ETC CE Report 2024/10

Drivers of consumption and sustainable consumption levels

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European Environment Agency
European Topic Centre
Circular economy and resource use

Cover design: EEA
Cover image © Unsplash
Layout: ETC CE

Publication Date November 2024

EEA activity Circular Economy and Resource Use

ETC CE coordinator: Vlaamse Instelling voor Technologisch Onderzoek (VITO)

ETC CE partners: Banson Editorial and Communications Ltd, česká informační agentura životního prostředí (CENIA), Collaborating Centre on Sustainable Consumption and Production (CSCP), Istituto Di Ricerca Sulla la Crescita Economica Sostenibile, Istituto Superiore per la Protezione e la Ricerca Ambientale, IVL Swedish Environmental Research Institute, Norion, Università Degli Studi Di Ferrara (SEEDS), German Environment Agency (UBA), Teknologian Tutkimuskeskus VTT oy, Wuppertal Institut für Klima, Umwelt, Energie gGmbH, World Resources Forum Association

European Topic Centre on
Circular economy and resource use
https://www.eionet.europa.eu/etcs/etc-ce

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Acknowledgements

Input from EEA-experts:
- Ioannis Bakas

Review by ETC CE experts:
- An Vercalsteren (VITO)
- Renato Marra Campanale (ISPRA)

Note that this report uses the term “consumption footprint” to refer to the aggregation of environmental and climate impacts linked to the EU consumption. The EEA has since the drafting of the report changed the term it uses for addressing such impacts into “global impacts from European consumption”.

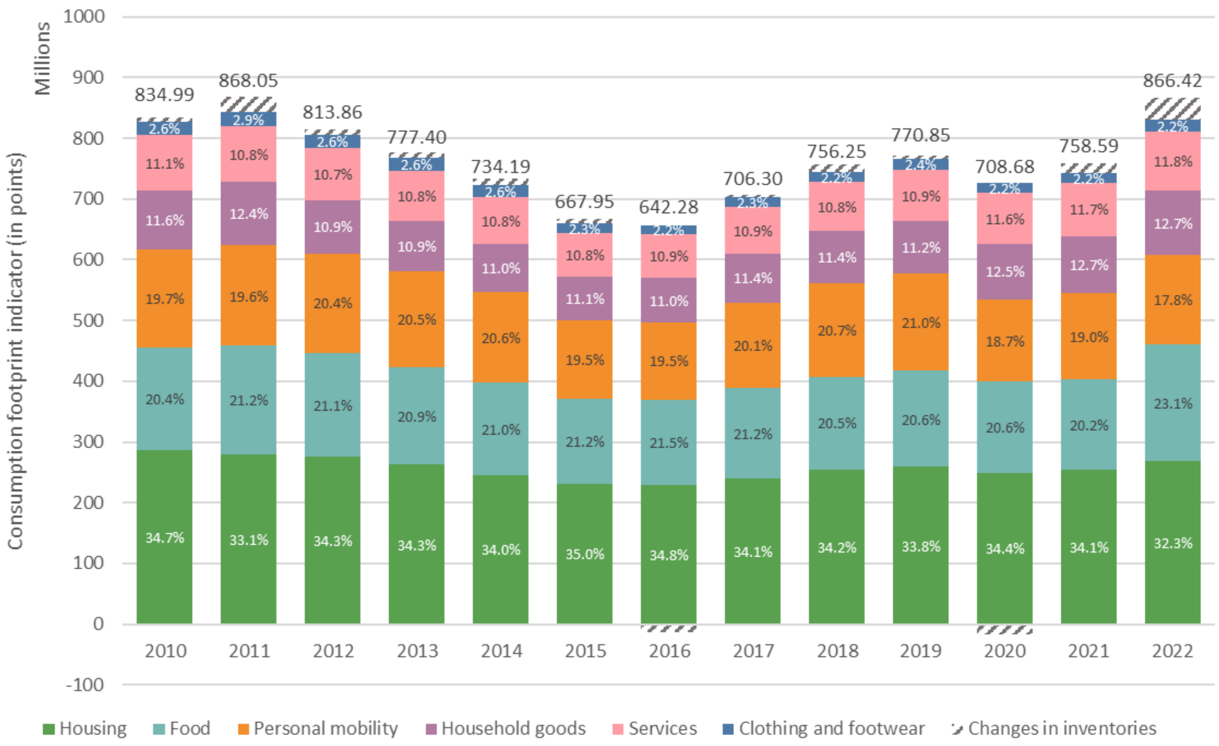
Summary

This report analyses the consumption footprint of EU-27 final use supporting a better understanding of the observed status, drivers, and trends. The consumption footprint refers to the environmental and climate impacts resulting from the consumption by EU citizens of goods and services, whether produced within or outside the EU. To monitor the EU’s consumption footprint, this indicator uses a single score that represents all types of impacts on the environment and climate caused by consumption of goods and services by EU citizens. The impact of EU-27 final use, or the consumption footprint indicator (CFI), decreased in the 2010-2016 period, but increased in the period 2016-2022, except for 2020 where we see a decrease due to the COVID crisis. The main drivers of these trends are discussed per consumption domain. In addition, the report provides the link between the consumption footprint and the planetary boundaries concept by applying allocation approaches to derive planetary boundaries at regional scale. As multiple planetary boundaries are transgressed, sustainable consumption pathways are discussed focusing on circular economy in food, mobility, and housing.

