imports and exports.

Figure 6. LCA-based framework to assess the environmental impacts of production and consumption at the macro-scale.



Regarding the Consumption Footprint, this follows a full bottom-up method, based on **LCA** of representative **products** which are then up-scaled to overall consumption figures (e.g. EC-JRC, 2012; Frischknecht et al., 2013). This methodological choice is the result of a previous exercise testing three different methodological alternatives (Sala et al., 2019):

(a) fully bottom-up (previously named Consumer Footprint, fully based on representative products) (Sala & Castellani, 2019);

(b) partially bottom-up (trade based on representative products, domestic on statistics) (Beylot et al., 2019; Corrado et al., 2020);

(c) top-down (multi regional input - output based) approaches (Beylot et al., 2019).

Based on the comparison of the results obtained with the three approaches and the need to ensure the highest granularity on products supply chains, **the selected method for the Consumption Footprint is fully bottom-up** to quantify the impact of an average EU citizen and the average impact of an average citizen of each Member State.

Highlighted limitations of the top-down approach (environmentally-extended input-output) merged when conducting a comparative exercise between bottom-up and top-down approaches (Castellani et al., 2019a) included:

- limited coverage of elementary flows, which lead to:
  - a partial implementation of the EF method as not all impact categories could be implemented (i.e., the Ionizing radiation and Ozone depletion impact categories);
  - a partial implementation of those EF impact categories for which elementary flows (emissions into the environment and resource use) were available in the environmental extensions used in the top-down approach (i.e., not all the elementary flows characterized in the EF method are available in the environmental extensions including information on resource extraction and emissions to the environment).
- and limited granularity of elementary flows, which led to higher uncertainty in specific categories (e.g., data on extraction of 'aggregated minerals' instead of individual minerals regardless their different environmental impacts and associated characterization factor in the EF method).

In this study, the assessment framework for assessing the environmental impact of EU consumption and production considers a number of key principles:

- the modelling approach is **consumption-oriented**, namely assessing impact arising from final consumption;
- the framework applies **system thinking approach**, namely including different interlinked components of production and consumption to assess the impacts;
- and **life cycle thinking and assessment** are the basis for modelling and impact assessment.

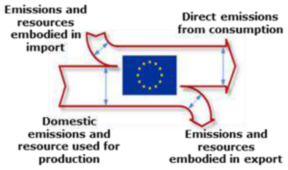
LCA has been performed following the **EF** impact assessment method recommendations (EC, 2021c) adopting the set of characterisation factors of the EF 3.1 version (Andreasi Bassi et al., 2023). Three steps have been implemented:

1. the calculation of the impacts, for the 16 impact categories of the EF method (the list of impact assessment models used for the calculations are detailed in Annex I);
2. their normalization against a reference system (namely against the environmental impacts at global scale) (as reported in Annex I) (Andreasi Bassi et al., 2023);
3. their weighting, in order to derive a single weighted score, applying the EF set of the weighting factors (Sala et al., 2018) (as reported in Annex I).

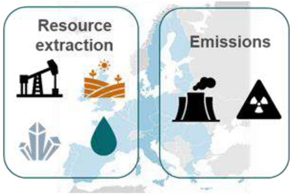
The Consumption Footprint | **The Domestic Footprint**

Goal and scope

The Consumption Footprint: LCA of products representative of the consumption of an average EU citizen



The Domestic Footprint: Environmental impacts taking place within the territory.

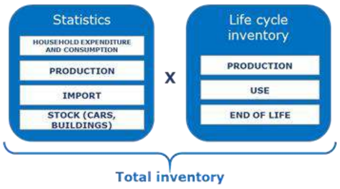


Life Cycle Inventory

For each stage of a product life cycle, data on resource used (e.g. metals, crude oil) and emissions into the environment (e.g. CO_2, benzene, organic chemicals) are collected in an inventory.
The two indicators are based on different modelling approaches to build the inventory.

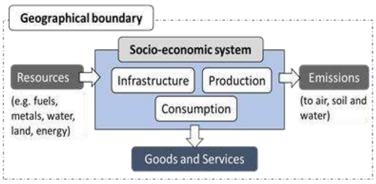
The Consumption Footprint:

- Emissions and resources used due to production and consumption during the entire life cycle of a product in selected areas of consumption (e.g. food, mobility, housing)
- Combining life cycle data (environmental profiles of products) with consumption statistics.



The Domestic Footprint:

- Emissions to the environment and resources extracted due to production and consumption activities taking place within the territory in one year in all sectors
- Combination of environmental statistics and modelling on environmental pressures



Life Cycle Impact Assessment: potential impact in 16 impact categories linked with SDGs

Each emission to the environment and resource used collected in the inventory is then characterized in terms of potential environmental impacts in the life cycle impact assessment phase, covering the 16 impact categories recommended for the Environmental Footprint.

SDG 3:
- **Human toxicity, cancer**
- **Human toxicity, non-cancer**
- **Particulate matter**
- **Photochemical ozone formation**
- **Ionising radiation**

SDG 6:
- **Impact due to water use**
- **Ecotoxicity**
- **Eutrophication**

SDG 13:
- **Climate chance**
- **Impact due to resource use**
- **Ozone depletion**

SDG 14:
- **Eutrophication marine and freshwater**
- **Ecotoxicity**

SDG 15:
- **Impact due to land use**
- **Eutrophication terrestrial**
- **Acidification**
- **Impact due to mineral and metal resource use**
- **Ozone depletion**

Normalization: comparing results with global references

The normalization helps understanding the relevance of the characterized environmental impacts compared to the environmental impacts generated at global level.

Weighting: aggregating results in a single score

Weighting allows the identification of the most relevant impact categories, life cycle stages, processes and substances to ensure that the focus is put on those aspects that matter the most. The final set developed for the Environmental Footprint (Sala et al., 2018) is considered in this study.

Planetary boundaries

Alternative to normalization and weighting, the results could be compared with environmental sustainability thresholds, as those developed in the context of the planetary boundaries assessment.

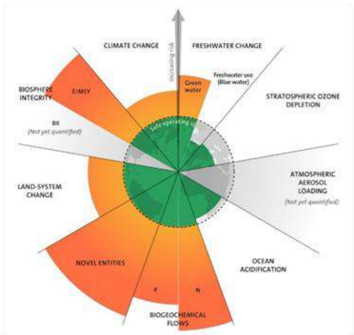


Figure 7. Main elements of the LCA-based framework to assess the environmental impacts of production and consumption at the macro-scale: Consumption Footprint and Domestic Footprint.

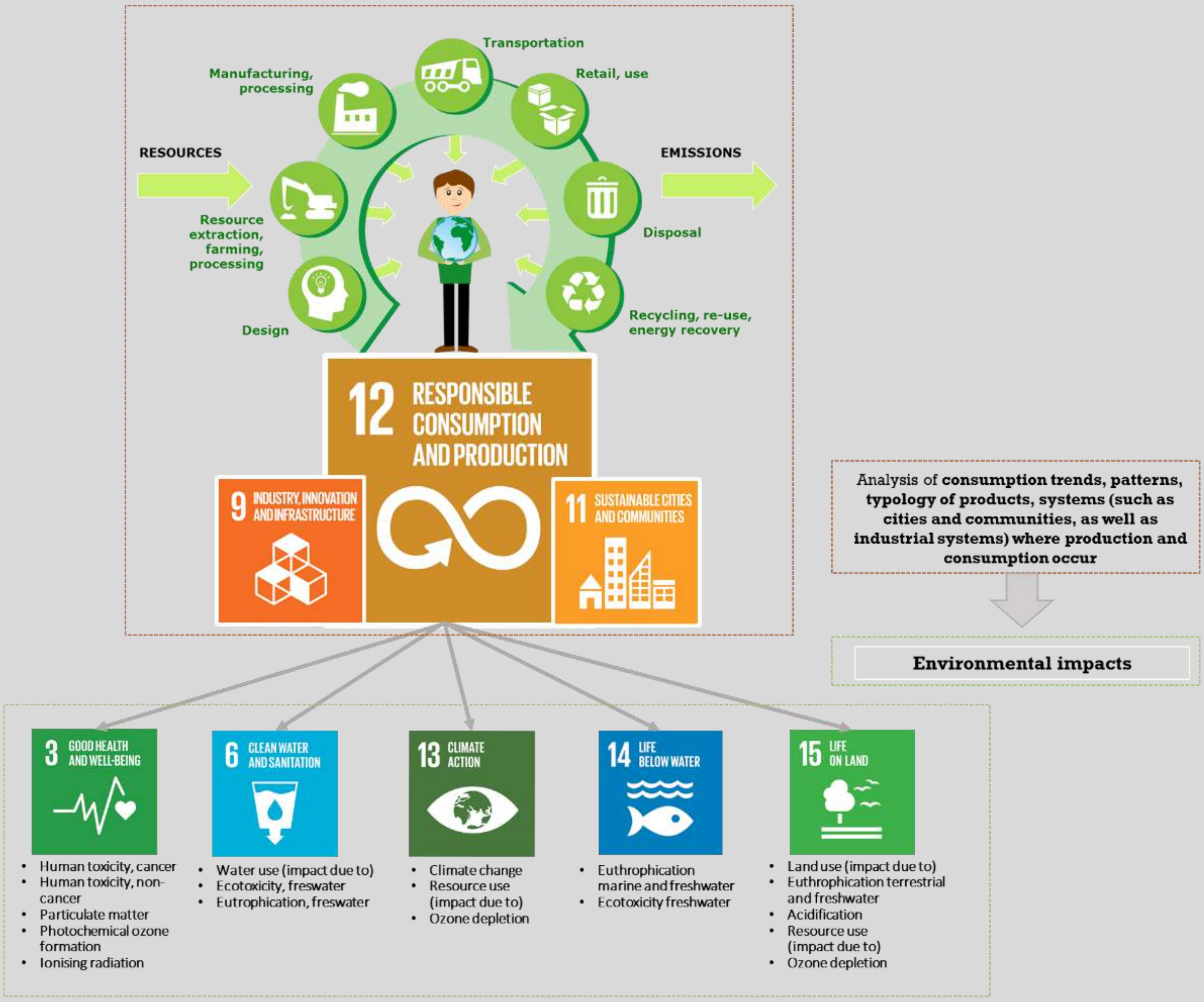
LCA-based framework and SDGs

The Domestic Footprint and Consumption Footprint are LCA-based indicators aimed at quantifying the environmental impacts of EU production and consumption considering respectively activities taking place within the territory and the overall consumption including trade. LCA is a comprehensive methodology meant to assess the environmental impacts of products, sectors, and projects. These two elements create several connections between Domestic Footprint, Consumption Footprint, and SDGs.

Fist of all, Domestic and Consumption Footprints provide an overall picture of the environmental impacts of consumption and production which can support the assessment and monitoring of decoupling of economic growth from environmental impacts, as foreseen by SDG 12 “Ensure responsible production and consumption patterns”. Moreover, the objectives of SDG 9 “Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation” and SDG 11 “Make cities and human settlements inclusive, safe, resilient and sustainable” are as well partially addressed by the Domestic and the Consumption Footprints.

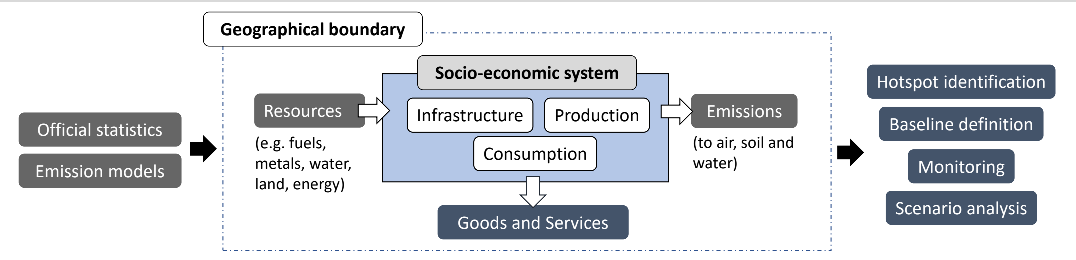
In addition, by addressing several types of environmental impacts, Domestic and Consumption Footprints have several connections with SDGs through the impact categories of the Environmental Footprint method focused on specific impacts, such as SDG3, SDG6, SDG13, SDG14, and SDG15. For example, the Environmental Footprint methods assess the impacts on water use, water eutrophication, and water ecotoxicity, which are closely linked with the objectives of SDG 6 “Ensure availability and sustainable management of water and sanitation for all” (Sanyé-Mengual & Sala, 2022).

Overview of the connections between Domestic Footprint, Consumption Footprint and SDGs



4 Domestic Footprint: which are the impacts generated within the EU territory?

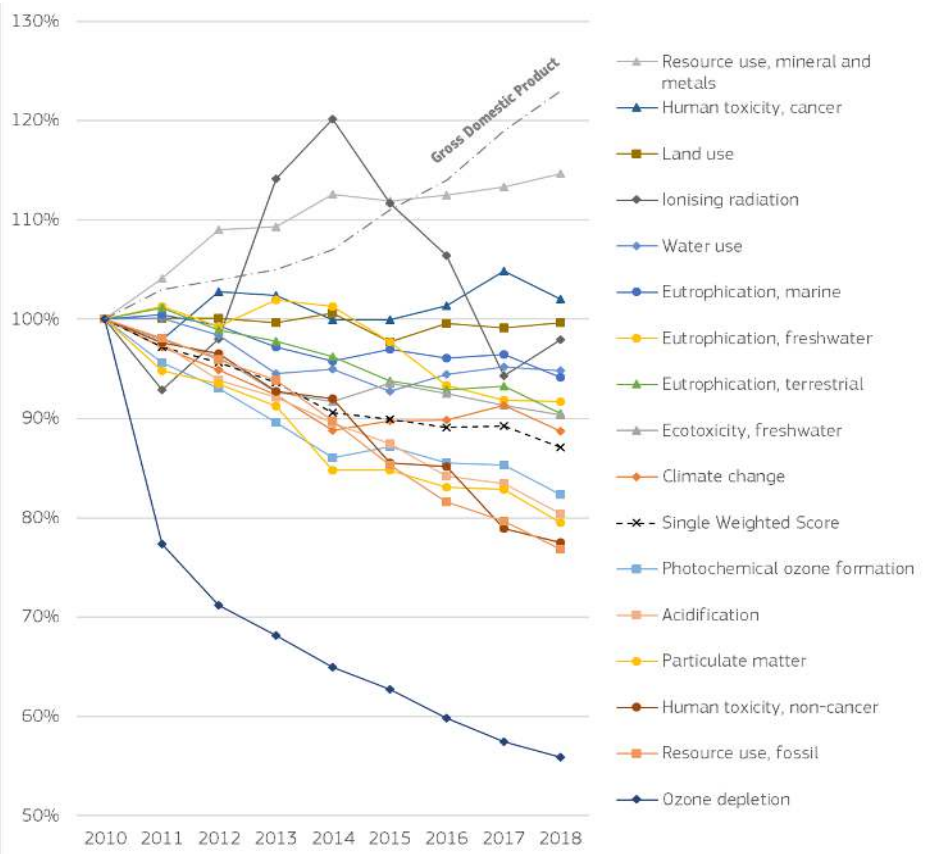
The **Domestic Footprint** aims at calculating the **impacts** due to resource extraction, and emissions in the **EU-27 territory** in order to monitor the efforts of EU Member States to decouple economic growth and environmental impacts (Sanye Mengual et al., 2022).



The Domestic Footprint builds upon an extensive data collection of detailed information on **resource extraction** and **emissions to the environment** (air, water, soil) in the EU and Member States territory. An overview of environmental pressures covered by impact category is provided in Annex 2.

Between 2010 and 2018, regarding most impacts to the environment and resources, the **EU Domestic Footprint decreased (-12%, as single score) while GDP increased (+23%)** (Figure 8), apart from the impact categories regarding resource use, mineral and metals and human toxicity, cancer. The impact decrease is more evident for ozone depletion (-43%), resource use-fossils, human toxicity-non cancer, particulate matter and acidification (all around -20%). This is mainly associated to the different EU territorial policies deployed previous and along this period which focus on reducing the domestic emissions or resource use. For example, Directive 2008/50/EC focuses on substances associated to acidification and particulate matter (e.g., SO_2, NO_2, NOx, $PM_{2.5}$, PM_{10}).

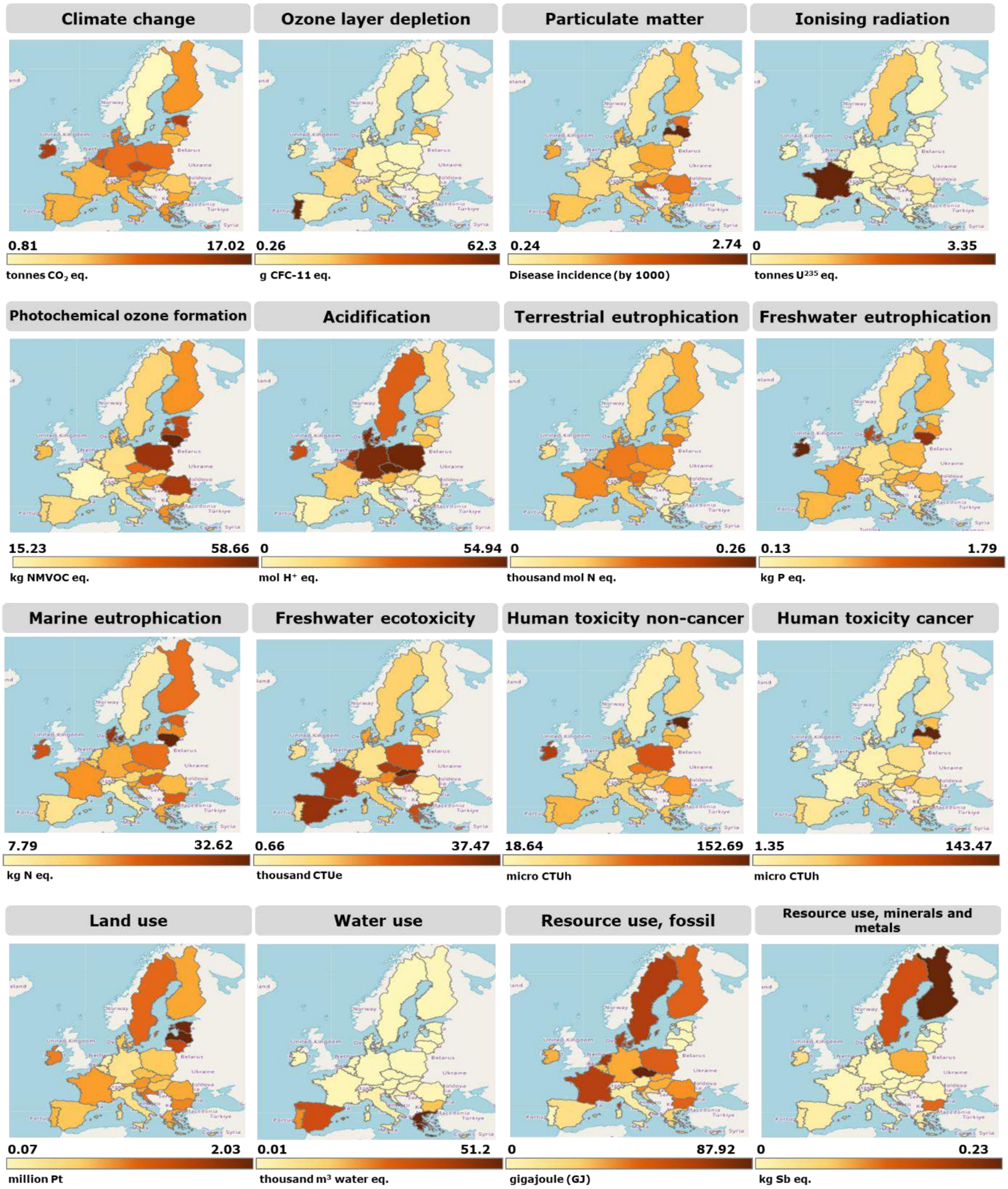
Figure 8. Domestic Footprint impact variation between 2010 and 2018 (single score and impact indicators).



Note: Results for 2010 are reported as 100%, and results for the other years are rescaled accordingly.

Member States contribute differently to the EU-27 Domestic Footprint. Figure 9 shows the Domestic Footprint per average citizen in each EU Member State, considering each impact to the environment and resources. Member States with a high GDP per citizen frequently present high impact per citizen (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 citizen, apart from the impact on water use and freshwater ecotoxicity (both linked with agricultural activities).

Figure 9. Domestic Footprint per citizen of the 27 EU Member States, considering 16 impacts on the environment and resources use (2018). Legend shows minimum and maximum values per country (Source: adapted from Sanyé Mengual et al., 2022)

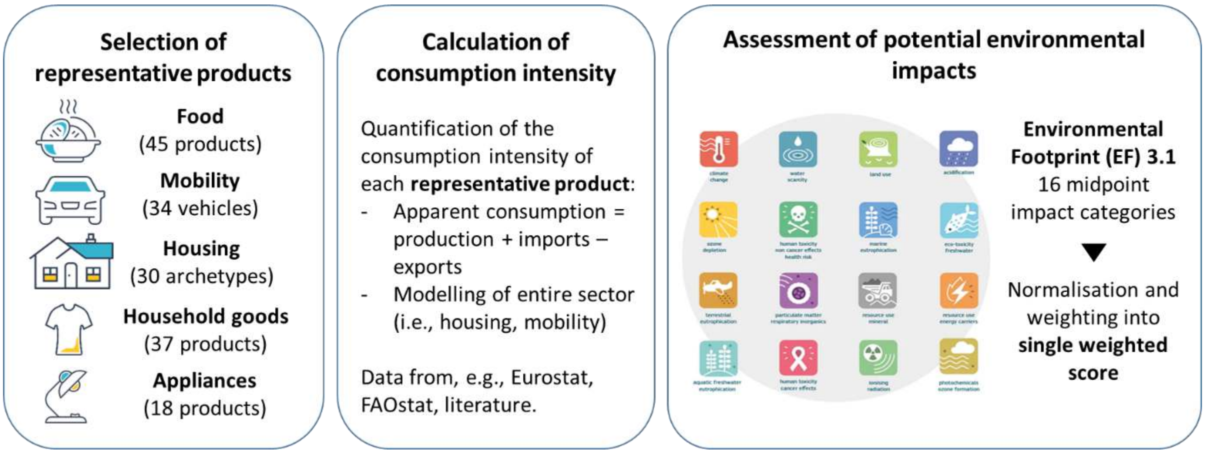


5 Consumption Footprint: which are the impacts of an average EU citizen?

The **Consumption Footprint** is a **set of 16 LCA-based indicators**, **aimed at quantifying the environmental impacts of an average EU citizen**, based on the consumption of goods in 5 areas (food, mobility, housing, household goods, and appliances) (Sala & Sanyé Mengual, 2022).