1 Introduction

The EU's Eighth Environment Action Programme (8th EAP) calls for a significant reduction in the EU's consumption footprint, to bring it within planetary boundaries. The consumption footprint refers to the environmental and climate impacts resulting from the consumption by EU citizens of goods and services, whether produced within or outside the EU. To monitor the EU's consumption footprint, this indicator uses a single score that represents all types of impacts on the environment and climate caused by consumption of goods and services by EU citizens. The impact of EU-27 final use, or the consumption footprint indicator (CFI), is presented in Figure 1.1, and further explained in Chapter 2.

Figure 1.1: The consumption footprint indicator, CFI, of total final demand in EU-27, per consumption domain, 2010-2022. Total values including changes in inventories, consumption domain percentages excluding changes in inventories.



Source: ETC CE calculations based on FIGARO (2024 Edition, 2010-2022 data).

Given the relatively small overall reduction in the consumption footprint in the last decade and the fact that the footprint has in fact increased since 2016, the EU faces a significant challenge in achieving its aim of significantly reducing the consumption footprint by 2030. At present, it is unclear whether this aim will be achievable.

This report aims to understand better the reasons or drivers behind consumption trends and behind trends in consumption-based environmental impacts. To reduce the consumption footprint, the EU would need to make significant efforts to reduce its overall consumption of goods and services or to shift to the consumption of goods and services that have a lower impact on the environment, or both. In general, consuming services has less of an impact on the environment than consuming physical products. Therefore, promoting circular business models based on sharing or product-as-a-service schemes could help to reduce the consumption footprint.

On the other hand, an established policy ambition for the EU is to live well within the limits of our planet. This hints to the planetary boundaries concept (Richardson et al., 2023; Steffen et al., 2015a; Rockström et al., 2009a) and the subsequent assessment about the Earth's carrying capacity to absorb resiliently impacts on ecosystems caused by human activities. The JRC has tried to operationalize this framework by associating planetary boundaries with the 16 impact categories included in the European Commission's Environment Footprint method.

Based on this analysis by the JRC, the question that arises, from a policy perspective, is how one can define sustainable consumption in Europe so that the long-term objective of living well within the limits of the planet can be achieved. Therefore, the overall aim of this report is twofold:

1. Understand, also quantitatively, the main contributors to consumption impacts in Europe and their trends over time.
2. Define sustainable consumption patterns that aim at not transgressing planetary boundaries.

The analysis of the trend, focusing on the impacts from EU-27 final consumption of 2010-2022, is discussed in **Chapter 2**. An introduction is given to the environmental footprint methodology, the calculation methodology and definitions and scope on final use and consumption domains. More details are found in Annex 1. The overall results are presented and assessed focusing on the most important contributors to Europe's environmental impacts from its consumption patterns in a dynamic way, meaning that trends over time are considered. The outcome of this analysis constitutes a hotspot identification, coupled with an analysis about consumption expenditure patterns in the EU-27 region. In **Chapter 3** the planetary boundaries concept is explained and linked to the European Commission's Environment Footprint method. Deriving science-based targets at regional and country level requires downscaling the concept of planetary boundaries. Multiple allocation principles exist to derive boundaries at national and regional scale. These downscaled boundaries at EU-27 level are compared to the results from Chapter 2. The concept of planetary boundaries goes along with multiple uncertainties. An introduction to the different types of uncertainties is given in Chapter 3. In **Chapter 4** three sustainable consumption pathways are discussed: a housing pathway, a food pathway and a personal mobility pathway. Each pathway comprises reduce, shift and improve solution strategies to reduce Europe's consumption footprint in order to stay within the Earth's safe operating space.

2 Drivers of consumption impacts in Europe

Key messages:

- Key message 2.1: The impacts of consumption generally follow the pattern of changes in the domestic final use volumes of EU-27 (see Figure 2.3). Overall, we see an upward trend in consumption volume (+10 %, in constant prices) in the 2010-2022 period, while the impacts of consumption only increase by about 4 % in this period. From 2013 to 2016, there is a widening gap between the two indicators. This gap reflects the reductions in the Consumption Footprint per unit of consumption volume due to improved production efficiency, reduced environmental impacts and structural changes in global production networks. However, from 2016 to 2022, this gap gradually starts to close again due to a reversal in the environmental impact reductions combined with growing consumption volumes.
- Key message 2.2: The results illustrate the importance of environmental improvements in production networks. While they partly cancel out the consequences of increasing consumption volumes in the EU-27, they are insufficient for an absolute decoupling of the impacts from consumption volumes.
- Key message 2.3: Striving towards reductions in the environmental footprint requires a speeding up of environmental improvements in production networks that focus on all environmental impact categories, but also putting more emphasis on reducing final consumption volumes and shifting consumption to products with a lower environmental footprint.

2.1 Introduction and structure

The EU's Eighth Environment Action Programme (8th EAP[1]) calls for a significant reduction in the EU's consumption footprint, to bring it within planetary boundaries. The consumption footprint refers to the environmental and climate impacts resulting from the consumption EU-27of goods and services by EU-27 citizens, whether produced within or outside the EU-27.

This assessment framework is built on a consumption-based perspective in which environmental impacts of the entire product life cycle (raw material extraction, production, use phase, re-use/recycling and disposal) are allocated to the country where the product is consumed, irrespectively of where they occur in the world. Therefore, based on trade statistics, environmental impacts of the production of imported goods consumed in the EU-27 are included in the analysis, whereas the impacts of production of exported goods are not.

The Consumption Footprint comprises a set of indicators for assessing the environmental impact of EU-27 consumption to monitor progress towards EU policy ambitions. The EU-27 consumption footprint indicator also aggregates all environmental impact indicators in a single score that represents all types of impacts on the environment and climate caused by consumption of goods and services by EU-27-citizens[2]. As described by the EC[3], the indicators can be employed for policy support:

- **Identification of environmental hotspots**: the granularity of the indicators can provide information at different levels (environmental issues with the highest relevance, most impactful areas of consumption, product groups and products with high footprints, most critical life cycle stages of products, most relevant type of resource used or emissions to the environment).
- **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 how

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[1] EC, 2022, 'Environment action programme to 2030', European Commission (https://environment.ec.europa.eu/strategy/environment-action-programme-2030_en) accessed June 24, 2022.

[2] EC, 2022, 'The environmental footprint pilots', (https://ec.europa.eu/environment/eussd/smgp/ef_pilots.htm) accessed July 1, 2022.

[3] Consumption Footprint | EPLCA (europa.eu) (https://eplca.jrc.ec.europa.eu/sustainableConsumption.html)

much the EU is decoupling environmental impacts from economic growth, the benefits of transitioning towards a circular economy, the ability of the EU to remain within planetary boundaries, as well as progress related to the SDGs (especially SDG12 on responsible consumption and production).

- **Setting a baseline** against which policy options, policy targets and scenarios can be tested: the modularity of the indicators allows to 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 spillover effects, since the indicators could unveil the trade footprint, namely the number of impacts embodied in imported goods.

The Consumption Footprint Indicator (CFI) includes the 16 environmental impact categories of the Environmental Footprint method, as follows (the description is taken from Mengual et al. (2023)):

- **CC**, **climate change**: Global impact due to changes induced to the climate, including increased average global temperatures and sudden regional climatic changes, as a consequence of the emissions to the atmosphere of the so-called greenhouse gases, such as CO_2, CH_4, and N_2O.
- **ODP**, **ozone depletion**: Global impact related to the breaking-down of stratospheric O_3, including increased skin cancer cases in humans and damage to plants, as a consequence of man-made emissions of halocarbons (as CFCs and HCFCs), halons, and other long-lived gases containing chloride and bromine.
- **HTOX_nc**, **human toxicity, non-cancer**: Local and regional impact to humans due to the exposure (i.e. due to inhalation of air, drinking water, etc.) to toxic substances emitted to the environment and responsible for diseases (e.g. respiratory disease) other than cancer.
- **HTOX_c**, **human toxicity, cancer**: Local and regional impact to humans due to the exposure to toxic substances emitted to the environmental and responsible for cancer effects.
- **PM**, **particulate matter**: Impact on human health due to the increased ambient concentrations of particulate matter (PM) due to the emissions of primary and secondary particulates (i.e. precursors, NO_x, SO_2).
- **IR**, **ionising radiation**: Impact to human health due to the exposure to ionising radiation (radioactivity) under normal operating conditions (i.e. excluding accidents in nuclear plants)
- **POF**, **photochemical ozone formation**: Local and regional impact to the environment and human health related to the formation of tropospheric ozone resulting from the oxidation of solvents and other volatile organic compounds (VOCs) released to the atmosphere that affects organic compounds in animals and plants and can increase the frequency of respiratory problems.
- **AC**, **acidification**: Regional impact to the environment regarding the modification of acidity of soils, as a consequence of the emission and deposition of acids (and compounds that can be converted to acids) into the environment.
- **TEU**, **eutrophication, terrestrial**: Local and regional impact on terrestrial ecosystems due to substances containing nitrogen (N) or phosphorus (P), which leads to the disappearance of ecosystems that are poor in nutrients.
- **FEU**, **eutrophication, freshwater**: Local and regional impact on freshwater ecosystems due to substances containing phosphorus (P), which leads to reduced oxygen availability following increased algal growth.
- **MEU**, **eutrophication, marine**: Local and regional impact on marine ecosystems due to substances containing nitrogen (N), which leads to reduced oxygen availability following increased algal growth.
- **LU**, **land use**: Impacts due to the effects of occupation and transformation of land in terms of reduction of soil qualities (e.g. modification in the organic matter content of soil, or loss of the soil itself (erosion)).
- **ECOTOX**, **freshwater ecotoxicity**: Local and regional impact on freshwater ecosystems due to the release of toxic substances that can accumulate and affect individual species as well as the functioning of the entire ecosystem.