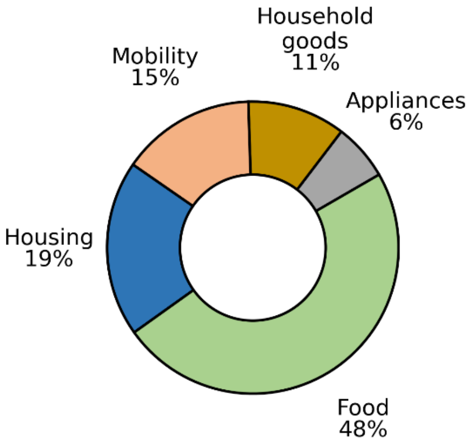
The Consumption Footprint encompasses the **5 areas of consumption**, i.e. Food, Housing, Mobility, Household Goods, and Appliances. The 5 areas have been selected as in literature they are considered the most relevant in terms of environmental impacts. For each of them a "Basket of representative Products" (BoP) has been defined and the environmental impacts of each BoPs has been calculated through LCA. Currently, the Consumption Footprint includes a total of **164 representative products** (complete list provided in Annex 2). The evaluation of the environmental impacts of the life cycle of representative products is conducted following the same modelling principles[13] (see Annex 3 for further details on methodological and data sources).

Figure 10. Overview of the Consumption Footprint structure



The Consumption Footprint of the average EU-27 citizen (2021) is dominated by food consumption (48% of the single weighted score), followed by the impacts due to housing and mobility. The consumption of household goods and appliances contribute to around 17% of the overall impact (Figure 11).

Figure 11. Consumption Footprint of EU-27 by area of consumption (2021)



[13] See specific publications by area of consumption: food (Castellani et al., 2017a; Crenna et al., 2019; Sinkko et al., 2019); mobility (Castellani et al., 2017b); housing (Baldassarri et al., 2017); appliances (Reale et al., 2019); and household goods (Castellani et al., 2019b). Life cycle inventory databases are employed to obtain data for background processes (e.g., electricity production, transportation, waste treatment): ecoinvent 3.6 (Wernet et al., 2016) and Agrifootprint (Blonk Consultants, 2019).

5.1 Which are the main areas of consumption driving the impacts in Consumption Footprint?

Daily activities, such as eating food and driving a car, appear to be the most contributing to the Consumption Footprint. Indeed, **Food, Housing, and Mobility** are, in the reported order, the **most impacting areas of consumption**, as well as the one characterised by the less durable products and higher use intensity.

The contribution of **Food is predominant** on impacts notably influenced by agricultural production, e.g. acidification, eutrophication, ecotoxicity, and land use, or associated to refrigeration (e.g., ozone depletion). **Housing and Mobility** show a more relevant contribution to impacts associated to energy production (e.g., ionising radiation, resource use - fossil). **Appliances** are the main hotspot for minerals and metals resources use because of the utilisation of rare raw materials, such as gold, in their inner components. **Household goods** is very relevant for land use (e.g., furniture) and human toxicity (cancer) due to the use of specific chemicals in the manufacturing of, e.g., footwear and furniture. Figure 12 reports the impact categories indicating the robustness level (I-III) of the underpinning assessment model: the lower the robustness, the higher the uncertainties of the results, and, therefore, the caution that should be adopted in their interpretation.

Figure 12. Contribution of the areas of consumption to the Consumption Footprint (EU-27, 2021)

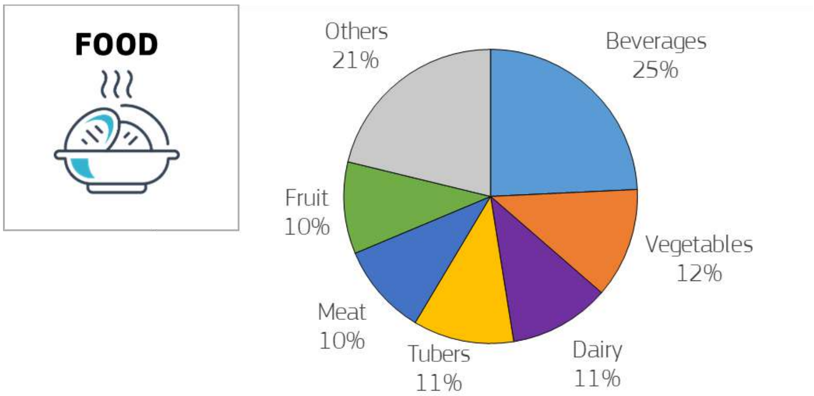
The estimation of the robustness is taken from EC (2021c). The lower the number, the higher the robustness of the model. This information is important for the interpretation of the results as specified in Section 2

5.2 Which are the main products driving the Consumption Footprint within each area of consumption?

5.2.1 Food

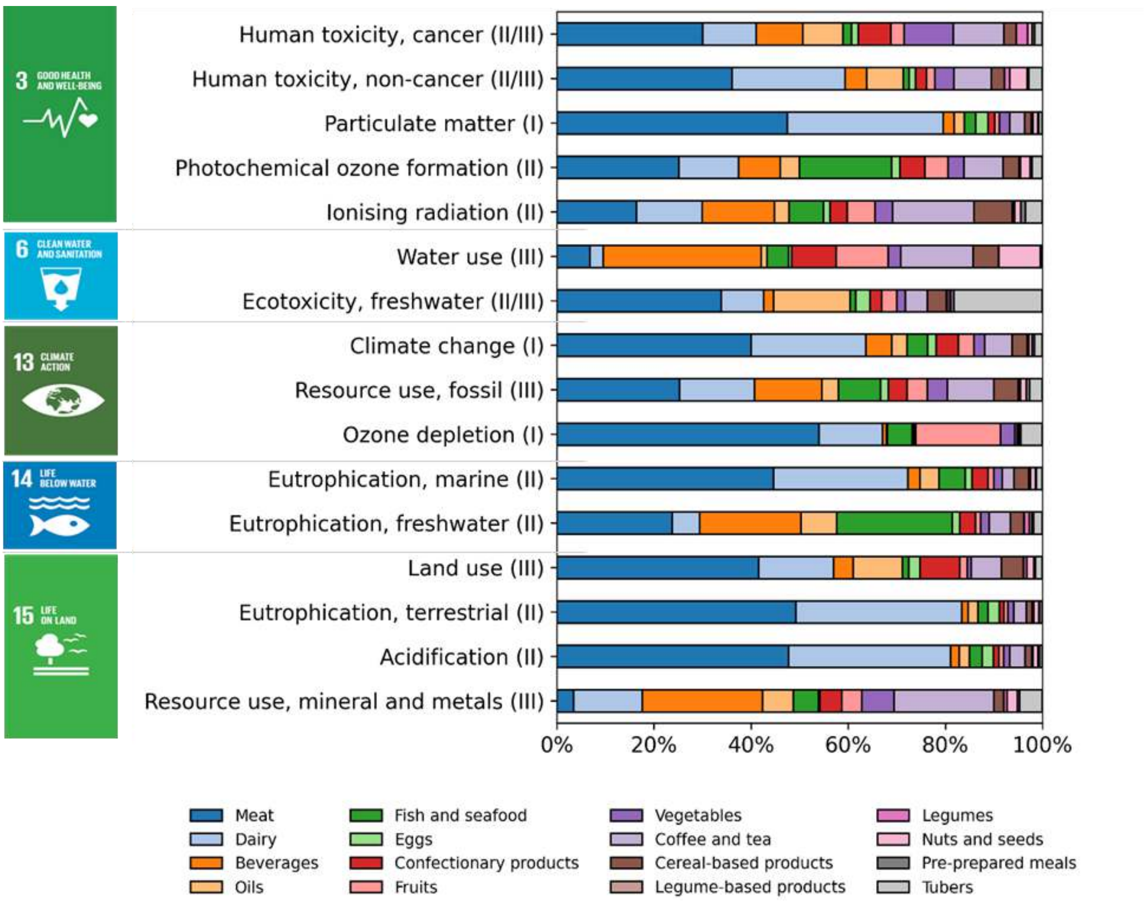
Forty-five representative food products have been evaluated for food consumption, with product groups with higher consumption intensity in terms of mass being beverages, meat, dairy, vegetables and tubers (Figure 13).

Figure 13. Share of the mass of food products consumed by an average EU citizen (2021)



When considering the consumption patterns of the average EU citizen, **animal-based products**, i.e. meat, dairy and eggs, **contribute for more than 50% to most of the environmental impacts** (Figure 14), while representing only about a quarter of the total amount of food consumed (Figure 13). The underpinning motivation is essentially the lower efficiency of the animal production systems, which requires more inputs to deliver the same amount of product when compared to vegetable-based ones.

Figure 14. Contribution of product groups to the environmental impacts of overall Food consumption in EU-27 (2021)

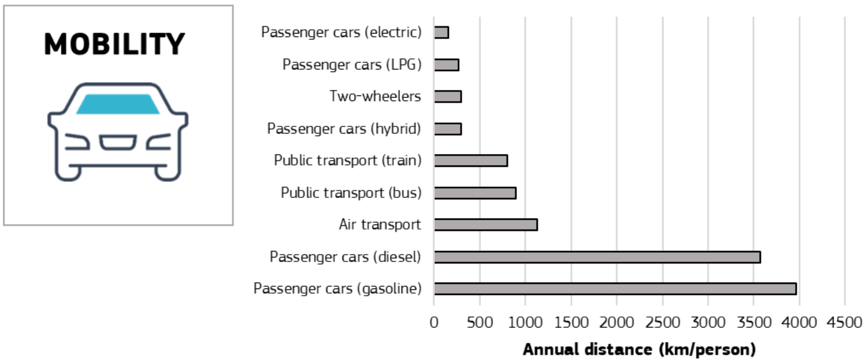


Model robustness of the impact assessment models used to assess each indicator is taken from EC (2021c).

5.2.2 Mobility

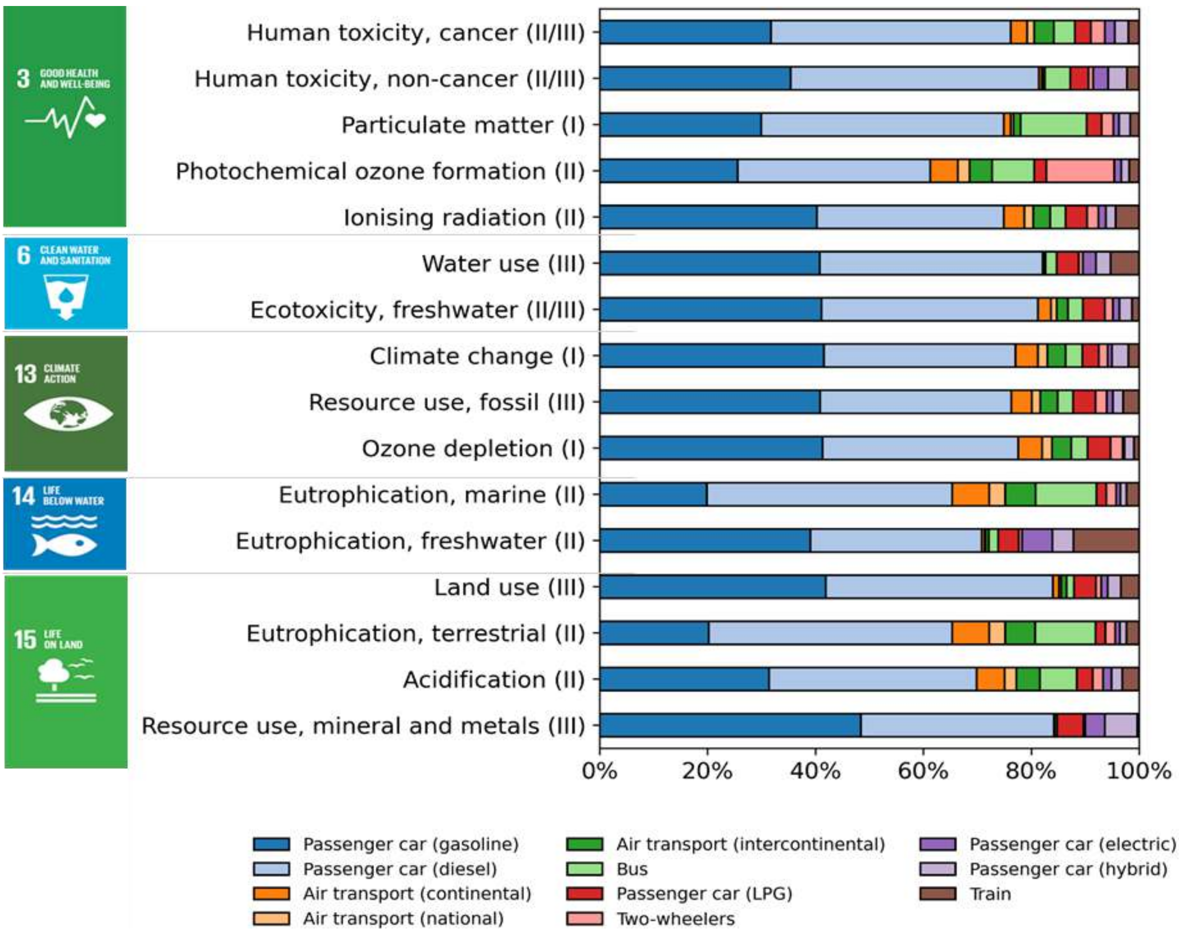
Based on available statistics, the area of consumption mobility has been modelled considering the kilometres travelled by an average EU citizen by means of transport (Figure 15). The LCA has been then applied to assess the environmental impacts associated to mobility.

Figure 15. Kilometres travelled yearly by an average EU citizen (2021)



Passenger cars, followed by air vehicles, are the most used means of transport in EU and are **responsible for the majority of the environmental impacts of Mobility** (Figure 15). When looking at the impacts of the analysed means of transport expressed per person and per km travelled, cars have on average the highest impacts, whereas trains have the best environmental performance.

Figure 16. Contribution of means of transport to the environmental impact of overall Mobility consumption in EU-27 (2021)



Model robustness of the impact assessment model used to assess each indicator is taken from EC (2021c).

5.2.3 Housing

The housing stock in Europe has been modelled with LCA by means of **30 building archetypes**, representative of building in three climatic zones, two building types and different year of construction (Figure 17).

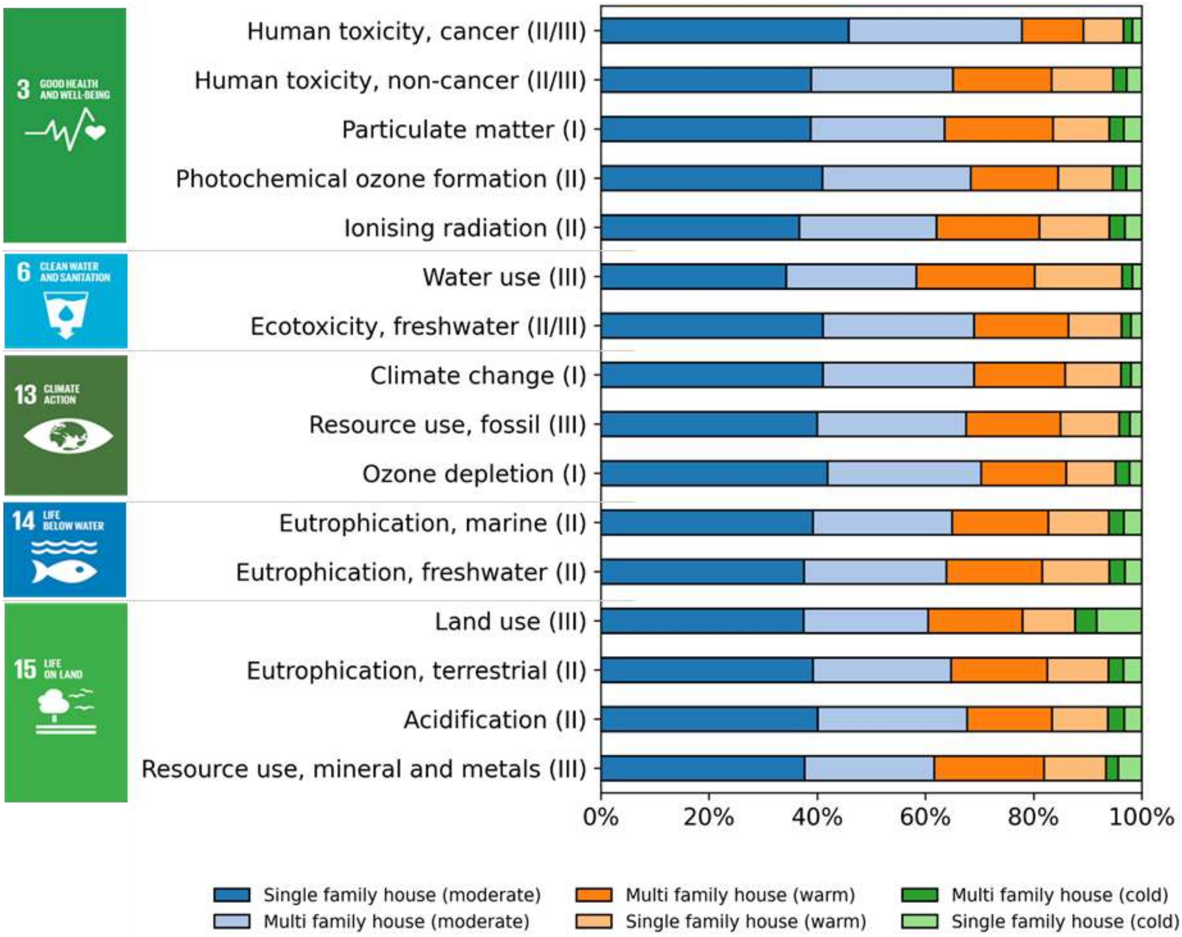
Figure 17. Share of the number of different types of dwellings in Europe by construction age, building type and climate area (2021)

HOUSING	<1945		1945-1969		1970-1989		1990-2010		>2010	
	MFH	SFH	MFH	SFH	MFH	SFH	MFH	SFH	MFH	SFH
Cold	0.6%	0.5%	0.8%	0.7%	0.8%	0.7%	0.4%	0.3%	0.1%	0.1%
Moderate	6.4%	7.6%	7.4%	8.4%	7.7%	9.2%	4.7%	6.0%	2.4%	3.0%
Warm	3.7%	1.9%	5.6%	2.7%	6.1%	3.3%	3.7%	2.2%	2.0%	1.0%

Dwellings are classified according to the type (single-family – SFH - or multi-family - MFH), the climate area (cold, moderate and warm), and the year of construction (<1945, 1946-1969, 1970-1989, 1990-2010, >2010)

The share of the impacts of each different dwellings to the overall impact of Housing in Europe depends on two factors: the impact per dwelling, and the number of dwellings in the EU. The **higher contribution** is **from the buildings in moderate climates**, which represent about 62% of the European building stock (Figure 17) and contribute to about 60-70% of the overall impacts (Figure 18). When analysing the impact per single dwelling, the single family houses in cold climate are the ones with the highest impact per dwelling per year for all the analysed impacts, mainly due to higher energy demand, except for climate change and resource depletion. The main reason for this countertendency is the higher embedded impact of concrete and bricks used in the moderate climate compared to the timber frame used in cold climate for these two categories.

Figure 18. Contribution of different dwellings to the environmental impacts of overall Housing consumption in EU-27 (2021)

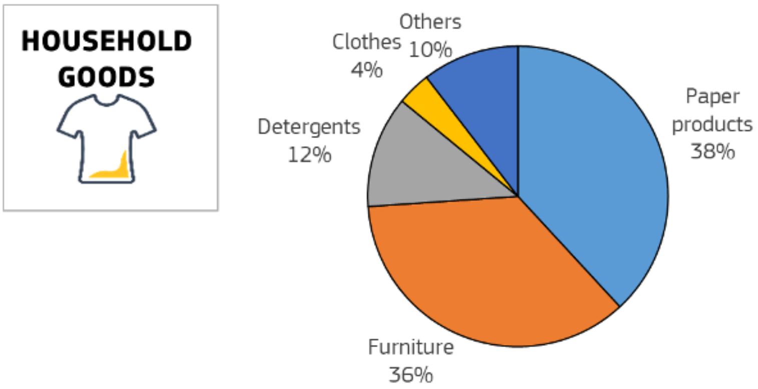


Model robustness of the impact assessment models used to assess each indicator is taken from EC (2021c).