- **WU**, **water use**: Impact related to the consumption of freshwater (lakes, rivers, or groundwater)
- **FRD**, **resource use, fossils**: Global impact related to the decreased availability and the potential scarcity for future generations of the total reserve of fossil resources.
- **MRD**, **resource use, minerals and metals**: Global impact related to the decreased availability and the potential scarcity for future generations of the total reserve of mineral and metal resources.

A detailed description of each impact category can be found in Annex 1 of Sala et al. (2023).

Those impacts might ultimately lead to the impairment of human health, biodiversity and natural resource loss, climate change, changing land and water availability, etc. These 16 impact categories can be normalized and weighted into a single weighted score[4]. Normalization means that all impact indicators are multiplied by normalization factors that represent the overall impact of a reference unit (e.g. a whole country or an average citizen). Normalized results based on the Environmental Footprint method express the relative shares of the impacts of EU consumption by citizens compared to global impacts (per person). Weighting means that all impact indicators are given a weight factor that expresses the 'importance' of the impact compared to the others. This allows the aggregation (summing up) of all impact indicators into one single value. Although the characterisation, normalisation and weighting factors are constant over time (same factors used for the entire 2010-2022 period), the different weighting factors across impact categories cause not all impact categories to be equally influential in the results. Because of these weighting factors, the overarching trend will be more dependent on impact categories that receive a relatively higher weighting factor, such as CC, PM, WU, FRD, LU and MRD.

The calculation of the EU-27 Consumption Footprint is based on an adapted version of the environmentally extended multiregional input-output model FIGARO. Annex 1 provides a description of the model FIGARO, followed by the calculation methodology and the modifications done to this model. A last part is added to this annex on the composition and description of the consumption domains used throughout this report. To allow for a more in-depth analysis on the consumption domains, we make use of the model EXIOBASE (Annex 1).

This report focuses on hotspots and trends in **total EU-27 final consumption**. When looking at these, it is important to define what is regarded as this total consumption. In statistics, it is Europe's so-called domestic final uses which includes final consumption expenditures by households, non-profit institutions serving households (NPISH) and governments, as well as gross capital formation. The gross capital formation comprises gross fixed capital formation and changes in inventories and acquisitions less disposals of valuables. The changes in inventories and changes in valuables comprises some smaller changes in company inventories.

Expenditures by households include all goods and services bought by households directly, such as energy, insurances, and expenditures at supermarkets/shops. Governmental consumption expenditures cover the provision of services to the community by governments, including education, health, the justice system, defence, and the police. Furthermore, expenditure by NPISH include for example, sports clubs, unions, churches, charities, etc. Investments, such as in infrastructure, machinery, and equipment, typically have no link or at least no direct link to household consumption but are required for serving societal or company purposes.

Following the above argument, **this report interprets total EU-27 final consumption in Europe more broadly than just consumption expenditure by households; it also includes consumption expenditure by NPISH, governments and investments**. This scope is more closely related to the concept of apparent consumption used by the Joint Research Centre (JRC) in its work on the basket of products indicators (Sala and Sanye, 2022). The intention of apparent consumption is to estimate the total use of a product group for any purpose within the territory. It is defined as production plus imports minus exports and is typically calculated for product groups.

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[4] In this report we apply the EF 3.1 normalisation and weighting factors.

This report distinguishes **seven consumption domains,** or areas of consumption, when looking at total EU-27 final consumption:

- **food** – food, drinks, and hotels and restaurants, etc;
- **clothing and footwear**;
- **housing** – dwellings, heating, hot water and electricity, including investment in dwellings by households;
- **personal mobility**;
- **household goods** – household equipment, appliances, and information and communications technology (ICT);
- **services** – health, education, finance, postal services, and recreation; and
- **changes in inventories** – changes in inventories and valuables.

Changes in inventories (or stocks) are defined as the difference between additions to and withdrawals from inventories. In national accounts they consist of changes in stocks of inputs, work in progress, and outputs that are still held by the units that produced them prior to their being further processed, sold, delivered to other units or used in other ways, and strategic stocks managed by government authorities (food, oil, stocks for market intervention).

These consumption domains follow the COICOP classification [5] and are aggregated to ensure comprehensive analysis and easy comparison between a limited number of large consumption domains in Europe. More details on the definition of the scope and the aggregated consumption domains can be found in Annex 1.

It is noted that the **scope of personal mobility is different from the scope of transport** as often referred to in other indicators. In this report, personal mobility is one of the household consumption domains, which covers the purchase of vehicles; their maintenance and repair, including servicing and parts; passenger transport services, for example, public transport and taxis; and the transport of goods, including postal and courier services. The consumption domain does not, at least not directly, consider freight transport, which is part of most supply networks, but is only indirectly linked to all consumption domains.

2.2 Overall results

Overall, the EU-27 Consumption Footprint indicator (CFI) is considered high, as it exceeds the planetary boundaries for several types of impacts, such as impacts on climate change and land use (see Chapter 3). Between 2010-2022, the CFI increased slightly, by around 4 %. However, Figure 2.1 shows a substantial decrease of 23 % between 2010 and 2016, followed by a steady increase in the indicator until a drop in 2020, the first year of the COVID-19 pandemic. In the aftermath of the pandemic, the consumption footprint continued its upward trajectory with a sharp increase of over 22 % between 2020 and 2022, reaching its second-highest level of the evaluated period in 2022. The CFI per capita increased from 1.89 points per capita in 2010 to 1.94 point per capita in 2022.