5.2.4 Household goods

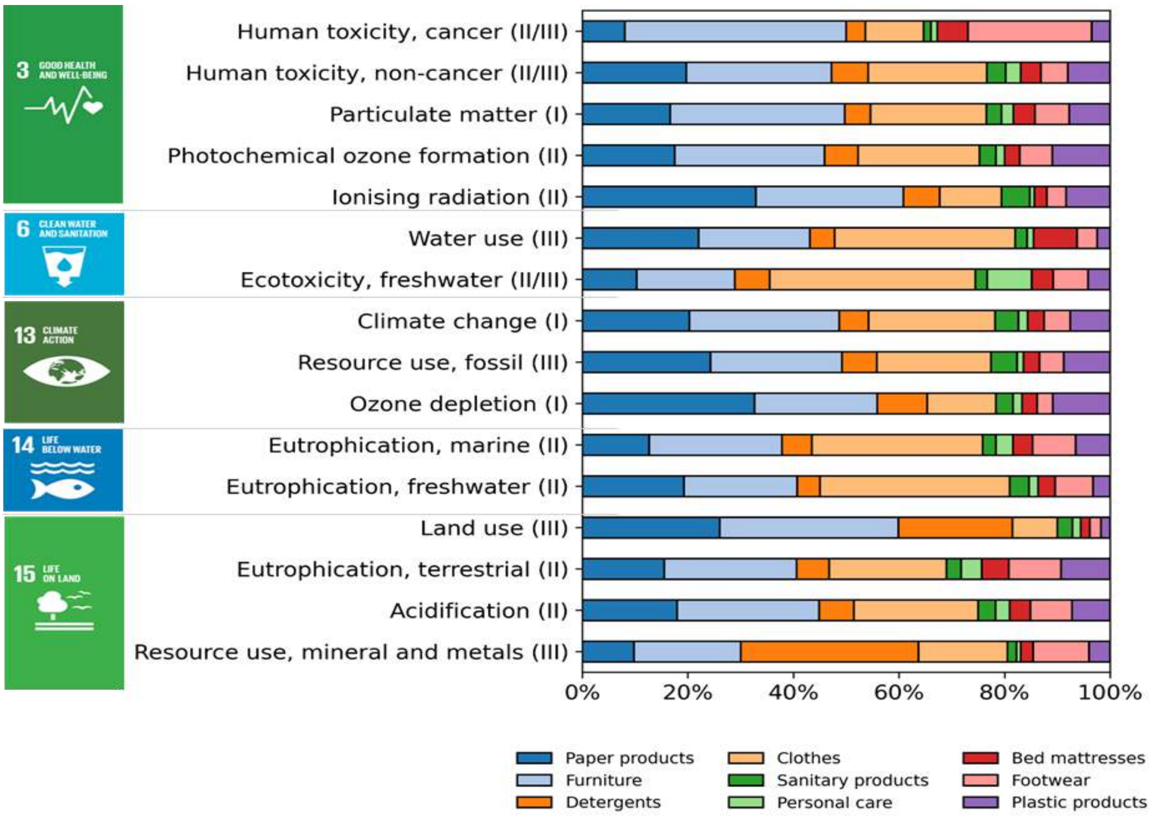
Household are consuming a huge variety of products and a selection of representative products has been done based on statistics, capturing products which large shares in mass (Figure 19).

Figure 19. Share of the mass of household goods consumed by an average EU citizen (2021)



Paper products, detergents, furniture, and clothes are the main contributors to the impacts of household goods (Figure 20), due to the relevant amount of products consumed, mainly for paper products and clothes (Figure 19), and high impacts per unit of product, especially for furniture and detergents. Hence, the reduction of the impacts of this area of consumption should encompass a decrease in the use of most diffused products, and improvements in the production processes. The main environmental hotspots of the production phase are the use of electricity to transform raw fibres in textile, happening mainly outside EU. This is particularly relevant for climate change, particulate matter, acidification, and water use. The tanning of leather used for shoes, responsible for the emissions of chromium into water, causes a large share of the impact on human toxicity cancer. As well, the use of coal to produce flame retardants used in sofas contributes significantly to particulate matter emissions.

Figure 20. Contribution of different products to the environmental impacts of overall Household Goods consumption in EU-27 (2021)

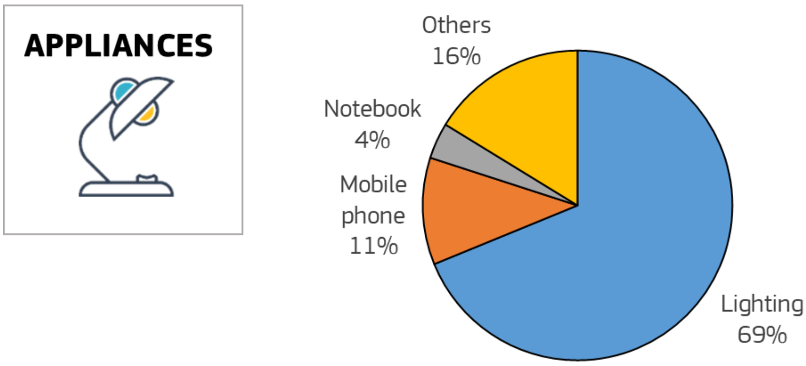


Model robustness of the impact assessment model used to assess each indicator is taken from EC (2021c).

5.2.5 Appliances

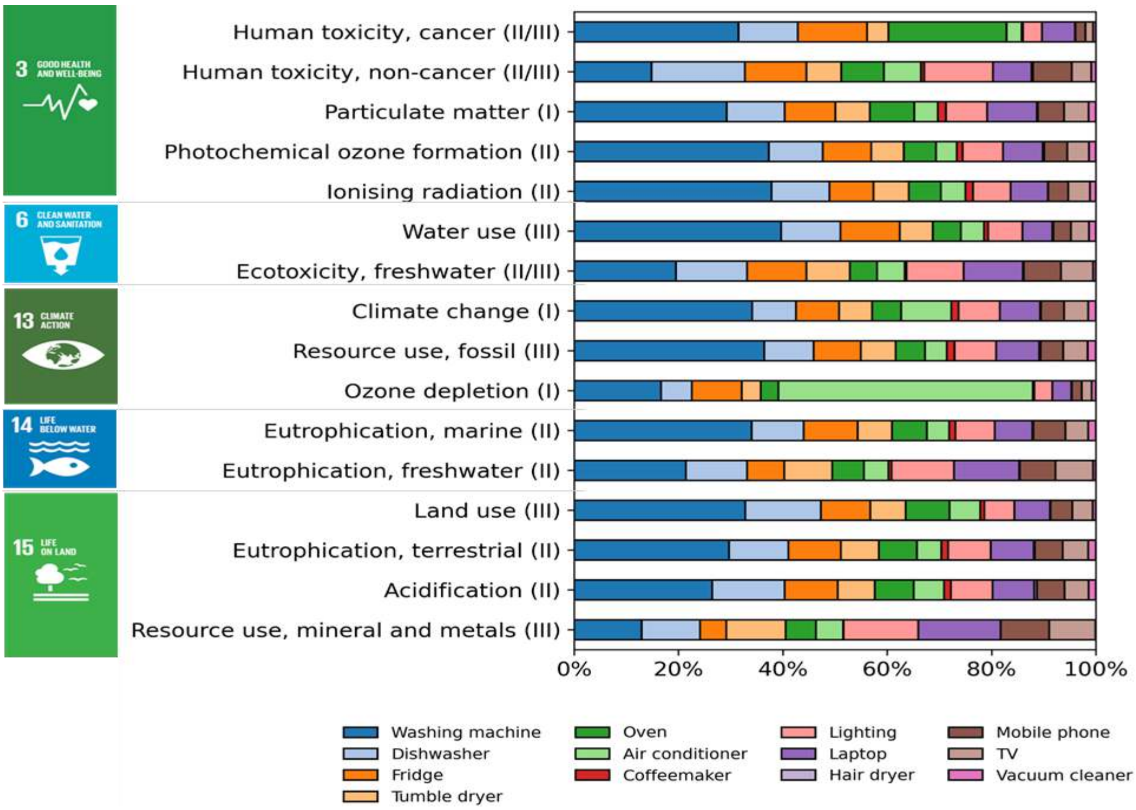
Appliances are increasingly used in EU household, serving multiple purposes, from lighting to washing, from storing to cooking. A selection of representative products has been performed considering the most relevant appliances in terms of energy consumption and market share in EU, and the appliances prioritised in the Ecodesign directive (European Parliament and Council, 2009).

Figure 21. Share of the pieces of household appliances owned by an average EU citizen (2021)



The **larger contribution** to the overall impacts generated by the EU purchase and use of appliances comes from **washing machines and refrigerators** (Figure 22), mainly for the large amount owned (Figure 21), and from **dishwater, lighting, and TV screen**, due to impact of components and materials. Main environmental hotspots are associated to electricity consumption during the use phase, for example for impacts on climate change, particulate matter, and ionising radiation. Specific hotspots are related to refrigerants leakages from air conditioning influencing ozone depletion, detergents impacts on marine eutrophication, and the use of gold in the printed circuited boards of TV screens, as main hotspot for resource use, mineral and metals.

Figure 22. Contribution of different products to the environmental impacts of Appliances consumption in EU-27 (2021).



Model robustness of the impact assessment model used to assess each indicator is taken from EC (2021c).

5.3 To which extent green transitions (incuding technological nd behavioural changes) may reduce the Consumption Footprint?

In Section 5.2 two recurrent drivers are identified for the investigated areas of consumption, i.e. the specific impact per unit of mass of products, and the amount of products purchased or consumed. Hence, the strategy to reduce the impacts of consumption needs to take into account peculiar features and criticalities of the products in each area of consumption. In the technical report by Sala et al. (2019), more than 50 scenarios on the different areas of consumption have been tested. Here the results of two scenarios are presented as example. On one hand, a scenario on focusing on the effects of a change in the average diet, considering that 25% and 50% of meat and dairy products are replaced with other product groups (e.g., cereals, nuts and seeds, vegetables) (Figure 23). On the other hand, a scenario on appliances evaluates the combination of efficiency of devices with benefits of circularity, technological benefits and changes in consumption (Figure 24).

The reduction in the consumption of meat and dairy, instead, has a positive effect on all the analysed impacts – apart from a limited trade-off due to water use in specific crops (e.g., nuts), considering that meat is being replaced by other food groups and decrease in impact is non-linear. In general, assessing different types of impact allows to have a broad picture of the effects of scenarios and to identify possible trade-offs. The green transition scenario shows **possible trade-offs**, e.g. for the use of resources, mineral and metals, for which the production of appliances is a hotspot (Section 5.1).

Figure 23. Effect on the impacts of EU food consumption of scenarios of substituting animal products (EU-27, 2021) (25% or 50%).

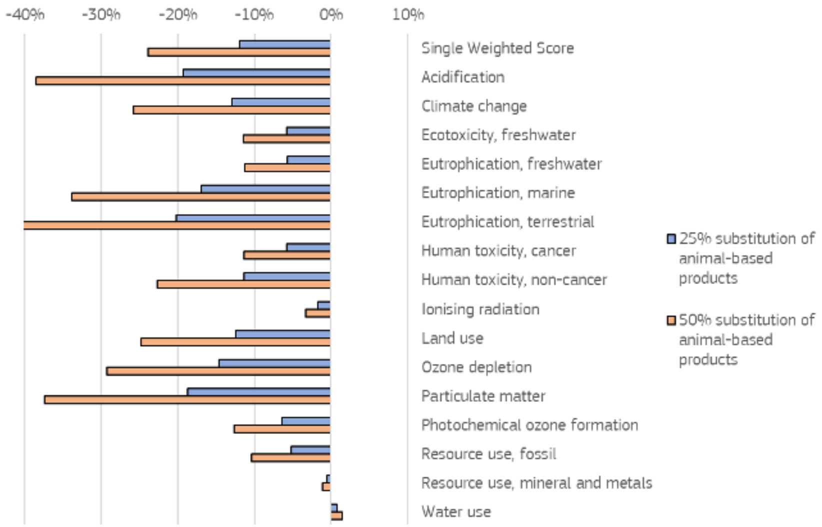
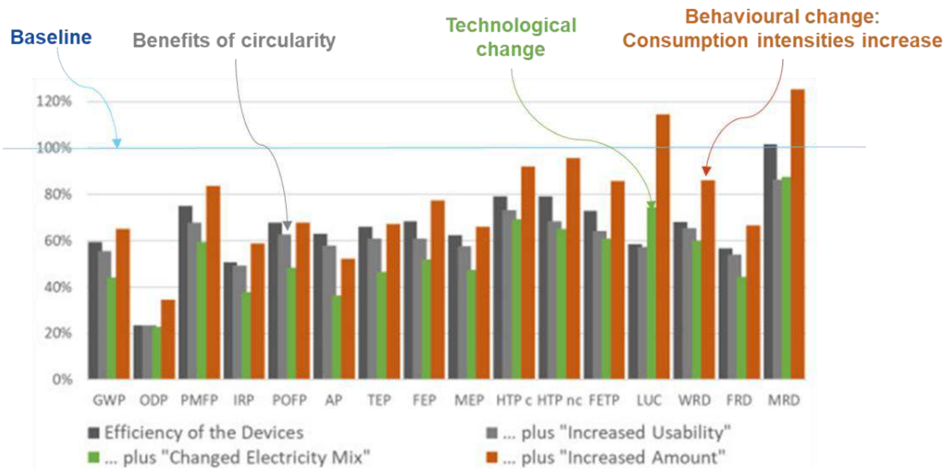


Figure 24. Effect on the impacts of EU appliances consumption of scenarios of efficiency, circularity, technology change and consumer behaviour (Source: adapted from Hischier et al., 2020).



Impact acronyms are detailed in Annex 1.

5.4 How the Consumption Footprint may assess different consumption patterns and lifestyles?

The Consumption Footprint is referred to an average EU or EU country citizen. However, individual lifestyles may diverge importantly from the average, resulting in different types of impacts and of different intensity**. The Consumption Footprint approach can be applied to consumption patterns and lifestyles different from the average one**, to highlight environmental hotspots and possible areas for improvement. This is the basis of the developed **Consumer Footprint Calculator** (further details in Section 8.1), with a consumer perspective consumption intensity is based on user data (and complemented when needed with average data) with the goal of assessing the individual lifestyle (Figure 25). This section presents a theoretical example of such analysis (Figure 26 and Figure 27).

Figure 25. Terminology, consumption intensity data, assessment level and associated tools of approaches derived from the Consumption Footprint methodology (Source: Sala & Sanyé Mengual, 2022).

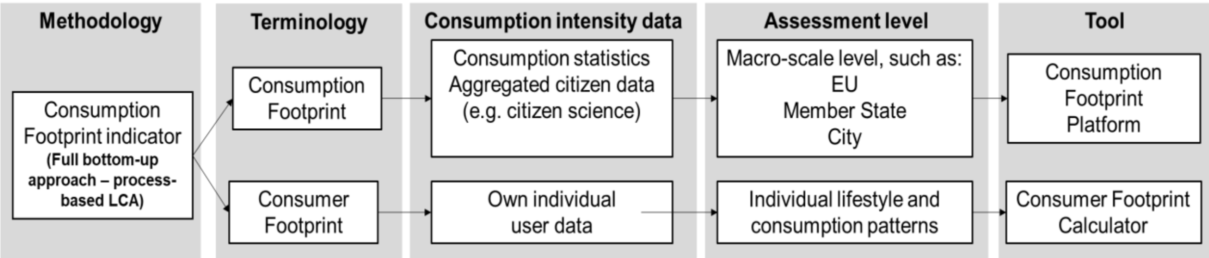
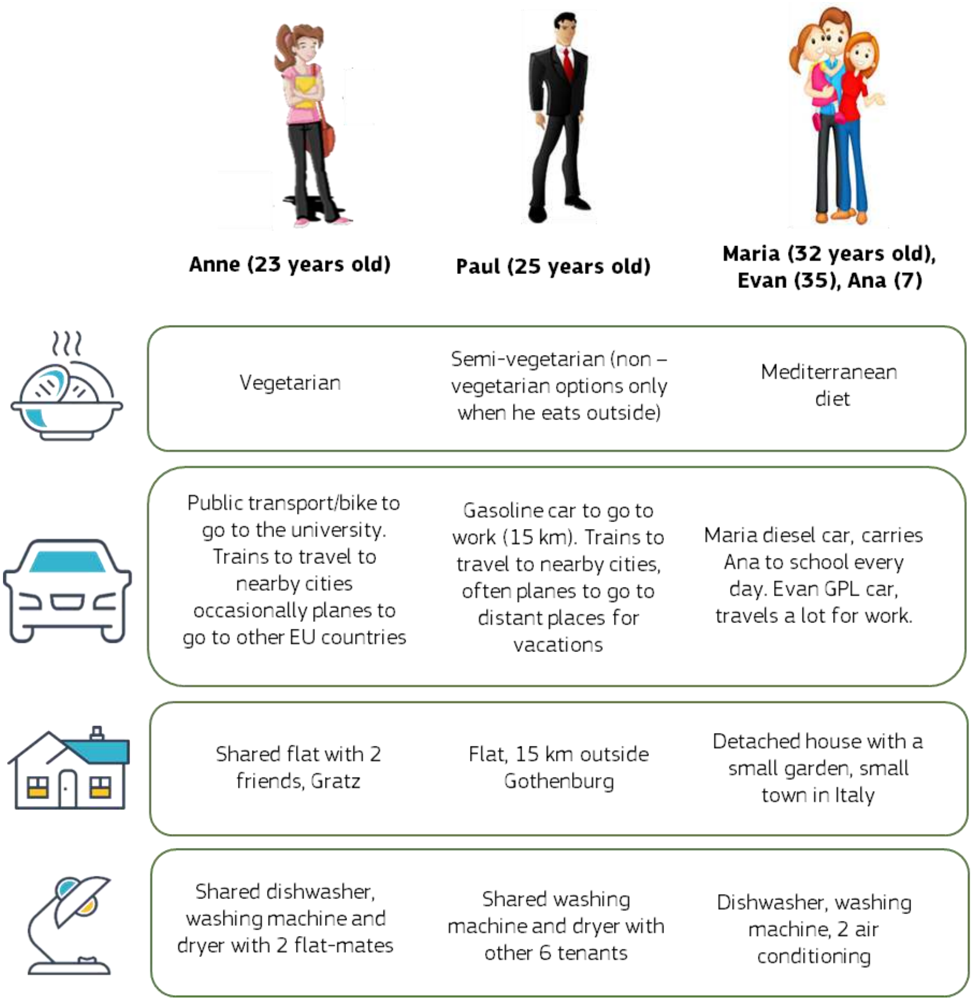


Figure 26. Description of three exemplary consumers' profiles

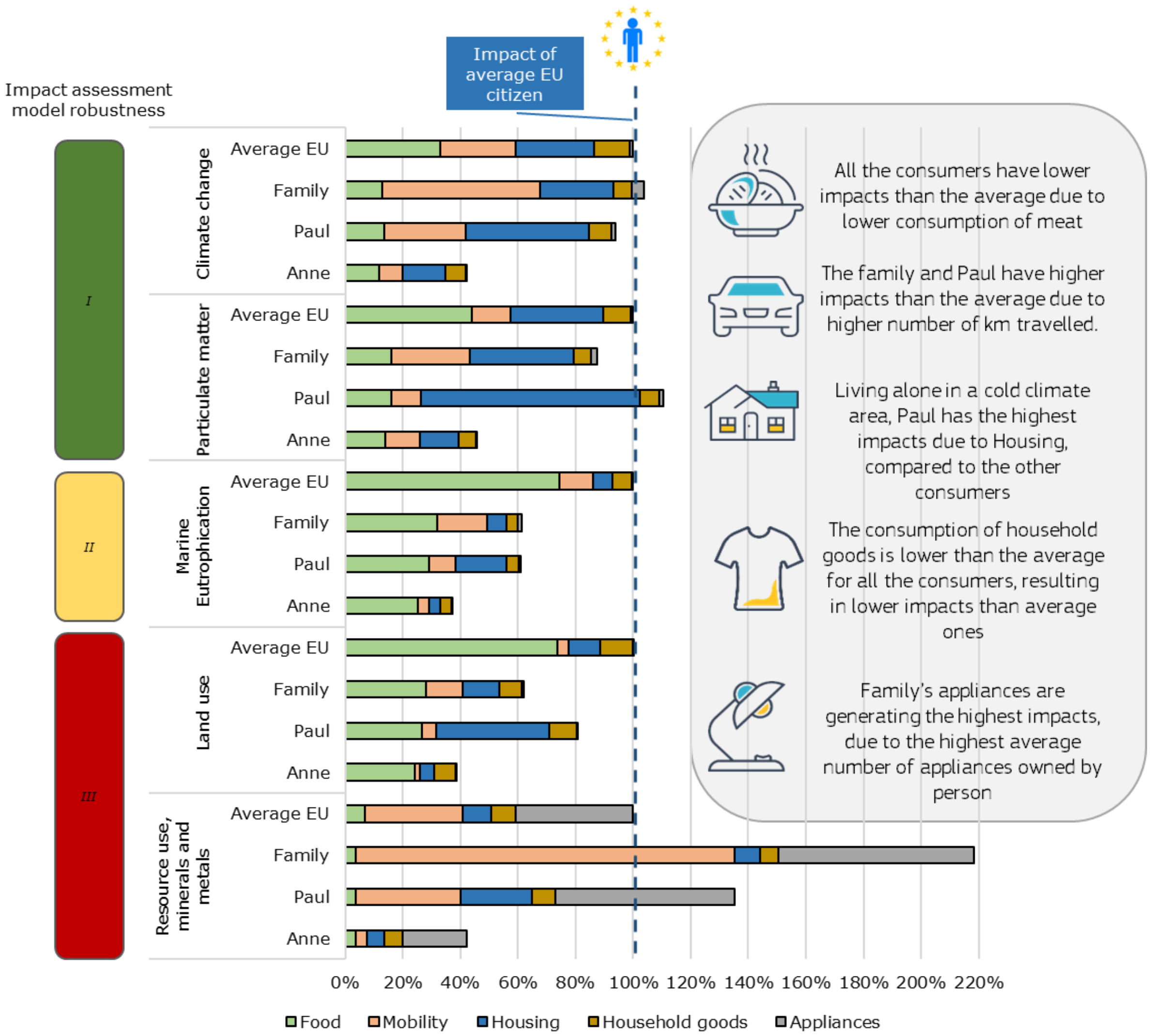


Significant differences are observed between the impacts of the analysed consumers' profiles and the one of an average EU citizen (Consumption Footprint) (Figure 27). Lower impacts than the average are observed for Anne in all the areas of consumption. Indeed, she adopts a series of environmentally friendly behaviours in the different areas of consumption, such as using public transportation, avoiding the consumption of meat, sharing the apartment and the appliances.

The impacts of the lifestyles of other consumers, instead, can be lower or higher than the average situation according to the area of consumption considered. This highlights that positive effects due to the adoption of low-impact behaviours in a certain area of consumption may be to different extents offset by the impacts associated to other consumption areas. This is the case, for example, of the impact on climate change generated by Paul. His choice of being semi-vegetarian resulted in a 60% reduction of the impact of Food compared to the average. However, the fact that he is living alone and has to drive every weekday at least 30 km by car increases his impact in the areas of consumption Housing and Mobility, partially offsetting the positive effect of being semi-vegetarian. Indeed, Paul's overall impact of climate change is only 5% lower than the impact of an average EU citizen.

The analysis of consumers' profiles points out the **need of adopting a comprehensive perspective, including all the areas of consumption, when assessing the impacts of consumption patterns**.

Figure 27. Impacts of consumers' profiles compared with the average EU citizen (set as 100%)



Model robustness of the impact assessment model used to assess each indicator is taken from EC (2021c). Results for the family are expressed per person. The graph only includes few impacts reported as example, but the full set of results are reported in Sala et al. (2019).

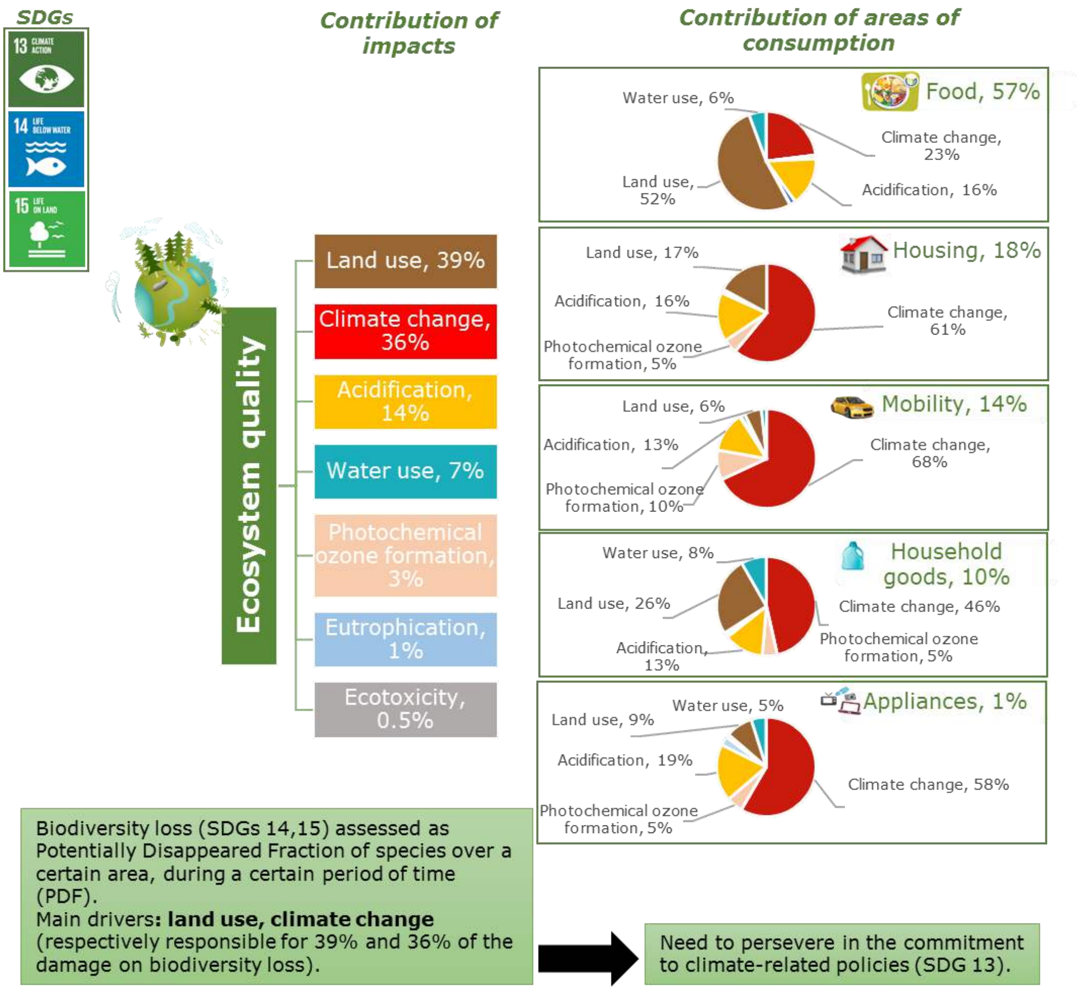
5.5 Which is the impact of Consumption Footprint on biodiversity and human health?

The 16 analysed LCA-based impact indicators assess changes in the aspect of the natural environment caused by environmental pressures. Estimating the impacts at the endpoint means modelling more broadly the effects of the environmental pressures, assessing the **damage effects** that may be generated on areas of protection, such as **ecosystem quality and human health**.

By focusing the evaluation of the damage provoked by environmental pressures on a few areas of protection, the endpoint modelling may facilitate the interpretation of the Consumption Footprint results in light of the SDGs objectives, as well as reveal potential connections between them. Indeed, the quality of aquatic and terrestrial ecosystems and the conservation of biodiversity are within the focus of SDGs 14 "Life below water" and 15 "Life on land", whereas human health is at the core of SDG 3 "Good health and well-being".

Land use and climate change are responsible for the largest share of the damage on ecosystem quality in terms of biodiversity loss caused by consumption in EU. These results are coherent with the findings already reported in the Millennium Ecosystem Assessment (MEA, 2005; WWF 2017), which identify climate change and land use among the main drivers of biodiversity loss. Food is the area of consumption that mostly affects ecosystem quality, especially due to the environmental impacts caused by primary production.

Figure 28. Damage on ecosystem quality generated by EU consumption (2010)



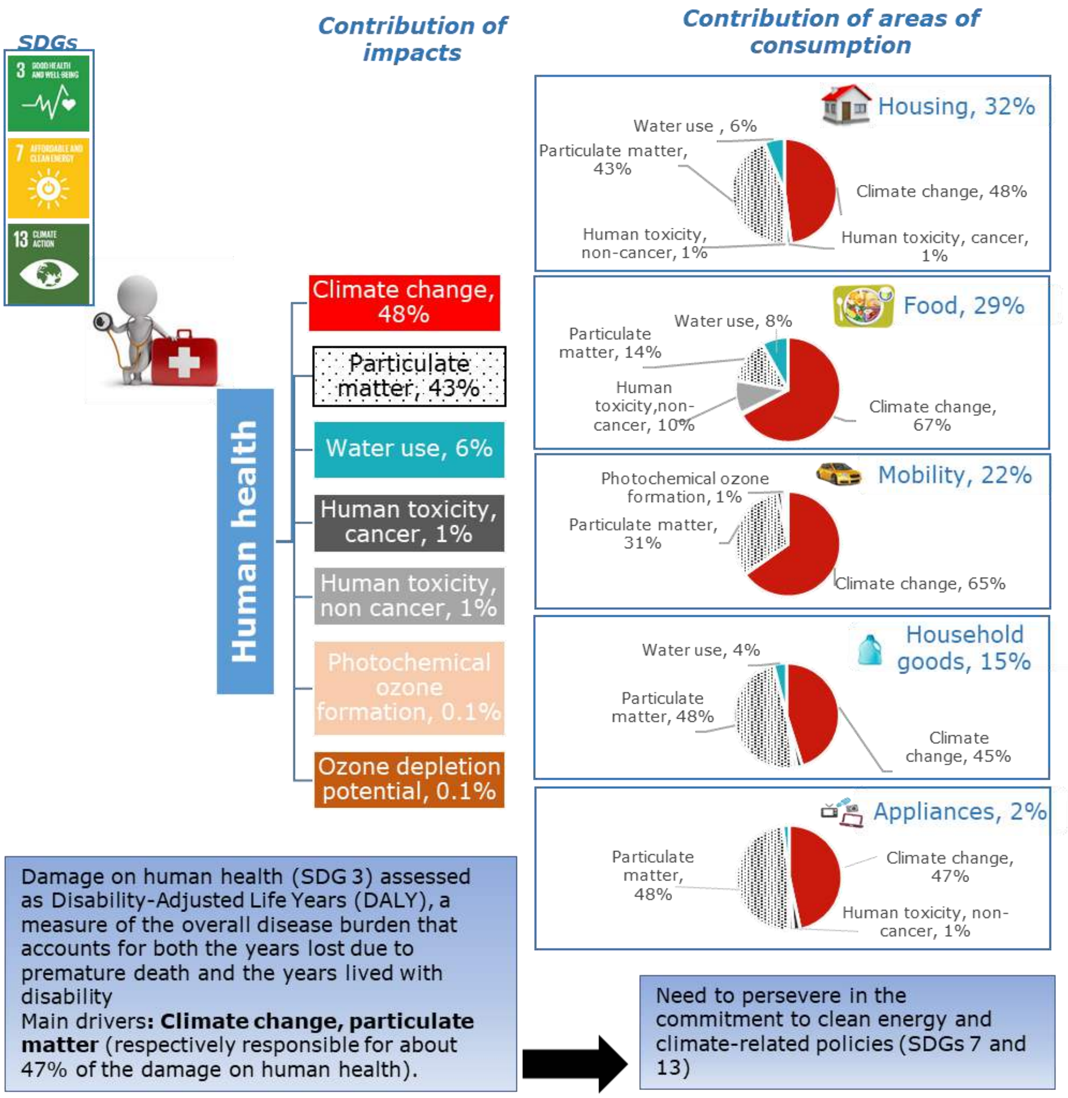
Endpoint assessment model: ReCiPe 2016 (Huijbregts et al., 2017), hierarchist cultural perspective.

Particulate matter and climate change are the main drivers of the effects on human health due to consumption in EU. This result is in line with statistics on mortality by WHO, which reports illnesses associated with respiratory apparatus as third cause of mortality in Europe in 2010 (WHO, 2022). Particulate matter prevails on climate change in damaging human health in those areas of consumption where electricity use is at high levels, i.e. Housing and Household goods.

As general conclusion, it is possible to say that climate change is one of the main contributors to the endpoint damage on both ecosystem quality and human health. The damage on ecosystem quality is driven by land use associated to food production, whereas electricity production, being responsible of a large share of particulate matter emissions, is the main driver for the impact on human health.

These considerations highlight the existing **interconnections** between **SDG 13** "climate action", **SDG 7** "Affordable and clean energy", and respectively **SDGs 14 and 15, and SDG 3.**

Figure 29. Damage on human health generated by EU consumption (2010)



Endpoint assessment model: ReCiPe 2016 (Huijbregts et al., 2017), hierarchist cultural perspective

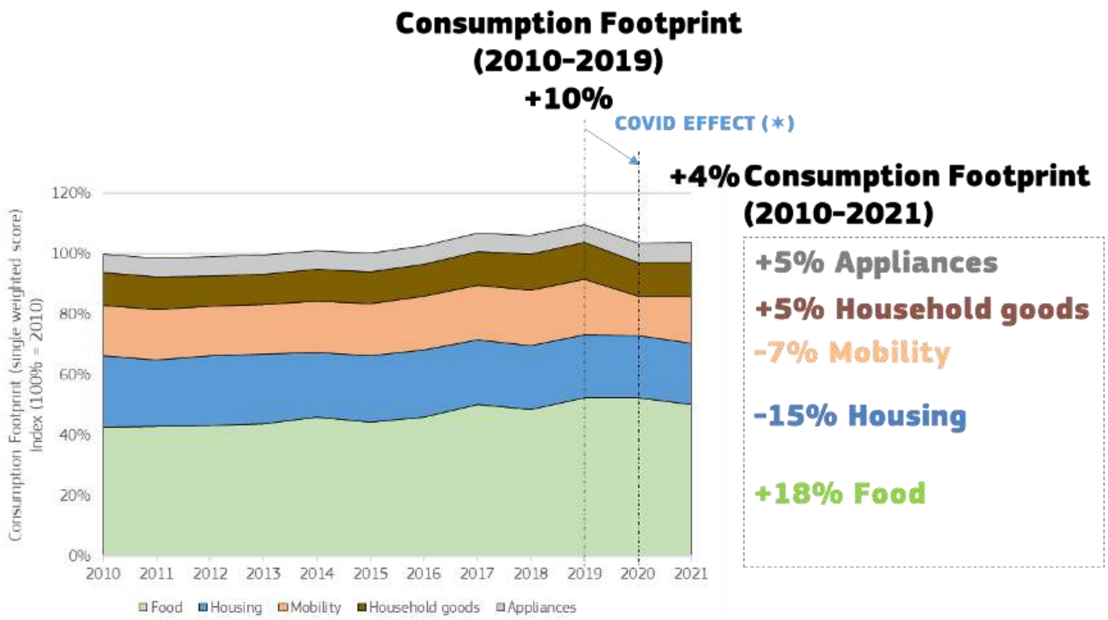
6 What is the temporal evolution and geographical distribution of the EU Consumption Footprint?

6.1 How is the Consumption Footprint evolving over time?

In the timeframe 2010-2021, the **Consumption Footprint has increased by 4%** (Figure 30). However, one should consider the effect of the COVID pandemic which has altered the usual consumption patterns and behaviours. **Until 2019 the Consumption Footprint showed a continuous increasing trend** leading to a 10% increase. Such trend suggests that the environmental impacts due to EU consumption would have kept increasing in a "normal" context. In 2021, consumption trends are slowly increasing and recovering from the pandemic. The most affected area of consumption by the pandemic has been mobility which was following an increasing trend up to 2019 (+11%) and drop by 7% in 2021 (Figure 32).

Between 2010 and 2021, the increase of the Consumption Footprint **can be only partially explained by population growth** (which was limited to around 1.5%) and therefore it is mainly **a consequence of the increasing consumption intensity** (i.e., citizens consuming more) **of certain product groups**. The highest increase along time is shown in Food consumption (Figure 31), which dominates the overall Consumption Footprint, and compensates the trends in other areas of consumption. Housing show a decreasing trend during the analysed period (2010-2021). The decrease in housing impacts is mainly driven by a general reduction of energy and water use in the buildings especially for space heating, and to energy efficiency regulations introduced since 2010 (European Parliament and Council, 2010) (Figure 33). The benefits of other policies affecting the other areas of consumption, e.g. the progressive reduction of car emissions (EC, 2008), were instead offset by the increased use of cars (so called "rebound effect"), highlighting the importance of putting in place policies aimed at enhancing more responsible consumption patterns (Figure 32).

Figure 30. Evolution of the Consumption Footprint EU-27 along the 2010-2021 period and contribution of the areas of consumption to the Consumption Footprint (index = 2010).

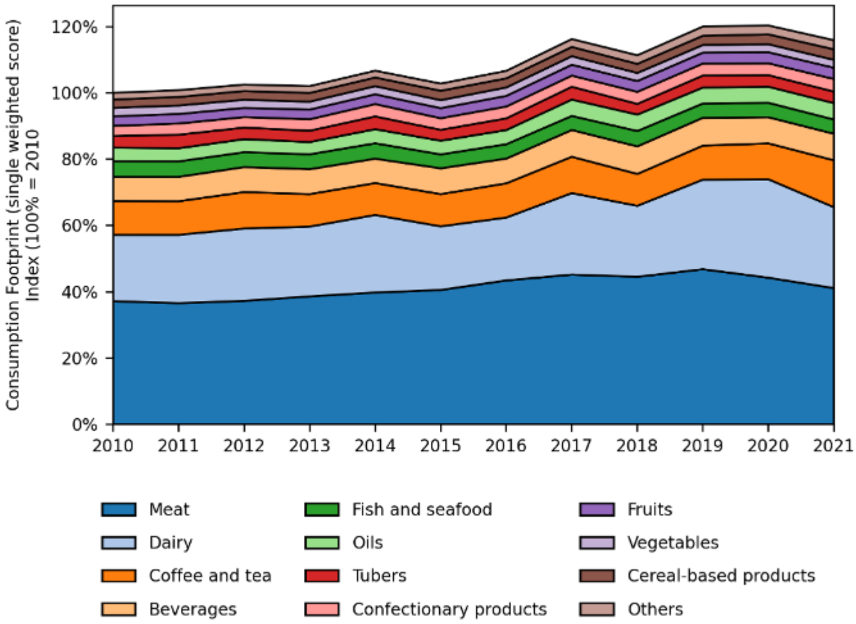


(*) Note that some datasets underpinning the calculation of the consumption intensities from FAOSTAT and Eurostat are still not public for 2021 and data were extrapolated from previous trends.

The **environmental impacts due to the consumption of food has shown the largest increase** along the analysed period (Figure 31). Impacts due to food consumption are dominated by meat and dairy products, the consumption of which grew during this period. Meat consumption grew between 12% (beef) and 32% (poultry), apart from pork meat (+1%), while consumption of products increased particularly for cheese (+82%). Highest increase was observed for quinoa (+994%), tofu (+298%) and avocado (+148%), mainly associated to changes in dietary patterns and consumption trends. Such changes were also reflected in the increase in legumes (+72%

for beans), soy-based beverage (+62%), and nuts and seeds (between 22% and 87%). The products that showed the largest decreased in consumption were chickpeas (-52%), tuna (-34%) and olive oil (-28%).

Figure 31. Evolution of the Food area of consumption for EU-27 between 2010 and 2021 (index = 2010).



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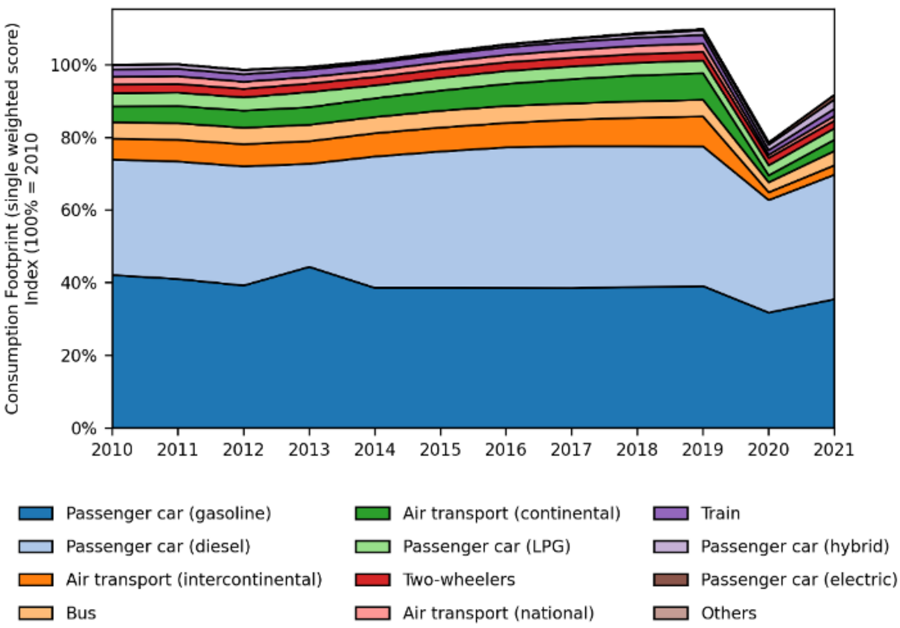
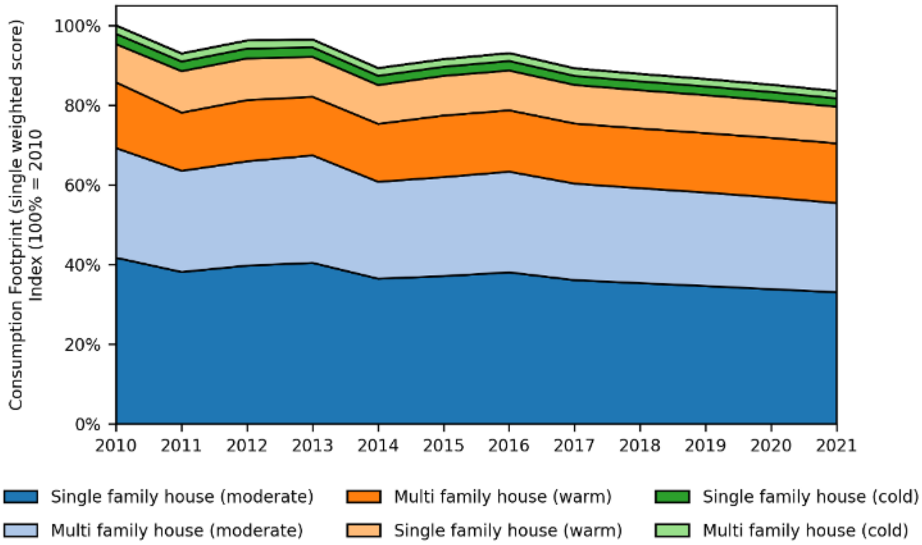
The **environmental impacts due to the mobility of EU citizens has decreased** along the analysed period (Figure 32), although this has been an effect of the COVID pandemic and its associated limitations starting in 2020. During the full period, the most affected type of transport was public transport by bus (-57%) and air mobility (-55%). Electric passenger cars showed the largest expansion among the alternative technologies to fossil fuels for private mobility (+1117%). In general, older passenger cars associated to higher direct emissions are being replaced by newer models that adjust to environmental restrictions of EU policy (EUR5, EUR6). **Without considering the effects of the pandemic, environmental impacts due to the mobility of EU citizens increased by 10%.** Beyond the growth of hybrid vehicles and the replacement of passenger cars, air mobility grew between 11% (domestic flights) and 69% (intra-EU flights). As well, public transport showed an increase both for trains (up to 17%) and buses (up to 8%).

Figure 32. Evolution of the Mobility area of consumption for EU-27 between 2010 and 2021 (index = 2010).