Starting from 2010, the CFI decreased until 2016 and increased again until 2022, with a dip in 2020. Based on our macro-economic analysis we found two main drivers for this trend. The first one is fluctuating **consumption volumes of EU-27 final demand corresponding with trends in population growth and affluence or spending (Figures 2.2-2.4)**. In each consumption domain the volume of consumption generally shows a decline until 2013, followed by an increase from 2014 to 2022, interrupted by a dip due to the coronavirus pandemic in 2020 (Figure 2.2). There is some variation in the volume-of-consumption

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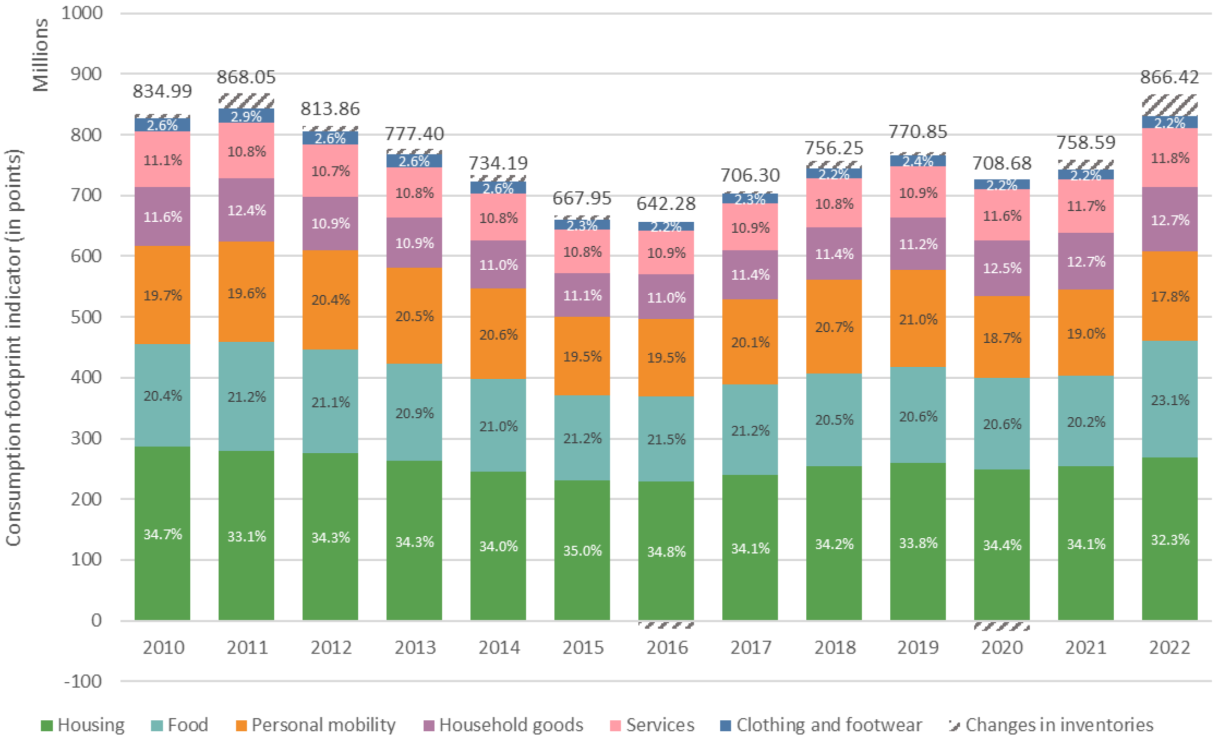
[5] Classification of Individual Consumption According to Purpose (COICOP). In this classification, consumption domains consist of certain product groups, but are not one-on-one related to specific material categories. For example, textiles products are included in category CPA03 ‘clothing and footwear’ and as well in CPA05 ‘furnishings, household equipment and routine household maintenance’.

trend across the consumption domains (e.g. the decline until 2013 is relatively limited for the food, services, and clothing and footwear domains compared to the other domains, while the dip due to the COVID crisis is relatively limited for the housing, household goods, and services domains). However, by 2022 the volume of consumption has increased for all consumption domains except for housing relative to 2010, resulting in an upward effect on the consumption footprint. Yet despite a 10 % increase in the volume of consumption between 2010 and 2022, we see a more limited increase of about 4 % in the CFI.