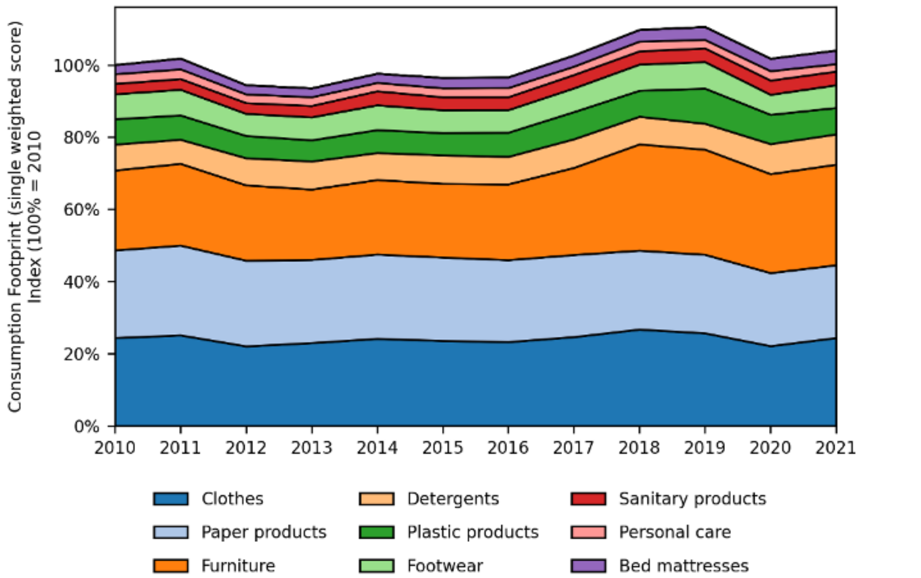
The **environmental impacts due to the consumption associated to housing has decreased** along the analysed period (Figure 33). The building stock has shown a renovation with older buildings being replaced by buildings constructed or renovated after 2010. The highest population density in the moderate EU countries drives the higher role of this climatic group among the EU results. Energy and water consumption per dwelling has been reduced along the period resulting from EU policies to make buildings more efficient. Energy used for space heating, cooking and lighting, as well as water consumption was reduced among all housing groups. The variation in energy used for appliances and domestic hot water depended on the climatic region (cold, moderate, warm) and building type (single and multi-family houses).

Figure 33. Evolution of the Housing area of consumption for EU-27 between 2010 and 2021 (index = 2010).



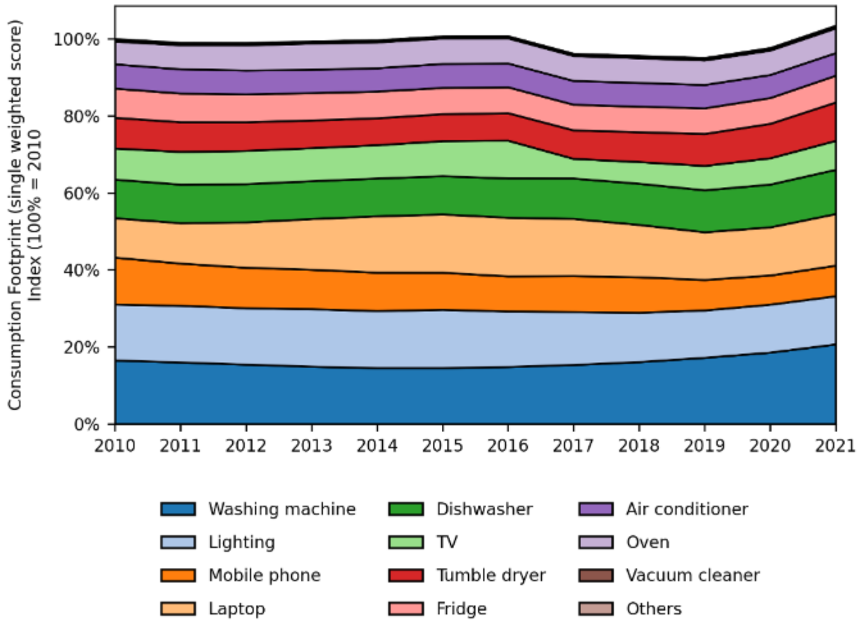
The **environmental impacts due to the consumption of household goods has increased** along the analysed period by 5% (Figure 34). The consumption of newsprint (-43%), plastic furniture (-38%) and jeans (-30%) showed the largest decrease, driving changes in paper products, furniture and clothes product groups, respectively. The largest increase in consumption intensity was associated to wooden table (furniture) (+104%), WW footwear (+69%) and liquid soap (+64%). Household goods consumption was affected by the COVID pandemic showing a steep decrease from 2019, although the previous trend was showing a steady increase.

Figure 34. Evolution of the Household goods area of consumption for EU-27 between 2010 and 2021 (index = 2010).



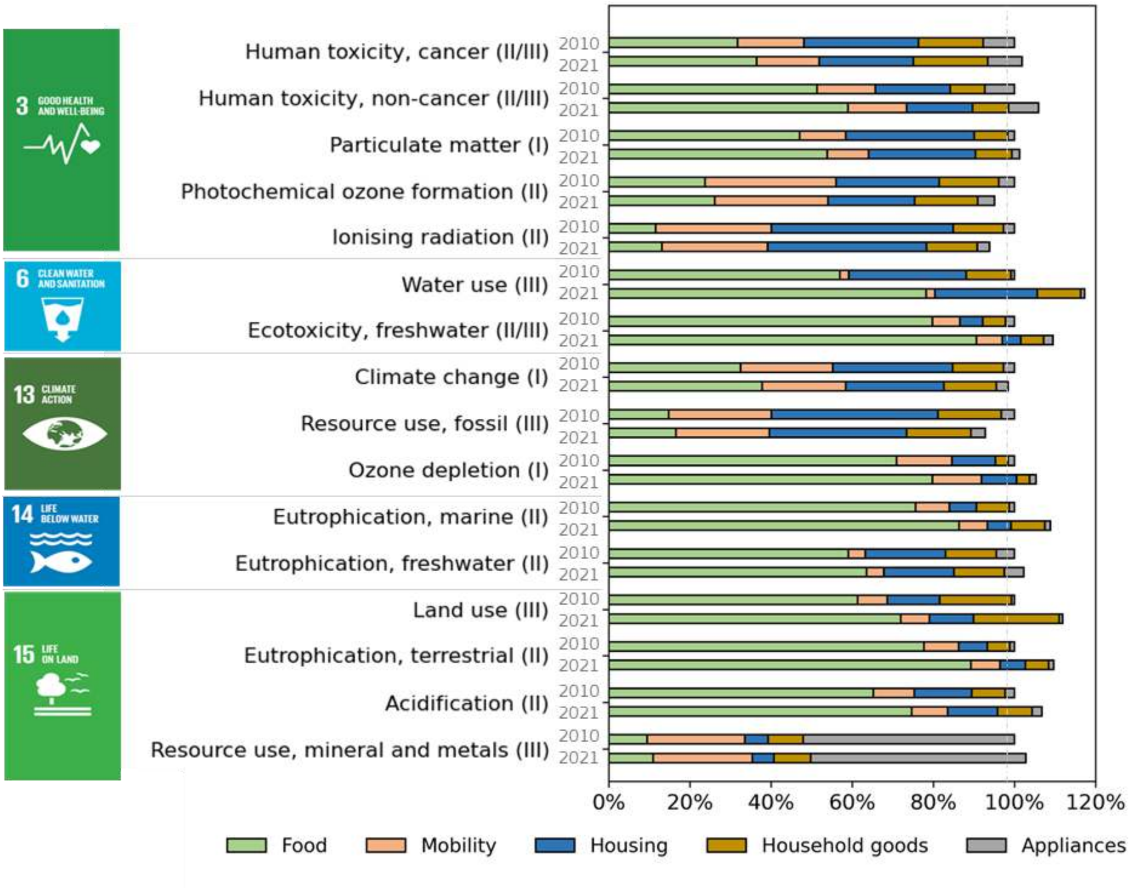
The **environmental impacts due to the consumption of appliances has increased** along the analysed period (Figure 35). The post-COVID pandemic shit towards hybrid modes of working has contributed to an increase in the consumption of notebooks (+31%). Washing machines (+25%) and coffee-makers (+18%) also showed a relevant increase. Until 2019, the consumption footprint of appliances showed a decreasing trend particularly due to the decrease of lighting technologies such as incandescent (-87%) and halogen lamps (-71%).

Figure 35. Evolution of the Appliances area of consumption for EU-27 between 2010 and 2021 (index = 2010).



The **effect in the environmental impact of the changes in consumption intensity depend on the impact category** (Figure 36). For example, appliances have a larger relevance on the resource use of minerals and metals compared to other categories. Largest increase occur in terrestrial eutrophication and ozone depletion mainly associated to food consumption, while changes in the electricity mix along time are leading to a decreased impact due to ionising radiation.

Figure 36. Evolution of the Consumption Footprint EU-27 between 2010 and 2021 and contribution of the areas of consumption to the Consumption Footprint, by impact category (index = 2010).

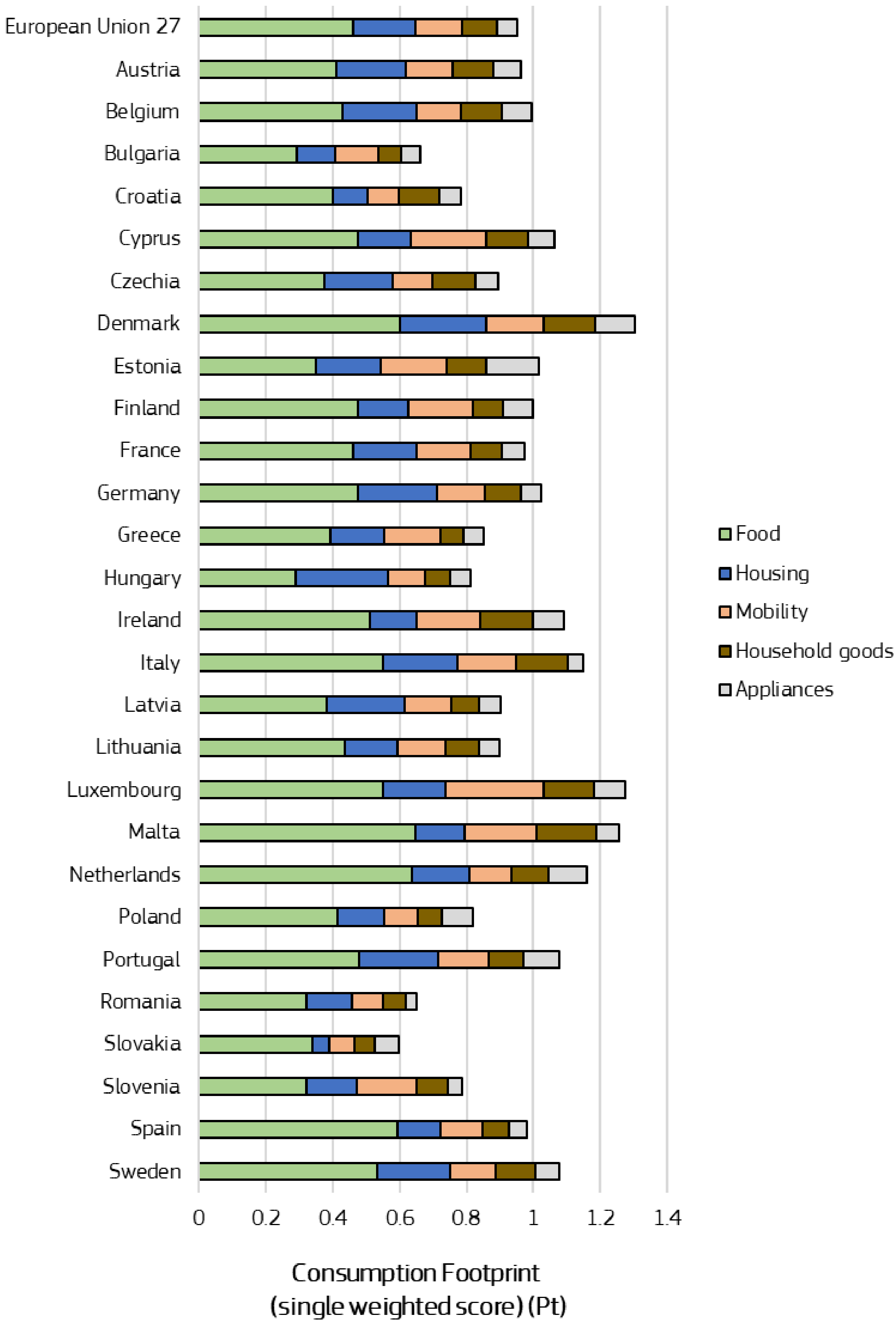


Model robustness of the impact assessment model used to assess each indicator is taken from EC (2021c).

6.2 Which are the impacts and related drivers in EU countries?

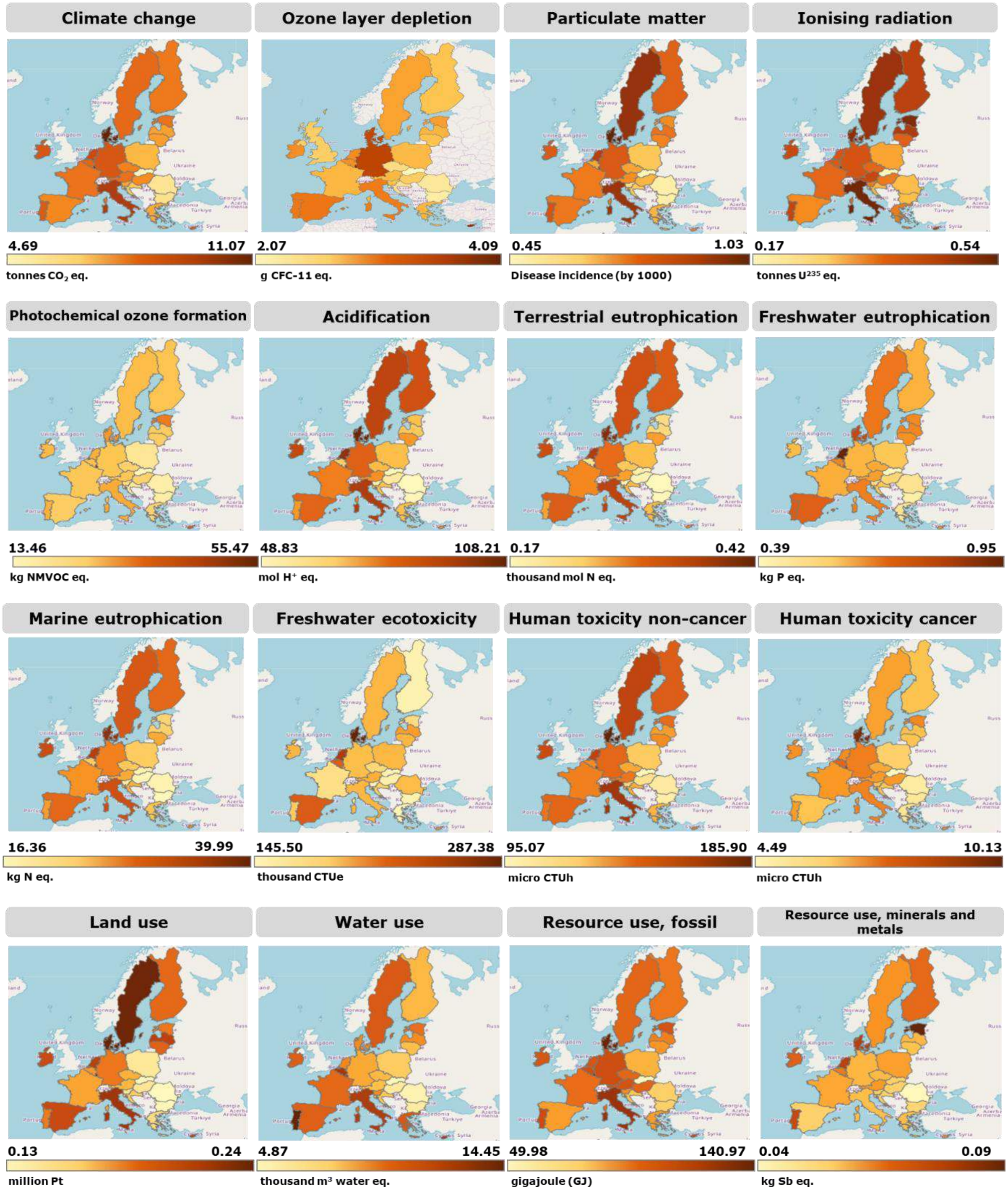
The Consumption Footprint per capita varies among the different Member States (Figure 37). **Food consumption is the main contributor in most EU countries**. Housing shows a larger relevance in moderate and cold countries compared to warm ones due to a higher **energy consumption for heating purposes**. The impacts linked to the consumption of household goods vary among countries depending on specific patterns and lifestyles. Mobility is more relevant in those countries requiring more air mobility due to specific characteristics (e.g., island such as Malta). Appliances generally reported the lowest contribution in all EU Member States, as the energy consumption during the use phase of appliances is considered in the housing area of consumption.

Figure 37. Consumption Footprint per capita and per area of consumption, by EU Member State (2021).



The Consumption Footprint per average citizen in each EU Member State, by each impact to the environment, is shown in Figure 38. **Member States with a high GDP per citizen frequently present high impact per citizen** (e.g. Luxemburg, the Netherlands, Denmark, Finland, Sweden, and Belgium). As well in terms of spatial distribution, southern countries tend to show a lower impact intensity per citizen, apart from water use. Compared with the Domestic Footprint per capita (Figure 9), it is noticeable the difference for resource use impact categories, e.g. water use impacts are more concentrated domestically than regarding consumption.

Figure 38. Consumption Footprint per citizen of the 27 EU Member States, considering 16 impacts to the environment and resources (2021)



7 Are the consumption patterns of EU citizens sustainable?

7.1 Decoupling assessment: why a consumption based approach is key for assessing decoupling in EU?

Decoupling: Using less resources per unit of economic output and reducing the environmental impacts (UNEP, 2011).

Absolute decoupling: The environmental impacts decrease while the economic activity keeps growing.

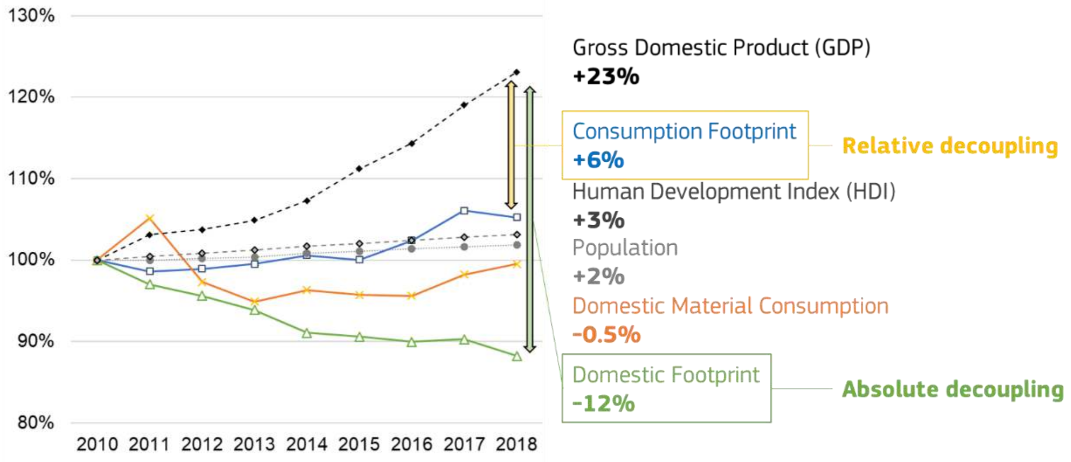
Relative decoupling: The increase of the environmental impacts is lower than the growth of the economic activity.

The assessment of the environmental impacts can be performed for a certain year to show the status quo (e.g. Figure 38), as well as for a period of time to evaluate the evolution of the environmental impacts. A desired trend along time is to decouple the environmental impacts of consumption and production activities from the associated economic output (e.g., in terms of Gross Domestic Product, GDP) (Sanyé-Mengual et al., 2019).

Considering a consumption-based perspective rather than a territorial or a production-based one is key in the evaluation of the decoupling of the environmental impacts of consumption from the economic input. Figure 34 compares the environmental decoupling behaviour of the EU for the weighted score of the Domestic Footprint and the Consumption Footprint. Between 2010 and 2018, the EU Domestic Footprint decreased by 12% showing an absolute decoupling from the economic output (GDP), which grew by 23% for the same time period. This trend indicates that the territorial environmental policies implemented in the EU framework are pushing towards a decrease of the environmental impacts (Figure 8).

However, trends are different when considering trade with the Consumption Footprint growing by 5% and leading to a relative decoupling from economic growth. Therefore, the environmental impacts embodied both in imports and exports have a significant role in the environmental burdens of consumption and, thus, a territorial perspective would lead to a biased conclusion as the environmental impacts are decoupling from the economic growth more intensely in the territory than abroad.

Figure 39. Environmental impact decoupling of the Consumption Footprint and Domestic Footprint from the economic growth (GDP) and human well-being (HDI) (EU-27, 2010-2018).



Beyond GDP: Decoupling can be evaluated also from indicators of well-being, such as the Human Development Index (HDI), towards considering other aspects of the progress as society beyond the economic output (e.g., GDP) but. When considering the HDI, the Domestic Footprint is still showing an absolute decoupling but the Consumption Footprint is showing no decoupling, with a higher increasing rate.

Resource decoupling: Resource decoupling can be assessed by comparing resources use in terms of Domestic material consumption (DMC), as a resource productivity indicator employed by Eurostat (2018), with the evolution of GDP. Resource use showed a higher degree of decoupling than environmental impact (Consumption Footprint) highlighting that assessing environmental impact decoupling is key to integrate the environmental behaviour of different resources beyond the absolute amount of resources depletion (Figure 39).