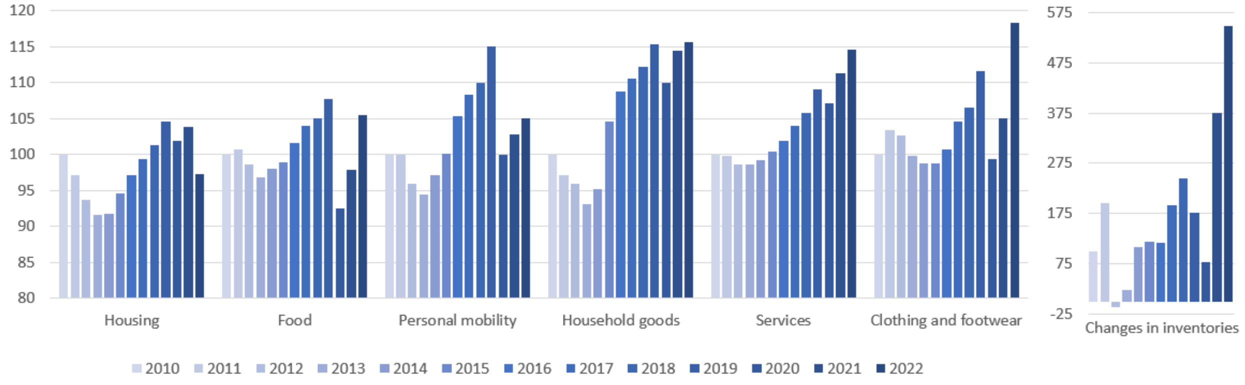
A second driver is a change in the Consumption Footprint per volume unit of production. This driver includes **environmental efficiency gains due to improved production/technology efficiency and the decarbonisation of energy production in both the EU and the rest of the world. (Figure 2.4)**. We observe a reduction in the Consumption Footprint per volume unit of production during the first part of the evaluated period (until ca. 2015) and in the last two years. However, our results show that the Consumption Footprint per volume unit of production increased between 2016 and 2020, contributing to the upward trend in the CFI between 2016 and 2019 (in combination with the increasing consumption volumes). In 2020, the increasing contribution of the Consumption Footprint per volume unit of production to the CFI is masked by the drop in the EU-27 volume of consumption due to the coronavirus pandemic. Conversely, in 2021 and 2022 the increase in consumption volumes causes the CFI to increase, despite renewed reductions in the Consumption Footprint per volume unit of production.

Figure 2.1: The consumption footprint indicator, CFI, of total final demand in EU-27, per consumption domain, 2010-2022. Total values including changes in inventories, consumption domain percentages excluding changes in inventories.



Source: ETC CE calculations based on FIGARO (2024 Edition, 2010-2022 data).

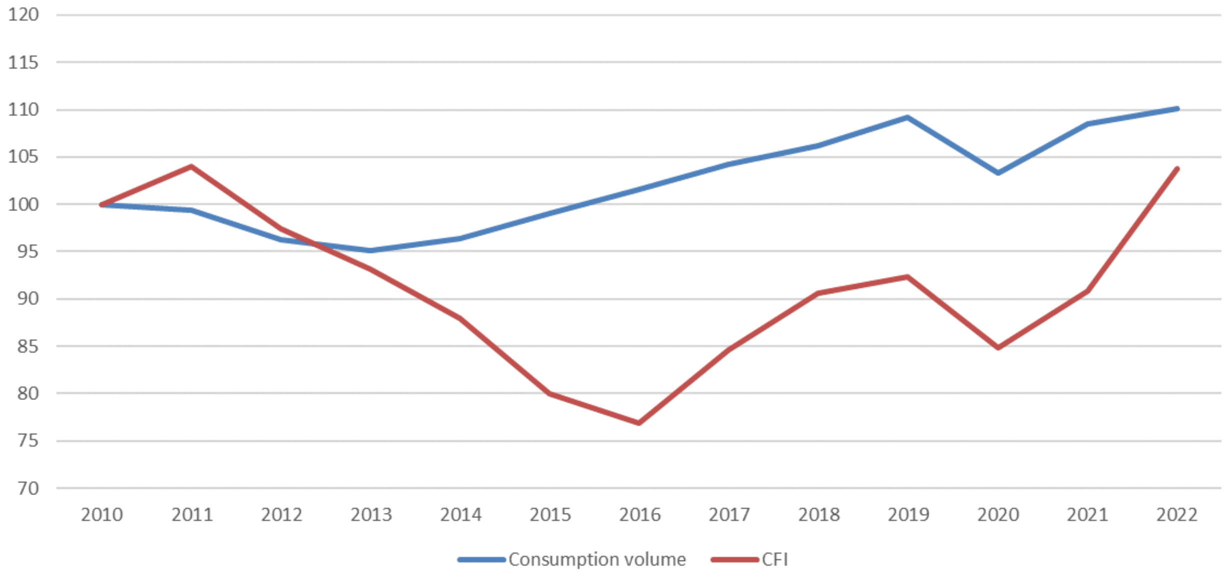
Figure 2.2: Consumption volumes of EU-27 final demand, per consumption domain, 2010-2022, indexed chain linked volumes at constant prices (2010 = 100).



Source: ETC CE calculations based on FIGARO (2024 Edition, 2010-2022 data) and Eurostat dataset [prc_hicp_aind].

Figure 2.3 visually shows the relationship between the first driver, consumption volume, and the CFI. The curve of the CFI does not exactly follow the same trend as the consumption volume, reflecting the influence of the second driver, improved production efficiency, on the CFI. Notably, the consumption volume starts to increase from 2013 onwards, while the CFI continues to decline until 2016. This widening gap between the two curves is thanks to the second driver: during that period, improvements in production efficiency (reductions in Consumption Footprint per volume production) lead to a decrease in the CFI, despite an increase in consumption volume. However, starting in 2016, the effect of this second driver reverses and combined with an increasing consumption volume, this causes the CFI to increase again.