The **difference in decoupling between production and consumption impacts are also observed at EU country** level. When comparing the decoupling of EU countries for the Domestic Footprint (Figure 40) and the Consumption Footprint (Figure 41), the situation shifts of mostly absolute decoupling countries (including the EU) for domestic impacts to mostly relative decoupling (including the EU) when trade impacts (balance between embedded impacts in imports and exports) are also accounted for.

Figure 40. Situation of EU-27 and EU countries in relation to decoupling the Domestic Footprint from the economic growth in terms of Gross Domestic Product (GDP) (2010-2018) (Abbreviations are provided in page 59).

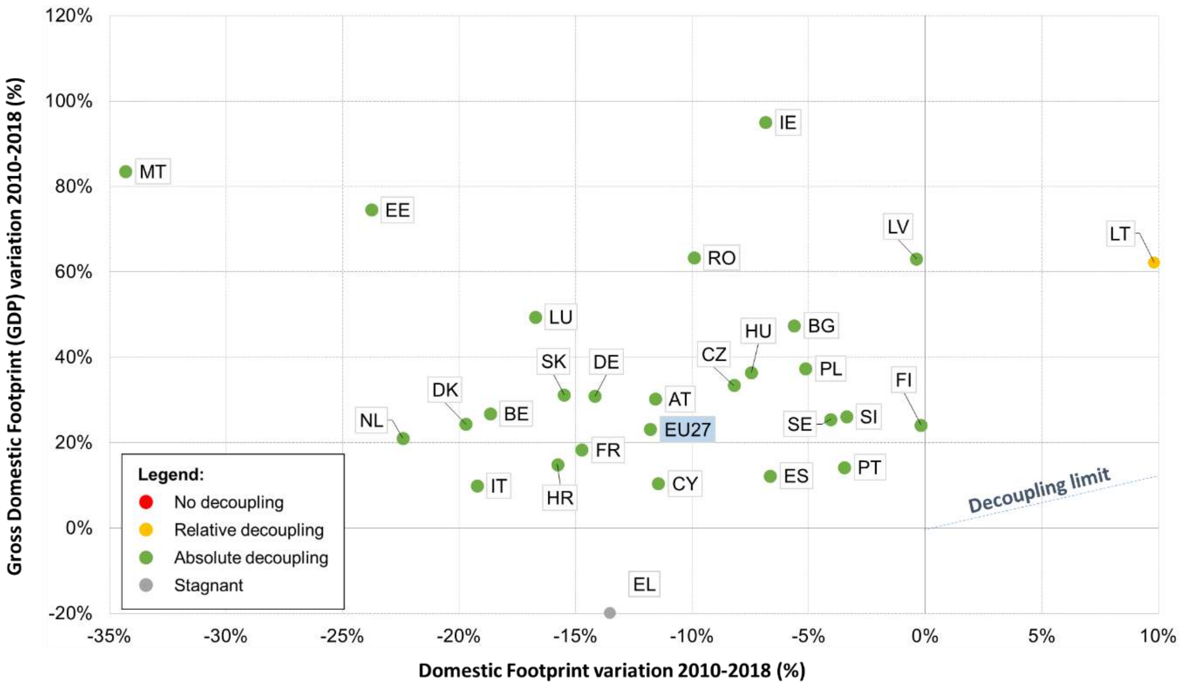
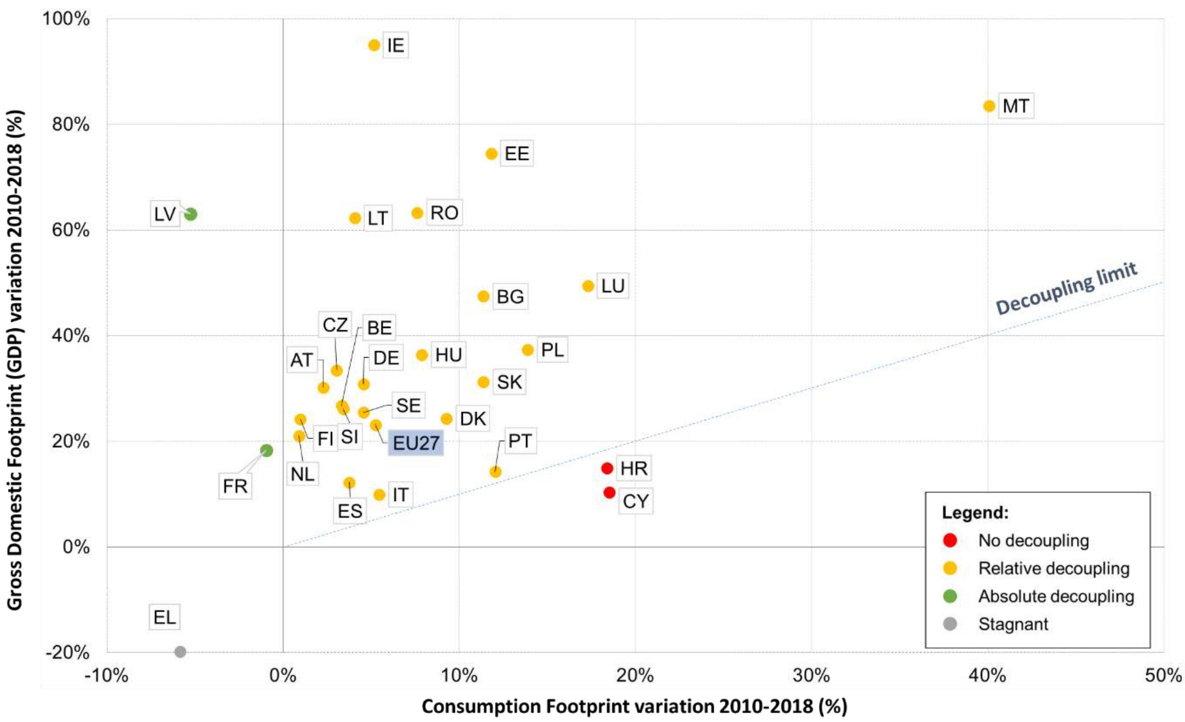


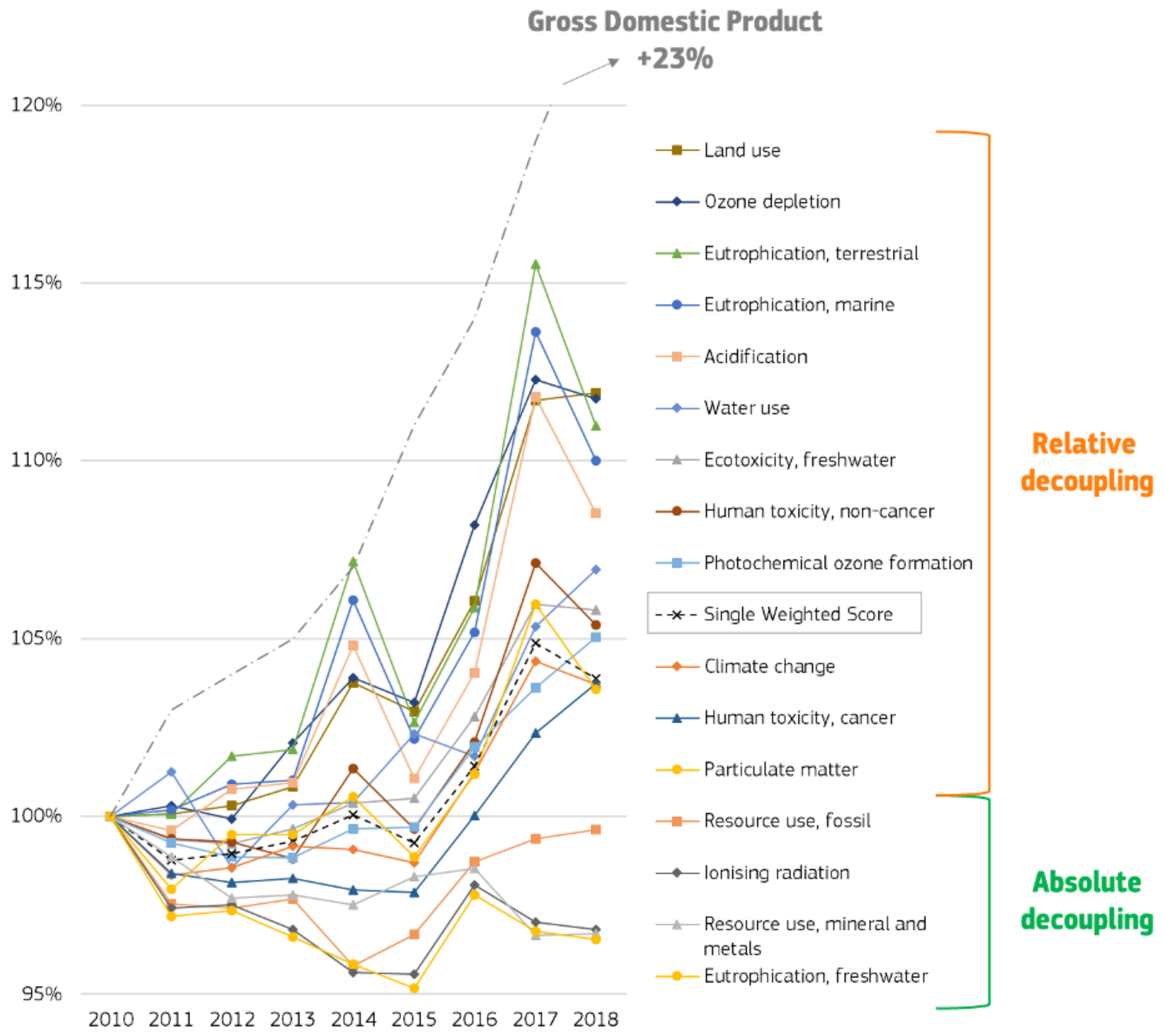
Figure 41. Situation of EU-27 and EU countries in relation to decoupling the Consumption Footprint from the economic growth in terms of Gross Domestic Product (GDP) (2010-2018) (Abbreviations are provided in page 59).



However, **the evolution along time and the resulting environmental decoupling (and its intensity) depends on the impact category**. Figure 42 displays the evolution of the Consumption Footprint single weighted score and the individual 16 impact categories compared with the GDP evolution for the period 2010-2018. The majority of the impact categories, including the single weighted score, show a relative decoupling: their increase was lower than the GDP one (+23%). These impact categories are associated mainly to the **area of consumption of food,** which dominates the Consumption Footprint and shows the largest increasing trend among the areas of consumption (Figure 30). In fact, the top-6 categories with the highest increase for this period are dominated by impacts due to food consumption (>62%) (Figure 12). On the contrary, four categories are showing a decrease and, therefore, an absolute decoupling.

This analysis highlights the **relevance to consider sets of indicators when assessing environmental decoupling to prevent trade-offs in policy actions**. While resource use indicators are usually employed in decoupling analysis (Eurostat, 2018), these address partially the plethora of environmental effects of human activities excluding environmental pollution. Some decoupling studies employ climate change to assess environmental decoupling (e.g., Schandl et al., 2016). In this analysis, these type of indicators (i.e., climate change, resource use – fossil, and resource use – minerals and metals) show a trend that is not reflecting the environmental impacts of EU consumption, such as the effects of increasing food consumption (e.g., affecting land use, water use, ozone depletion). In fact, resource use indicators show absolute decoupling, which would mislead policy needs to tackle environmental impacts. This is in line with the literature questioning the use of resource footprints as proxy for environmental footprints (Heijungs, 2017).

Figure 42. Evolution of the Consumption Footprint single weighted score and the individual 16 impact categories and associated decoupling from the economic growth in terms of Gross Domestic Product (GDP) (EU-27, 2010-2018).



7.2 Is consumption in EU environmentally sustainable and within planetary boundaries?

The environmental impact of EU consumption could be further linked to specific **SDGs** (3, 6, 13, 14, and 15) and related to **planetary boundaries**, which represent the quantitative estimation of the **Earth carrying capacity**. This link is in line with the EU's long-term vision to 2050 of **living well, within planetary boundaries** of the 8th EAP (European Parliament and Council, 2022), and means the quantification of the environmental performance of the EU consumption with respect to the Earth system capacity as an **absolute term of comparison**. The connection to SDGs and planetary boundaries helps determining whether the consumption in Europe is **environmentally sustainable**.

The **planetary boundaries concept** presents "a set of nine planetary boundaries within which humanity can continue to develop and thrive for generations to come" (Stockholm Resilience Centre), therefore transgressing such limits can lead to ecological processes to reach a new state (Rockström et al., 2009, Steffen et al., 2015).

Figure 43. Impacts of EU: relative and absolute assessments

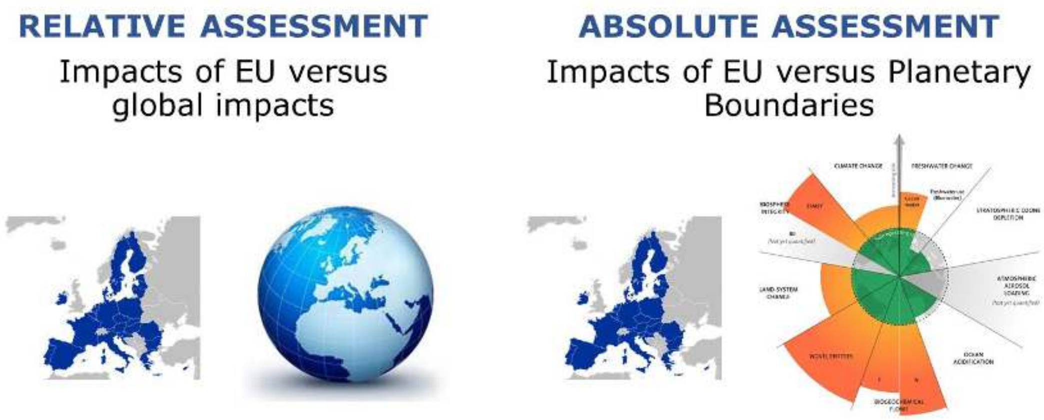


Figure 44. Overview of the link between the (midpoint) impacts adopted in Life Cycle Impact Assessment, the Sustainable Development Goals and the planetary boundaries (adapted from Sala et al., 2020).

		PLANETARY BOUNDARIES									
SDGs	LCA impact categories (EF 3.1)	Biodiversity integrity – Functional / Biodiversity integrity - Genetic	Climate change	Novel entities	Stratospheric ozone depletion	Atmospheric aerosol loading	Ocean acidification	Biogeothermal flows - Nitrogen / Biogeothermal flows - Phosphorus	Freshwater change	Land-system change	Resource use
3	Human toxicity, cancer			●							
3	Human toxicity, non cancer			●							
3	Particulate matter					●					
3	Photochemical ozone formation	●		●							
3	Ionising radiation			●							
6	Water use (impact due to)	●							●		
6	Ecotoxicity, freshwater	●		●							
13	Climate change	●	●				●				
13	Resource use, fossil		●								●
13	Ozone depletion				●						
14	Euthrophication, marine	●						●			
14	Eutrophication, freshwater	●						●			
15	Land use	●								●	
15	Euthrophication, terrestrial	●						●			
15	Acidification	●						●			
15	Resource use, minerals and metals										●

The Domestic Footprint (Figure 45) and Consumption Footprint (Figure 46) are **overcoming several Planetary Boundaries**. The level of overcoming is larger for the Consumption Footprint than for the Domestic Footprint due to the impacts embedded in trade. The different methodological approach (statistics for domestic and modelling for consumption) is particularly relevant for freshwater ecotoxicity – which is largely transgressed in the Consumption Footprint, where a complete evaluation of emissions to the environment is performed.

Figure 45. EU Domestic Footprint per capita compared to global (whole world) impact per capita and Planetary Boundaries per capita.

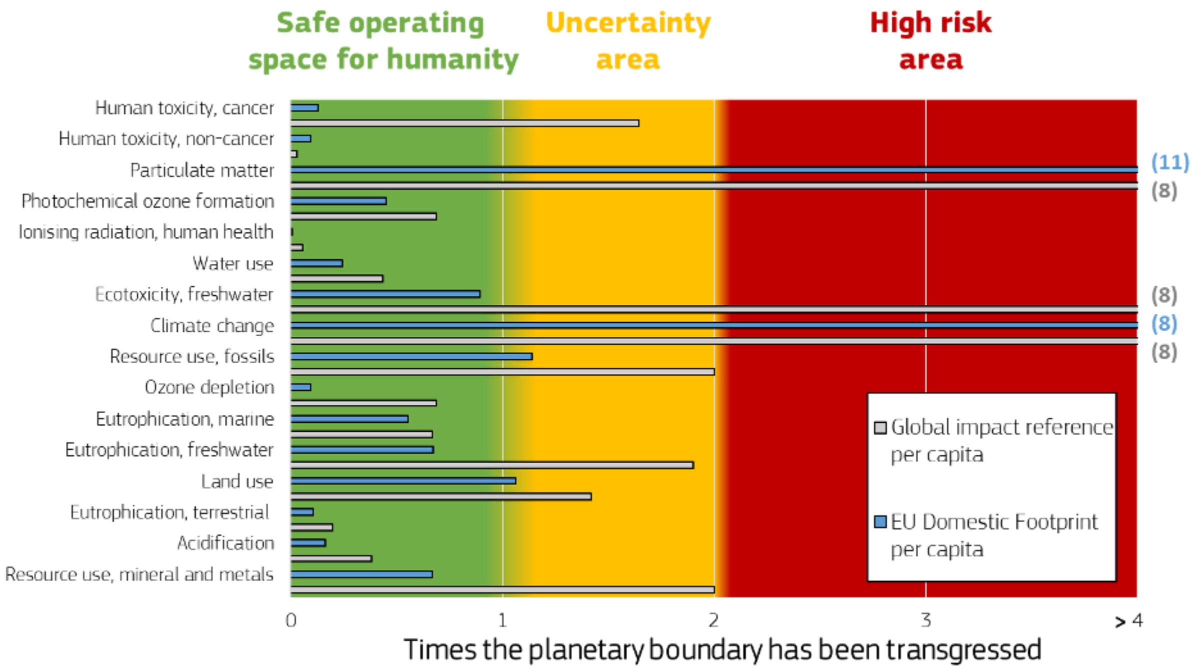
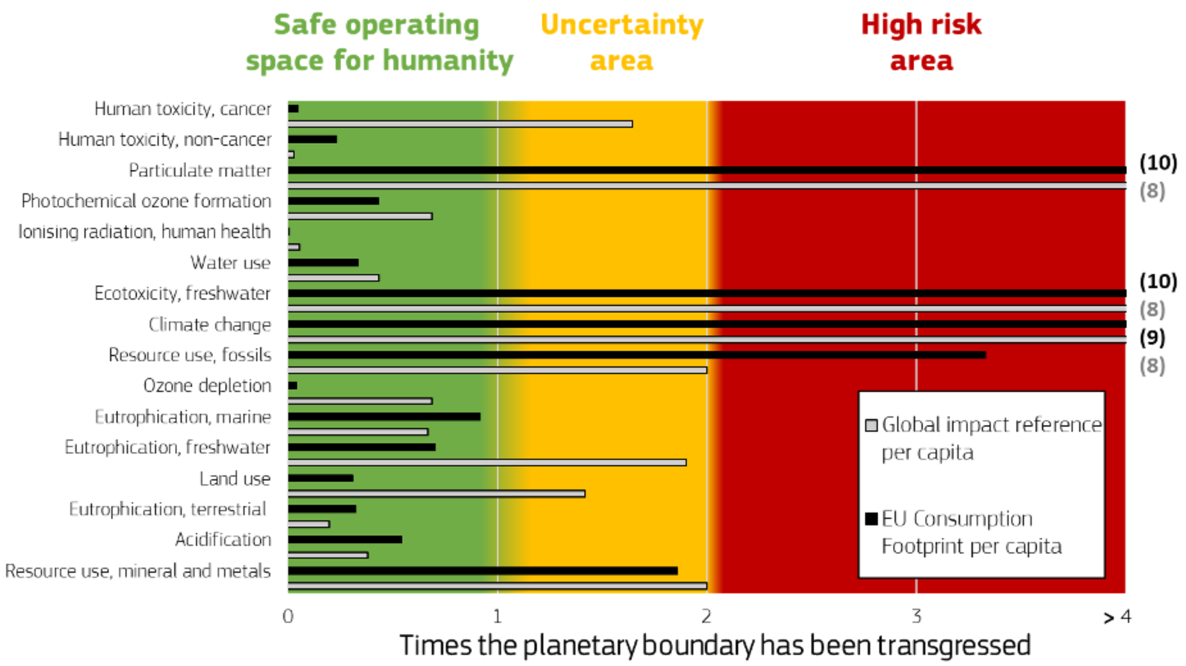


Figure 46. EU Consumption Footprint per capita (2018) compared to global (whole world) impact per capita and Planetary Boundaries per capita.

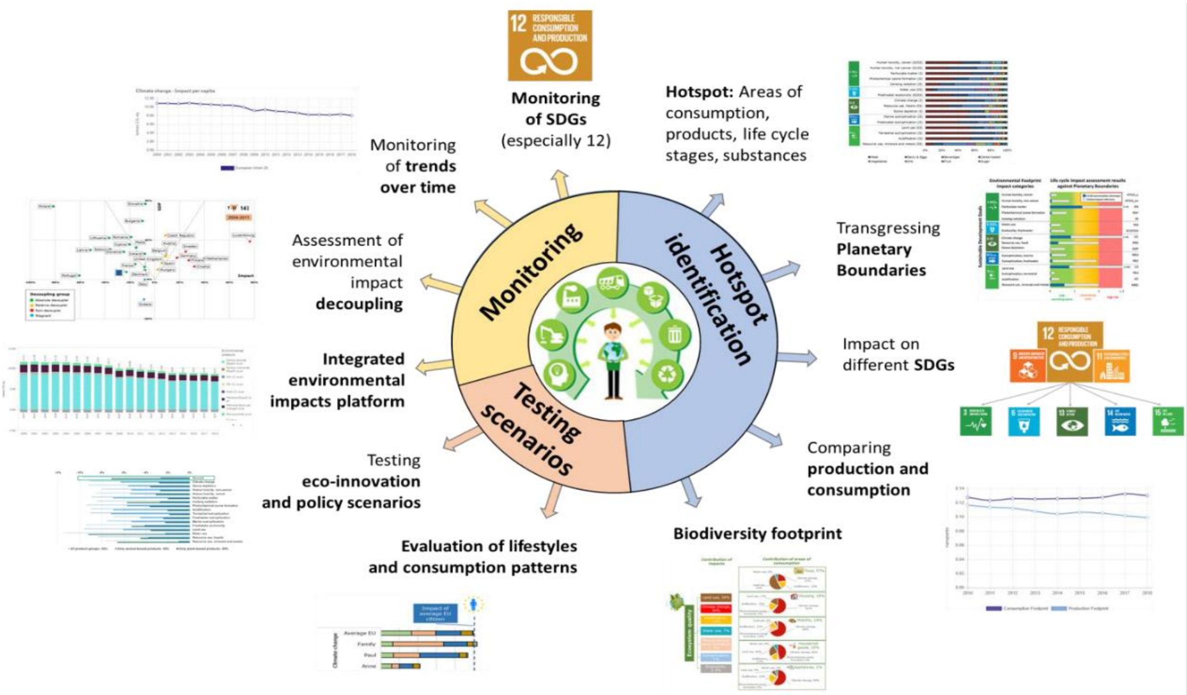


8 What are the applications of the developed framework?

The **Consumption Footprint and Domestic Footprint indicators show considerable potential to support policy making through different uses**, including (Figure 47):

- **Identifying environmental hotspots**: the granularity of the indicators can provide information on hotspots at different levels (environmental issues with the highest relevance, areas of consumption, product groups and products, life cycle stages of products, and of most relevant resource used or emissions to the environment). The indicators could be presented as 16 different environmental impact categories or as a single score. Biodiversity footprint could be presented as well complementing the Environmental footprint with a life cycle impact assessment method addressing biodiversity loss (endpoint).
- **Monitoring:** yearly updates of the indicators allow tracking the evolution of impacts associated with changes in production and consumption patterns. This may be strategic for monitoring e.g. how much EU is decoupling environmental impacts from economic growth, the benefits of transition towards circular economy, the ability of EU to remain within planetary boundaries as well as progress related to the SDGs (especially SDG12 on responsible consumption and production). The indicator can also be employed to set targets for policy purposes as called by the European Parliament for circular economy[14], e.g. Sweden parliament recently agreed on having a consumption-based perspective for climate targets[15].
- **Setting a baseline against which testing policy options and scenarios:** the modularity of the indicators 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.
- **Evaluating lifestyles and consumption patterns**, which can be compared to EU and Member State average lifestyles.
- **Identifying transboundary and spillovers effects**, since the indicators could unveil the trade footprint, namely the amount of impacts embodied in imported goods.

Figure 47. Overview of policy uses of the developed framework.



[14] https://www.europarl.europa.eu/news/en/press-room/20210122IPR96214/meps-call-for-binding-2030-targets-for-materials-use-and-consumption-footprint

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

8.1 Developed platforms and tools

The project resulted in the development of three different online platforms and tools developed for different purposes and targeting different stakeholders groups.

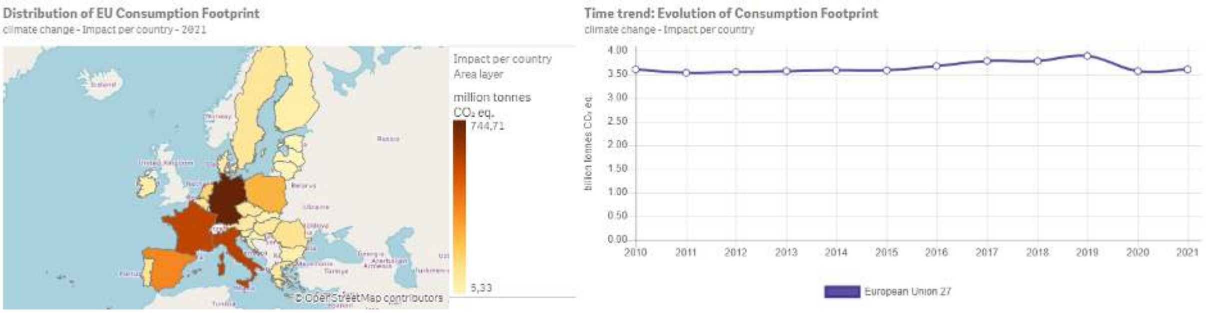
Online tool	Targeted stakeholders	Main goal
Consumption Footprint Platform	Policy-makers Researchers Stakeholders	Explore Consumption Footprint and Domestic Footprint data Access and download data
Consumer Footprint Calculator	Citizens	Assess the individual Consumption Footprint Identify hotspots of 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

Through the **Consumption Footprint Platform**[16] (EC-JRC, 2023a) it is possible to explore the results of the Consumption Footprint for the period 2010-2021, and of the Domestic Footprint for the period 2000-2018 (forthcoming data up to 2021). Both indicators are available at EU and Member State level with data per country, per capita and per km^2.

The platform includes:

- 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 assess the environmental and biodiversity impacts of the EU food system,
- access to regionalized Consumption Footprint data.

Figure 48. Example of chart provided in the Consumption Footprint Platform regarding the overall Consumption Footprint.



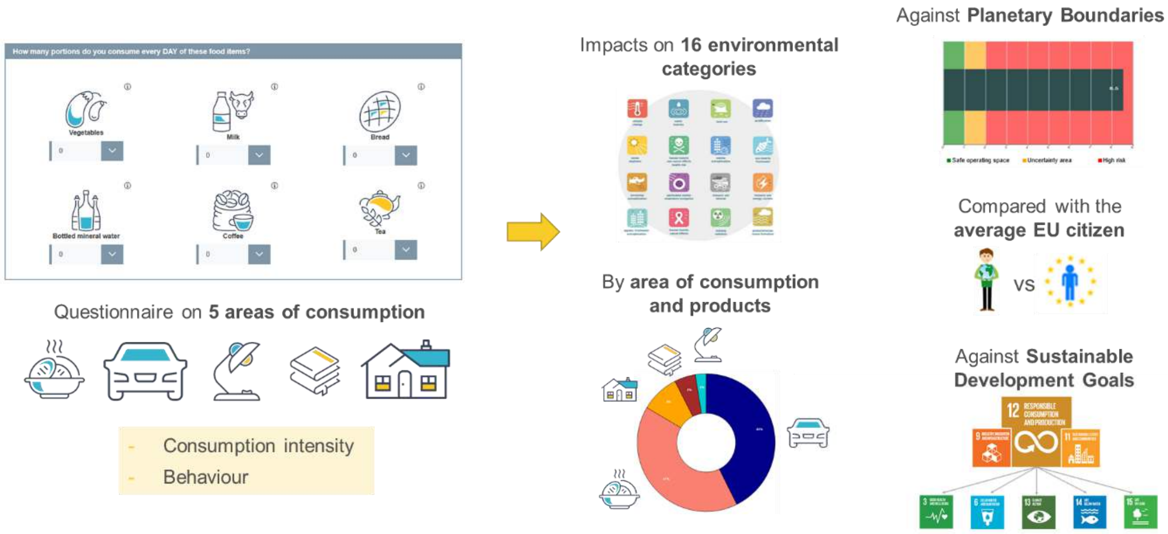
The **Consumer Footprint Calculator**[17] allows EU citizens to calculate the environmental impacts of their consumption patterns and to evaluate how changes in their lifestyle may affect their personal footprint (Sala et al., 2022). The calculator is available in English, Italian and Spanish.

[16] Access to the platform: https://eplca.jrc.ec.europa.eu/ConsumptionFootprintPlatform.html
[17] Link to the Consumer Footprint Calculator: https://knowsdgs.jrc.ec.europa.eu/cfc

The Calculator allows citizens to explore the impacts of their lifestyles (Figure 49):

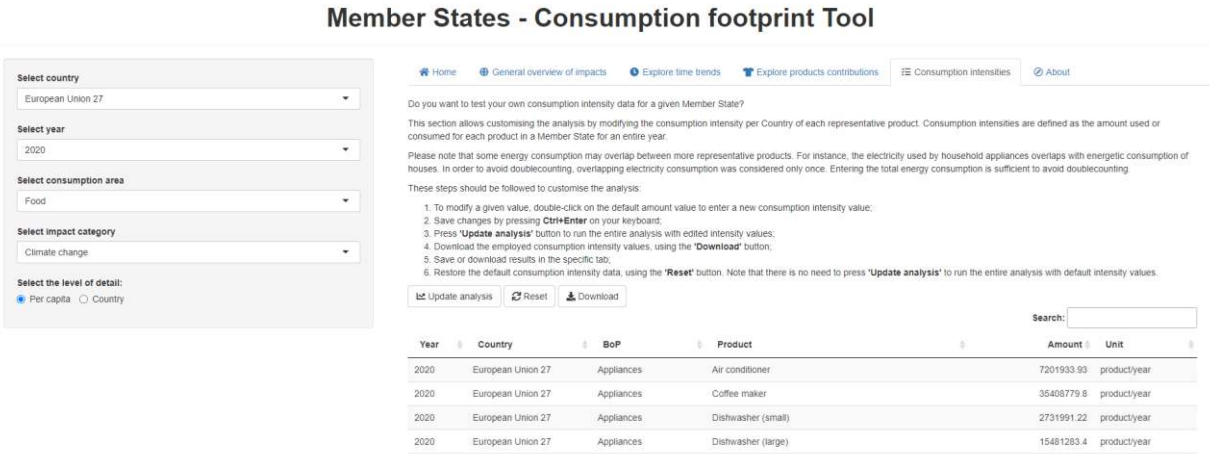
- through 16 environmental impact categories and a single weighted score
- displaying the impact by area of consumption and product
- assessing the results against the Planetary Boundaries and the Sustainable Development Goals
- comparing the impacts against the average EU citizen

Figure 49. Overview of the structure of the Consumer Footprint Calculator: questionnaire and results visualization options.



The **Member States – Consumption Footprint Tool**[18] (EC-JRC, 2023b; Sanye Mengual et al., 2023) 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 50).

Figure 50. The 'Modify intensity' module of the Member States – Consumption Footprint Tool.



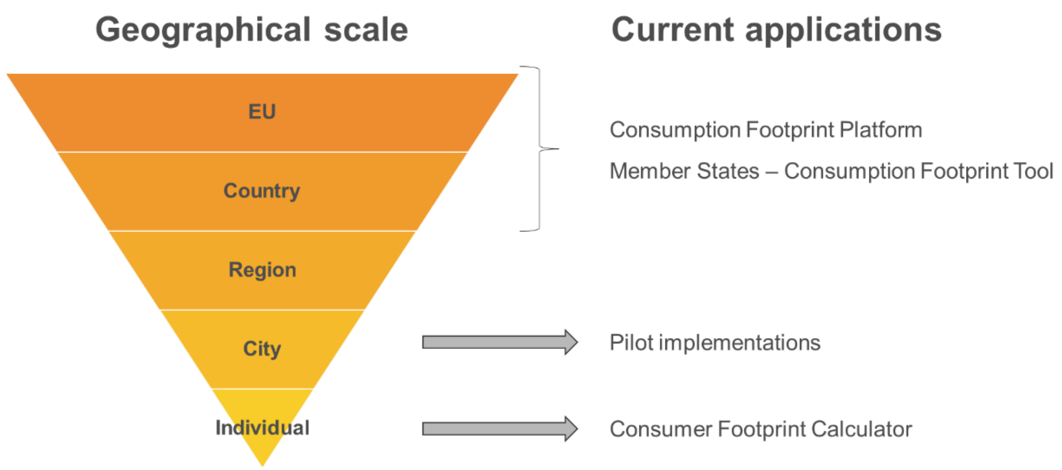
[18] Link to the Member States Consumption Footprint Tool: https://eplca.jrc.ec.europa.eu/MSConsumptionFootprint.html

8.2 The different geographical scales at which the Consumption Footprint could be applied

The Consumption Footprint can be applied at different geographical scales and at different granularity, from the EU to the individual consumer (Figure 51):

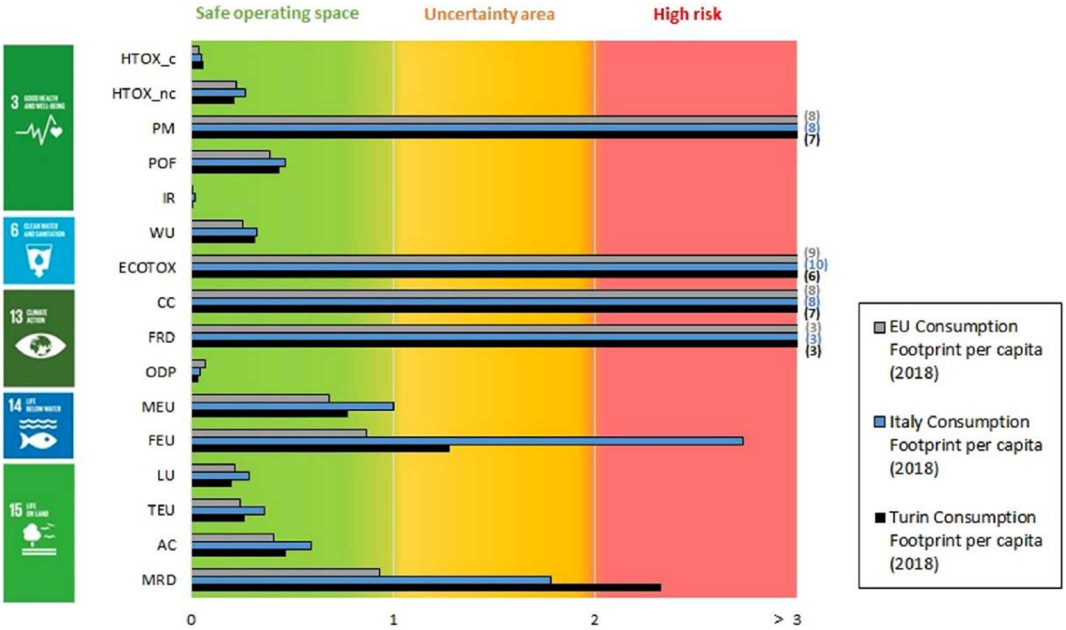
- The **Consumption Footprint Platform** (EC-JRC, 2023a) provides data at EU and country level. At the country level, the **Spanish Ministry of Consumer Affairs** has employed the data from the Platform to analyse the case of Spain in collaboration with the JRC (Ministerio de Consumo/EC-JRC, 2022). Member States can also use the Member States – Consumption footprint Tool (EC-JRC, 2023b) to calculate their Consumption Footprint with national data sources.
- The indicator can also be calculated at regional or urban scale, by using consumption statistics at higher granularity. A **pilot implementation at city level** was developed in collaboration with the Politecnico of Turin for the city of Turin (Italy) (Genta et al., 2022). The exercise required combining household consumption surveys with other data sources, e.g. geographic information systems on residential buildings, data on urban public transportation from the transport company.
- 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.

Figure 51. Potential applications of the Consumption Footprint at different geographical scales.



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 this comparison of the footprint of Turin citizens against an average Italian and an average EU citizen (Genta et al., 2022) (Figure 52).

Figure 52. Consumption Footprint of an average Turin, Italian and EU citizen (2018) (Source: Genta et al., 2022).



8.3 Uncertainties and limitations

The proposed framework and developed LCA-based indicators are the results of a significant effort in data gathering, data curation, and integrated modelling. Both the input data and the modelling can be affected by uncertainties, and this should be taken into consideration when interpreting the results and in the use of the results for policy support. The main types of uncertainties are related to:

— Uncertainties and outliers in the different data sources (e.g., emissions statistics or consumption statistics), including required data gap filling procedures

— Uncertainty in modelled emissions (e.g., chemical emissions of toxic substances besides those reported in official statistics) (Domestic Footprint)

— Uncertainty in the modelled representative products (Consumption Footprint), regarding both the foreground data considered to model the life cycle of the product and the background data used from life cycle inventory databases

— Uncertainty in the impact assessment models of the Environmental Footprint, as transparently reported in the EF recommendations.

— Uncertainty in the estimate of Planetary Boundaries in the original sources, as well as uncertainties due to the translation of the boundaries in the EF indicators. Furthermore, for those boundaries missing an estimation of the safe operating space in the original publications, figures have been provided based on complementary literature (Sala et al., 2020).

The indicators are meant to act as a “thermometer”, to identify trajectories of evolution of impacts overtime and the main hotspots. The modelling exercise is designed to allow updating the indicators overtime and being able to capture main trends associated to consumption patterns. The scope of the indicators is mainly addressing products, and covers services as follows:

- Transport services are covered in mobility
- Food services: Food consumption is included without making a distinction among food products consumed at home or outside home.
- Tourism: Food consumption, transport and peer-to-peer accommodations are included.

Moreover, it is beyond the scope of the analysis the consideration of rebound effects or effects of re-exports when dealing with transboundary impacts.

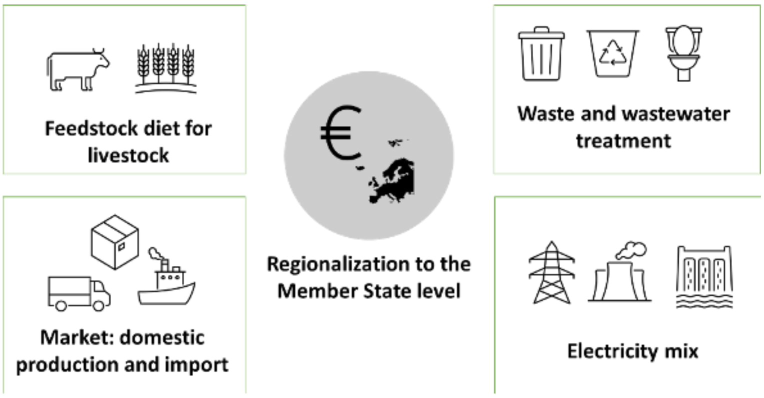
The indicators are under constant refinement to ensure the highest reliability, hence, the reader is invited to check the latest results in the above presented **Consumption Footprint Platform**.

9 A regionalized Consumption Footprint

The environmental impacts of the representative products of the Consumption Footprint currently represent the EU average. For example, the production of the products considers the EU electricity mix (apart from specific cases such as clothes), the market for imported goods to define international transport considers the EU average, or the waste treatment for a specific product or materials considers the EU average waste management (namely considering the share of different waste treatments). However, the differences among the EU countries on these aspects imply differences in the environmental impact of the representative products (e.g., beef meat can have a different impact whether produced in the EU or imported, and depending also on how and where the feedstock is cultivated – such as the imports of soya).

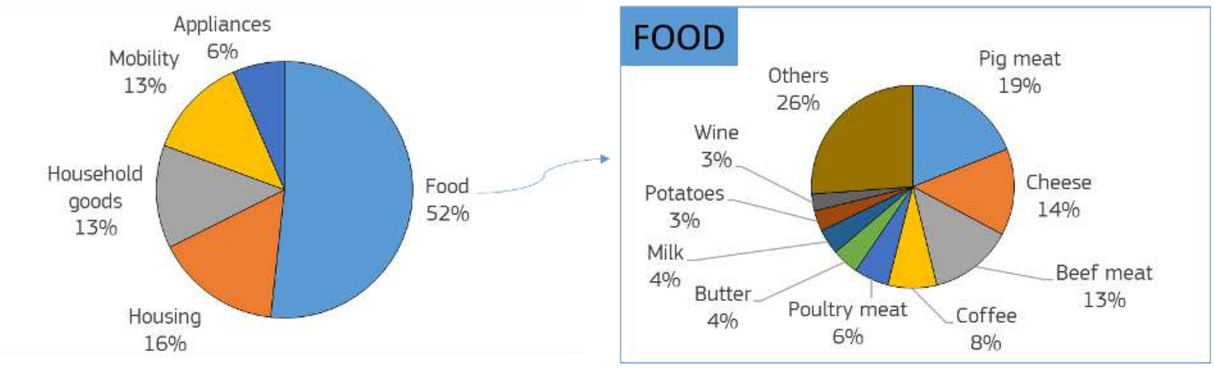
For this purpose, a regionalized version of the Consumption Footprint has been calculated by using official statistics to model four main aspects that varies along the EU geography (Figure 53). The life cycle stage and area of consumption in which these different aspects are regionalized, as well as the statistical data sources employed for the regionalization are reported in Annex 5.

Figure 53. Aspects regionalized in the Consumption Footprint at Member State level.