Figure 2.3: The consumption volumes of EU-27 final demand at constant prices and the Consumption Footprint Indicator, 2010-2022, indexed values (2010 = 100).



Source: ETC CE calculations based on FIGARO (2024 Edition, 2010-2022 data) and Eurostat dataset [prc_hicp_aind].

Figure 2.4 illustrates the effect of the two drivers, with the effect of the driver on consumption volumes split into growth in affluence and population growth. These results are based on **a decomposition analysis** of the CFI using these three components. The results show annual changes.

Figure 2.4: A decomposition analysis of the consumption footprint indicator of EU-27 final demand.

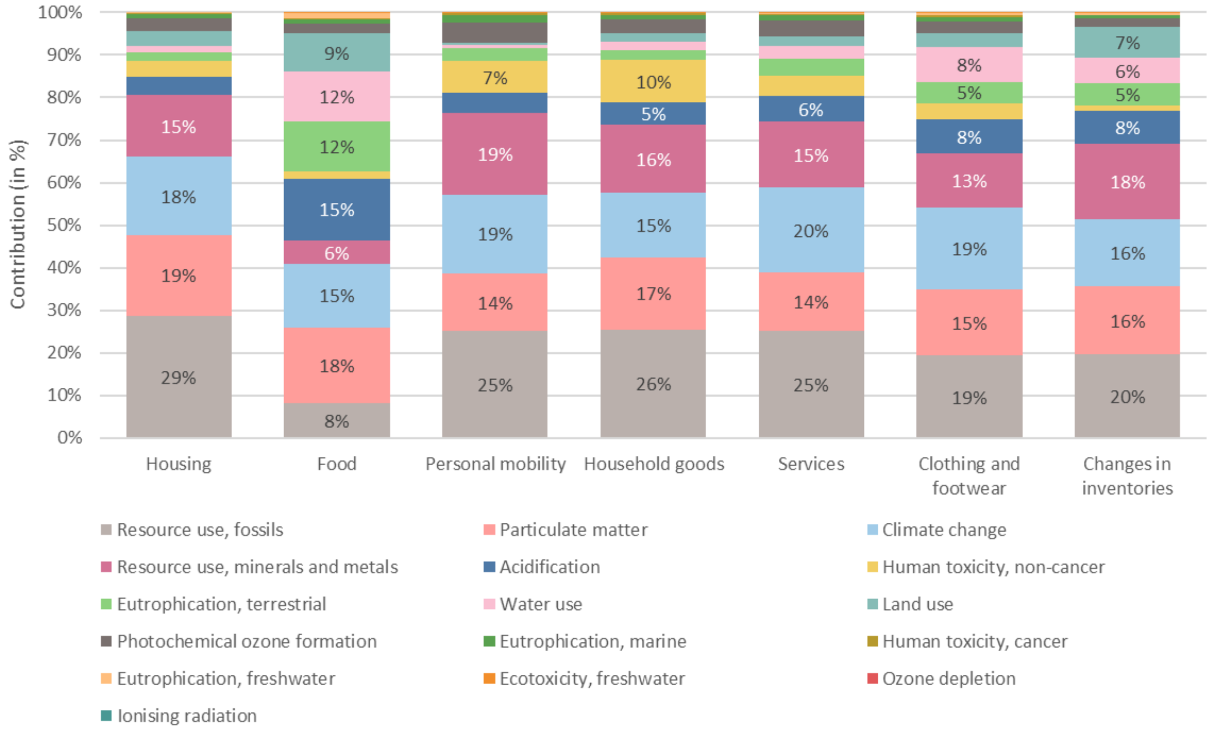
Source: ETC CE calculations based on FIGARO (2024 Edition, 2010-2022 data).

Overall, in the period 2010-2016 the positive effects on the CFI of environmental efficiency gains and changes in the production networks (i.e., different sourcing of input products or input substitutions) are much larger than the negative effect on the CFI from increasing and changing consumption and increasing population. The net effect resulted in a decrease in fossil resource use, minerals and metals resource use, particulate matter, and climate change. In the 2016-2022 period, the CFI increases mainly due to an increase in the consumption volume (i.e., affluence), and to a lesser extend an increase in population. The environmental efficiency gains were too small, or even absent, to outweigh the effects of increased consumption (Figure 2.4).

The contribution shares of the consumption domains are stable over time (Figure 2.1). The consumption domain housing represents the largest share with a contribution to the Consumption Footprint indicator of 32.3 % in 2022, followed by food (23.1 %), personal mobility (17.8 %), household goods (12.7 %), services (11.8 %), and clothing and footwear (2.2 %). Although consumption volumes increased, shifts across consumption domains are limited.

The environmental impact categories contributing the most, after normalisation and weighting, to the CFI are fossils resource use (FRD, 22 %), followed by climate change (CC, 17 %), particulate matter (PM, 17 %), and minerals and metals resource use (MRD, 14 %). Figure 2.5 shows that these four impact categories make up at least 66 % of the CFI of all consumption domains except the food domain (47 %). Looking at food, most impact categories have a significant contribution to the CFI. The largest environmental impact results from PM (18 %), followed by CC (15 %), acidification (AC, 15 %), water use (WU, 12 %), and eutrophication, terrestrial (TEU, 12 %). The contribution of the other environmental impact categories to the CFI of the consumption domains varies (Figure 2.5).