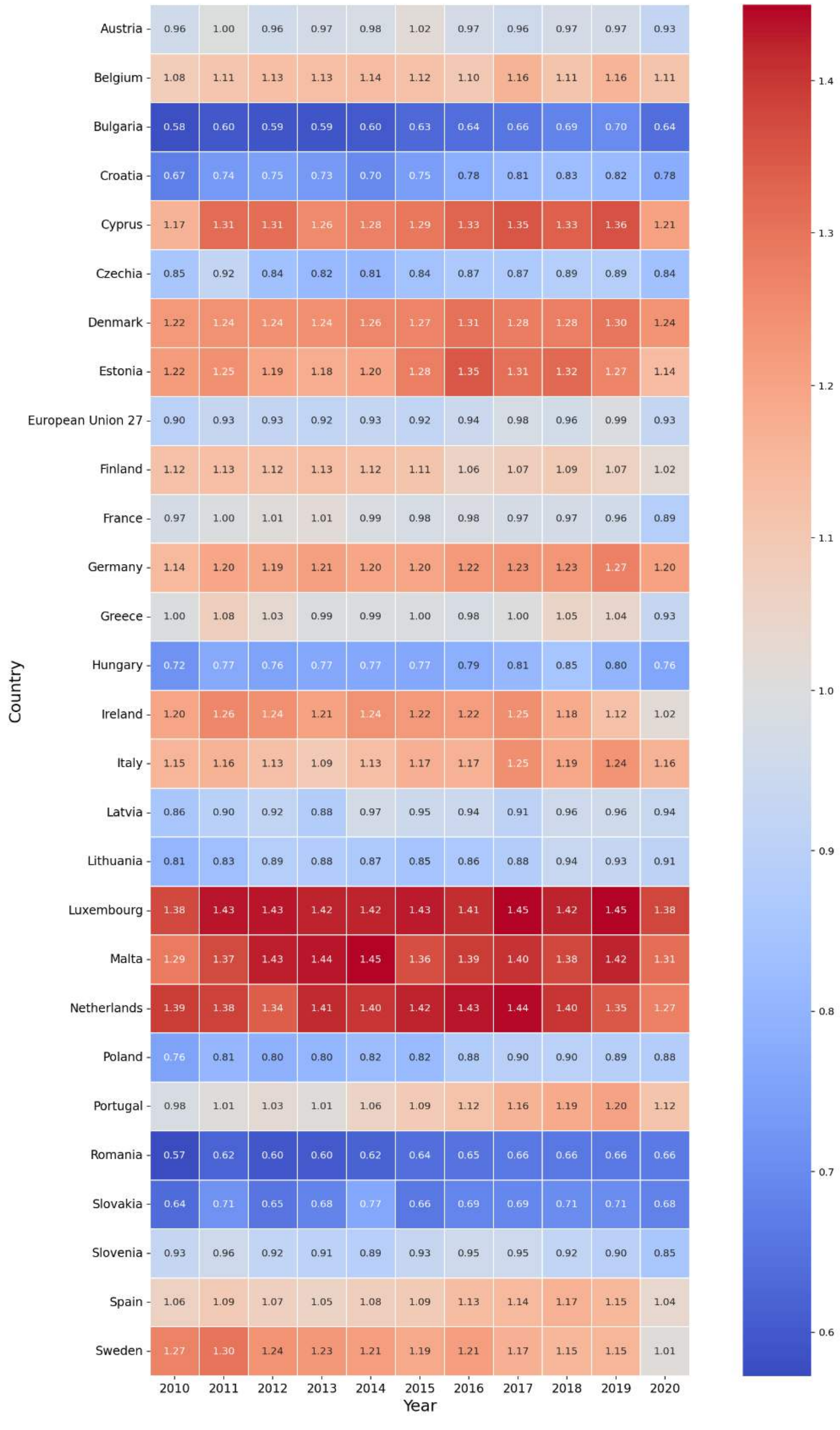
The role of the different areas of consumption remains similar to the non-regionalized data at the EU level, where food is the largest contributor to total impact (Figure 54) and where animal-based products (meat and dairy) are the ones contributing the most to the environmental impacts of EU food consumption.

Figure 54. Contribution to the regionalized Consumption Footprint (EU27) by area of consumption (left), and contribution of food products to the impacts due to food consumption (right).



When comparing the different EU countries the year of consumption, the regionalized Consumption Footprint per capita varies (Figure 55). The countries showing the largest impact per capita are Luxembourg, Malta, Cyprus and Netherlands. For all these countries, the impact per capita has increased overtime. On the contrary, the lower impact per capita is shown for Romania, Bulgaria, Croatia and Slovenia. Specific years are remarked for some countries (e.g., 2011 for Sweden, 2012 for Italy) outlining the relevance of the annual variance of the different aspects considered in the regionalization. In particular, changes in import needs and the countries satisfying such needs can be crucial in the resulting environmental impacts. Generally, it is observed the influence of the consumption intensity evolution which may offset improvements due to green transitions, e.g. due to less impactful energy mix.

Figure 55. Variation of the regionalized Consumption Footprint per capita among EU countries and period (2010-2018).



Performing the regionalization of the Consumption Footprint, outliers were identified in the statistical data sources, e.g. in relation to data concerning the waste treatment. Such outliers may have an unexpected effect on the resulting environmental impacts. However, due to the nature of the data (i.e., official data provided by Member States) these outliers have not been modified. The regionalized results are available in a devoted section of the Consumption Footprint Platform[19] for EU countries to signal unexpected results and potentially revise the data employed for the regionalisation.

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

10 Conclusions

The Consumption Footprint and Domestic Footprint indicators assess the environmental pressures and impacts due to EU production and consumption. The calculation framework allows the estimate of **16 environmental impacts** (e.g., climate change, freshwater ecotoxicity, land use related impacts, water use related impacts, etc.). **Modelling consumption in Europe to address SDG 12**, the calculated environmental impacts can be linked with **5 other SDGs (3, 6, 13, 14 and 15)**. The assessment has been performed at different scales: **EU, 27 Member States, areas of consumption and products, and individual citizens**. The framework includes an **assessment against the planetary boundaries.** A **single headline indicator** (a single weighted score of the 16 environmental impacts covered) can be calculated for communicating these results.

The Consumption Footprint set of indicators may help assess the main drivers of the environmental impacts of EU consumption. Food consumption, followed by housing and mobility, are responsible for the largest share of impacts. The **environmental impacts of the consumption of an average EU citizen are outside the safe operating space for humanity** for several impact indicators. Despite inherent uncertainties linked to this type of assessment, the results are indicating the need of actions to significantly reduce the environmental impacts due to consumption.

The **Consumption Footprint and Domestic Footprint indicators show considerable potential to support policy making through different uses**, e.g., hotspot identification, monitoring of the evolution of impacts over time, testing of scenarios and policy options, definition of baselines, or the assessment of the environmental impact of citizens' lifestyles.

LCA-based indicators can have a crucial role in ensuring the adoption of a systemic approach in environmental impact assessments as well as to help unveil and assess trade-offs. However, this work is not exhaustive of all environmental concerns: it assessed potential impacts according to the impacts selected in the Environmental Footprint. Future work may focus on **improving the robustness of the assessment of the overcoming of planetary boundaries**, as well as **to improve assessing impacts related to biodiversity loss** and **to address additional environmental concerns** related to consumption, such as e.g. **marine litter, noise**.

Main findings

- Five areas of consumption (Food, Mobility, Housing, Household goods and Appliances) have been assessed through the life cycle assessment of more than 160 representative products. Consumption of food emerged as the main driver of impacts generated by household consumption, followed by Housing (especially for space heating) and Mobility (especially the use of private cars). An increase of Consumption Footprint between 2010 and 2021 was driven by higher consumption intensity in Food and Mobility.
- The EU-27 can be considered a "net importer of environmental impacts": environmental impacts of imports are larger than those of exports. This implies that the Consumption Footprint (overall impacts related to consumption including trade) is higher than the Domestic Footprint (impacts generated in the EU-27 area).
- Between 2010 and 2018, the Domestic Footprint in the EU-27 has decreased (-12% as weighted score) while GDP has increased (absolute decoupling). Yet accounting for emobodied impacts due to trade (Consumption Footprint), a more limited relative decoupling is observed.
- The environmental impact of the consumption of an average EU citizen is outside the safe operating space for humanity for several impacts, namely climate change, particulate matter, resource use (fossils fuels) and freshwater ecotoxicity. Despite the differences in the robustness of the different impacts, results conclude that for most categories the impacts are close to the threshold, when not over it.
- The Consumption Footprint can be use to set a baseline scenario against which different policy options and green transitions can be tested, from substituting a raw material, to changing a consumer behaviour or a product waste management option. Adopting LCA, trade-offs related to green transitions emerge clearly. More than 50 scenarios on the different areas of consumption have been tested. Overall, results showed that only an integrated action combining several interventions may ensure reducing significantly the environmental impacts.

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List of abbreviations

BoP	Basket of Products
CAP	Common Agricultural Policy
CFC	Chlorofluorocarbons
CTUh	Comparative Toxic Unit for humans
CTUe	Comparative Toxic Unit for ecosystems
DALY	Disability-adjusted life years
DMC	Domestic material consumption
EF	Environmental Footprint
ETS	Emission Trading System
EU-27	European Union, included EU Member States
GDP	Gross Domestic Product
GHG	Greenhouse gas
HDI	Human Development Index
HH	Human health
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LPG	Liquefied petroleum gas
MFF	Multiannual Financial Framework
MFH	Multi-Family House
NMVOC	NonMethane Volatile Organic Compounds
OEF	Organisation Environmental Footprint
PDF	Potentially disappeared fraction of species
PEF	Product Environmental Footprint
PM	Particulate matter
RME	Raw Material Equivalent
SDG	Sustainable Development Goals
SFH	Single-Family House
TV	Television
UV	Ultraviolet

Environmental Footprint impact categories:

CC	Climate change
ODP	Ozone depletion
PM	Particulate matter
IR	Ionising radiation
POF	Photochemical ozone formation
AC	Acidification

TEU	Eutrophication, terrestrial
FEU	Eutrophication, freshwater
MEU	Eutrophication, marine
ECOTOX	Freshwater ecotoxicity
HTOX_nc	Human toxicity, non-cancer
HTOX_c	Human toxicity, cancer
LU	Land use
WU	Water use
FRD	Resource use, fossils
MRD	Resource use, minerals and metals

EU countries

AT	Austria
BE	Belgium
BG	Bulgaria
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
EL	Greece
ES	Spain
FI	Finland
FR	France
IE	Ireland
HR	Croatia
HU	Hungary
IT	Italy
LT	Lithuania
LU	Luxembourg
LV	Latvia
MT	Malta
NL	Netherlands
PL	Poland
PT	Portugal
RO	Romania
SK	Slovakia
SE	Sweden
SI	Slovania

List of definitions

Definiendum	**Definition**
Absolute decoupling	The environmental impacts decrease while the economic activity keeps growing.
Apparent consumption	It is the mathematical sum of domestic production plus imports minus exports (APPARENT CONSUMPTION = IMPORTS + DOMESTIC – EXPORTS). It differs from actual consumption because it does not take into consideration changes in stocks.
Area of protection (AoP)	A cluster of category endpoints of recognisable value to society, viz. human health, natural resources, natural environment and sometimes man-made environment (Guinée et al., 2002)
Carrying capacity	The carrying capacity of a biological species in an environment is the maximum population size of the species that the environment can sustain indefinitely, given the food, habitat, water and other necessities available in the environment. In population biology, carrying capacity is defined as the environment's maximal load, which is different from the concept of population equilibrium (Hui, 2006; Sayre, 2008)
Consumer Footprint	The Consumer Footprint refers to the application of the Consumption Footprint with the Consumer Footprint Calculator, where users provide their own consumption intensity data with the aim of performing an analysis of their individual lifestyle.
Consumption Footprint	The Consumption Footprint is a set of 16 LCA-based indicators (also available as a single score) whose purpose is to quantify the environmental impacts of consumption at EU and Member State level. It is based on the combination of: i) the emissions in air, soil and water as well as the resources used along the life cycle of circa 160 representative products, belonging to 5 areas of consumption (food, mobility, housing, household goods, and appliances); ii) the consumption intensities of those products; iii) the Environmental Footprint (EF) impact modelling, which translates emissions and resource consumption into potential environmental impacts (Sala & Sanyé Mengual, 2022)
Domestic Footprint	The Domestic Footprint is a set of 16 LCA-based indicators (also available as a single score) aiming to quantify the environmental impacts due to domestic production and consumption, hence limiting the scope to emissions (as well as resources extracted) within the EU territory translated in impacts by means of the EF impact models (Sanyé Mengual et al., 2022).
Domestic Material Consumption (DMC)	Environmental accounting tool that covers flows of resources by accounting for their mass, adopting the 'apparent consumption' perspective. Products in import and export do not take into account materials used in their production.
Environmental Footprint (EF) – PEF/OEF	Life cycle based methodology for the assessment of the environmental profile of products (PEF) or organisations (OEF).
Environmentally-extended input-output (EEIO) analysis	Accounting method which builds on economic input output tables, complemented with environmental extensions, so to attribute emissions to the environment or resource use from the production stages to final demand in a consistent framework.
Environmental impact	A consequence of an environmental intervention in the environment system (Guinée et al 2002). Potential impact on the natural environment, human health or the depletion of natural resources, caused by the interventions between the technosphere and the ecosphere as covered by LCA (e.g. emissions, resource extraction, land use).
Footprint	A "footprint" is a quantitative measurement describing the appropriation of natural resources by humans. A footprint describes how human activities can impose different types of burdens and impacts on global sustainability (Čuček et al., 2012).
Life Cycle Assessment (LCA)	LCA is a methodology for the systematic evaluation of the environmental aspects of a product or service system through all stages of its life cycle.
Life Cycle Thinking	Life Cycle Thinking (LCT) is about going beyond the traditional focus and production site and manufacturing processes to include environmental, social and economic impacts of a product over its entire life cycle.
Normalisation	According to ISO 14044, normalisation is an optional interpretation step of a complete LCA study. Normalisation allows the practitioner expressing results after characterization using a common reference impact. Using normalisation references in combination with weighting factors, the relative magnitude of an impact may be related to other impacts in the life cycle with a common unit.
Planetary boundaries	A framework concept developed by Rockström et al (2009) to define a desired operating range for essential Earth-system features and processes. Transgressing a terrestrial planetary boundary implies a risk of damaging or catastrophic loss of existing ecosystem functions or services across the entire terrestrial biosphere.
Relative decoupling	The increase of the environmental impacts is lower than the growth of the economic activity.
Trade Footprint	The Trade Footprint aims at calculating the impacts due to the emissions of pollutants and extraction of resources along the supply-chain of trade (namely, imports and exports). It accounts for environmental impacts associated to product's stages of the supply chains happening outside EU borders. It is calculated according to two modelling approaches: bottom-up and top-down.
Weighting	According to ISO 14044, weighting is an optional interpretation step of a complete LCA study. Weighting allows expressing results as a single final score, resulting from assigning a weight to each impact category based on the relative importance of an impact compared to another.

List of figures

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 IPCC 2013) (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 Saouter et al., 2018 (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]EC (2021); [b] Andreasi Bassi et al. (2023); [c] Sala et al. (2018).

Annex 2. Domestic Footprint: substance groups considered by impact category

The following table provides an overview of substance groups considered by impact category. The data sources used by impact category are detailed in Sanye Mengual et al. (2022a).

Impact category	Substance groups
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)
	Clorofluorocarbons (CFC)s; Hydrochlorofluorocarbons (HCFCs)
Ozone Depletion (ODP)	CFCs; HCFCs
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.
Particulate matter (PM)	NO_x; NH_3; SO_2; PM_{10}; $PM_{2.5}$; CO
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
Photochemical ozone formation (POF)	NMVOC as aggregated; NO_X, CH_4; CO
	NMVOC breakdown
Acidification (AC)	NO_x; SO_2; NH_3
Eutrophication, Terrestrial (TEU)	NO_x; NH_3
Eutrophication, freshwater (FEU)	Phosphorous (total) to soil and water, from agriculture
	Phosphorous (total) to soil and water, from sewages
Eutrophication, marine (MEU)	NO_x; NH_3
	Nitrogen (total) to water, from agriculture
	Nitrogen (total) to soil and water, from sewages
Land use (LU)	"Land occupation" and "land transformation": forest, cropland, grassland, settlements, wetlands, unspecified
Water use (WU)	Gross freshwater abstraction & Gross water consumption
Resource use	Minerals and metals (MRD)
	Fossils (FRD)

Annex 3. Consumption Footprint: Complete list of representative products by area of consumption

FOOD	**Product group**	**Representative product**	**Product group**	**Representative product**
	MEAT	Pork meat	BEVERAGES	Beer
		Beef meat		Wine
		Poultry meat		Mineral water
	FISH & SEAFOOD	Salmon	CONFECTIONERY PRODUCTS	Biscuits
		Cod		Chocolate
		Shrimps	TUBERS	Potatoes
		Tuna	FRUITS	Apples
	DAIRY	Milk		Oranges
		Cheese		Bananas
		Butter		Avocados
	EGGS	Eggs		Strawberries
	CEREAL-BASED PRODUCTS	Bread	NUTS & SEEDS	Almonds
		Pasta		Cashew
		Rice	COFFEE & TEA	Coffee
		Quinoa		Tea
	SUGAR	Sugar	VEGETABLES	Tomatoes
	OILS	Sunflower oil		Broccoli
		Olive oil		Carrots
		Rapeseed oil	LEGUMES	Beans
		Soybean oil		Chickpeas
		Palm oil		Lentils
	LEGUME PRODUCTS	Tofu	PRE-PREPARED MEALS	Meat-based dishes
		Soy drink		

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**	**Product group**	**Representative product**
	DETERGENTS	All-purpose cleaners	CLOTHING	T-shirt
		Detergent for dishwashers		Women blouse
		Hand dishwashing detergents		Men trousers
		Laundry detergents liquid		Jeans
		Laundry detergents powder	PAPER PRODUCTS	Newspaper
	SANITARY PRODUCTS	Baby diapers		Book
		Sanitary pads		Toilet paper
		Tampons	PLASTIC PRODUCTS	Toys
		Breast pads		Plastic articles of apparel and clothing
	PERSONAL CARE PRODUCTS	Bar soap		Hair-related products
		Liquid soap		Sandals
		Shampoo		Household plastic articles
		Hair conditioner		Furniture of plastic
	FURNITURE	Bedroom wooden furniture		Sleeping bags
		Kitchen furniture	FOOTWEAR	Work and waterproof
		Upholstered seat		Sport
		Non-upholstered seat		Leisure
		Dining room table		Fashion
	BED MATRESSES	Mattress		

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 4. Consumption Footprint: overview of data sources by area of consumption

The Consumption Footprint is based on the combination of:

i) the emissions to air, soil and water as well as the resources used along the life cycle of circa 160 representative products, belonging to 5 areas of consumption (food, mobility, housing, household goods, and appliances);

ii) the consumption intensities of those products;

iii) the Environmental Footprint (EF) 3.1 impact assessment method, which translates emissions and resource consumption into potential environmental impacts (see Annex 1 for a detailed list).

The Consumption Footprint results from aggregating the environmental impacts of consuming representative products. For each representative product, the consumption intensity is calculated for the year under analysis and multiplied by the environmental impact of the life cycle of the product (allocated to 1 year in case of a longer lifespan, e.g. durable goods). The following equation summarizes the calculation:

$$\text{Consumption Footprint} = \sum_{RP=0}^{RP=n} \text{consumption intensity}_{RP} * \left(\sum_{i=0}^{i=n} \text{environmental pressures}_{i,RP} * \text{impact factors}_{i}\right)$$

The following table provides an overview of the data sources used to calculate the consumption intensity by area of consumption. Further detailed is provided in the JRC technical report detailing the methodological approach[20].

BoP	Product groups	Data source
Food	Meat, Dairy, Oils, Cereal-based products, Beverages, Confectionary, Sugar, Coffee and tea, Fish and seafood, Pre-prepared meals.	PRODCOM database (Eurostat, 2023a) COMEXT database (Eurostat, 2023b)
	Tubers (potatoes), Eggs, Vegetables (tomato, broccoli, carrots), legumes (chickpeas, lentils, beans), fruit (oranges, apples, strawberries), tropical fruits (bananas, avocado), nuts (almonds), quinoa.	FAOSTAT (FAO, 2023a)
	Legume products (Tofu, soy milk)	EFSA (2023)
Appliances	All	PRODCOM database (Eurostat, 2023a) COMEXT database (Eurostat, 2023b)
Household goods	All	PRODCOM database (Eurostat, 2023a) COMEXT database (Eurostat, 2023b)
Housing	Archetypes (number of dwellings)	EU Building database (EC, 2023)
	Energy and water consumption	Hotmaps Project (IWU, 2016) TABULA web-tool (Pezzutto et al., 2018) EU Building database (EC, 2023)
Mobility	Passenger cars	Statistical pocketbook 2022 (EC, 2022b), Eurostat (2023c; 2023d;2023e)
	Motorcycles and mopeds	Eurostat (2023f)
	Public transport (bus)	Eurostat (2023g)
	Rail transport	Statistical pocketbook 2022 (EC, 2022b)
	Air transport	Eurostat (2023h, 2023i, 2023j)

[20] https://publications.jrc.ec.europa.eu/repository/handle/JRC132734

Annex 5. Regionalization of the Consumption Footprint: overview of data sources

The regionalization of the Consumption has addressed the aspects detailed in the following table, by life cycle stage and area of consumption. A set of data sources with official statistics has been combined in order to collect information at the Member State level.

Stage	Area of consumption	Aspect	Data source
Raw materials	Food	Feedstock diet	Global Livestock Environmental Assessment Model – interactive GLEAM-i (FAO, 2023b).
		Feed market	Import and production data from COMEXT (Eurostat, 2023b), PRODCOM (Eurostat, 2023a) and FAOSTAT (FAO, 2023a).
		Transport	
		Food products market	
	Appliances, household goods, mobility, housing	Raw materials origin	Import and production data from COMEXT (Eurostat, 2023b), PRODCOM (Eurostat, 2023a) and FAOSTAT (FAO, 2023a).
		Transport	
Manufacturing	All	Food products & Manufactured goods origin	Import and production data from COMEXT (Eurostat, 2023b), PRODCOM (Eurostat, 2023a) and FAOSTAT (FAO, 2023a).
		Electricity consumption during manufacturing	Annual electricity mix by country (Eurostat, 2023k; IEA, 2020). Domestic production and trade (Eurostat, 2023n, 2023o, 2023p).
Packaging	Food, appliances, household goods	EoL treatment	Annual waste treatment by type (Eurostat. 2023l).
Distribution	Food, appliances, household goods, mobility (passenger cars)	Food products & Manufactured goods origin	Import and production data from COMEXT (Eurostat, 2023b), PRODCOM (Eurostat, 2023a) and FAOSTAT (FAO, 2023a).
Use	All	Electricity consumption	Annual electricity mix by country (Eurostat, 2023k; IEA, 2023).
	Food	Wastewater treatment	Annual wastewater treatment level (Eurostat, 2023m).
End of Life	All	EoL treatment	Annual waste treatment by type (Eurostat. 2023n).
		Wastewater treatment	Annual wastewater treatment level (Eurostat, 2023m).

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