Figure 2.5: The contribution of the environmental impact categories in the CFI per consumption domain, 2022.

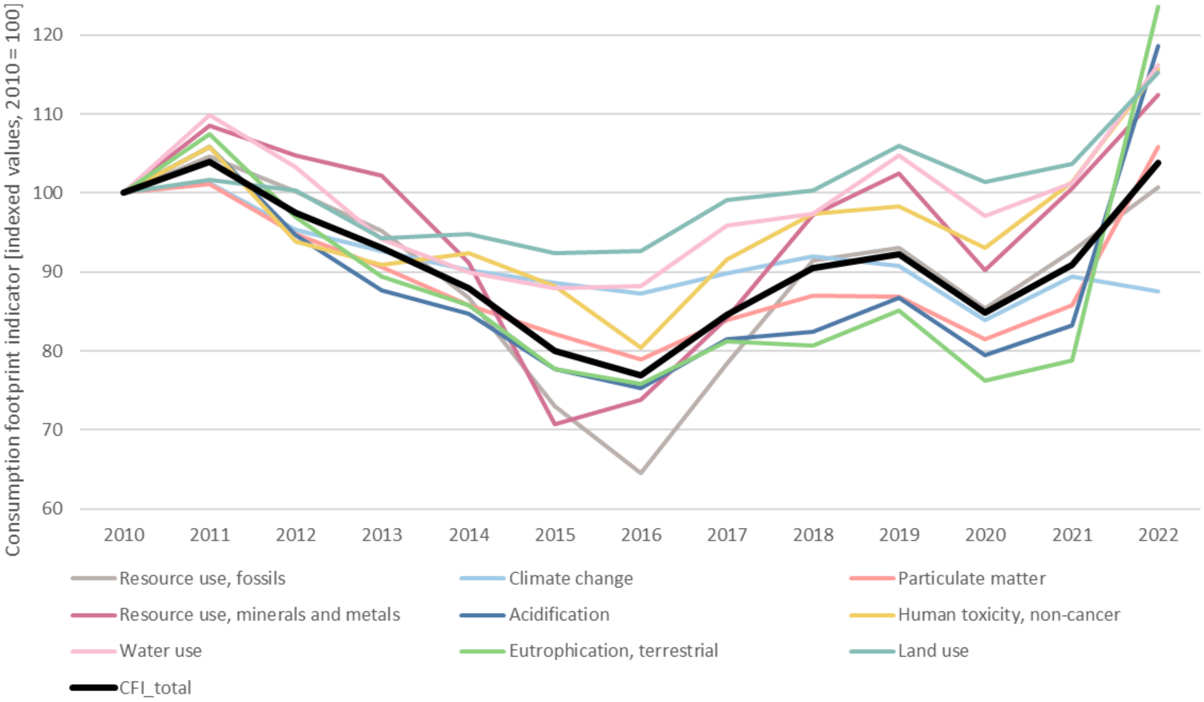


Source: ETC CE calculations based on FIGARO (2024 Edition, 2010-2022 data).

In terms of temporal evolution, most of the individual environmental impact categories follow a pattern similar to the overall CFI, with a notable exception for climate change (Figure 2.6). The CFI contribution of the influential impact categories resource use, fossils (FRD) and resource use, minerals and metals (MRD) shows a strong decline in the years leading up to 2016, but a steep increase in the second half of the evaluated period causes the 2022 value of FRD to be on par with its 2010 value, while the MRD exceeds its original value by about 12 % in 2022. Conversely, the contribution of the CC impact category to the CFI remains relatively stable after an initial decline, even in 2022 when all other impact categories show a sharp increase. The CC impact category is the only one with a lower value in 2022 than in 2010 (about a 12 % decrease).

In 2022, activities within the EU-27 account for 45 % of the impacts, while 55 % originate from outside the EU-27. These shares are stable in the 2010-2022 period. Thus, **more than half of the environmental impact of EU-27 consumption takes place outside Europe**. The consumption domains of clothing and footwear, changes in inventories, and household goods have the highest share of their impact outside the EU, with a non-EU share of respectively 84 %, 81 %, and 76 % in 2022. It means that these consumption domains are mainly covered through imports from outside the EU-27, or at least that the impacts from production activities originate mostly from outside the EU-27. Housing and food have the lowest impact outside the EU with, respectively, 53 % and 50 %. Personal mobility (61 %) and services (58 %) have a moderate share of non-EU impacts. The environmental impacts which are outsourced most outside the EU-27 are resource use, minerals and metals (MRD, 85 %), human toxicity, non-cancer (HTOX_nc, 69 %), resource use, fossils (FRD, 65 %), water use (WU, 63 %) and Ecotoxicity, freshwater (FEU, 62 %). Photochemical ozone formation (POF, 33 %), eutrophication, marine (MEU, 36 %), and climate change (CC,39 %) have the highest share of impacts in the EU-27.

Figure 2.6: The consumption footprint indicator, CFI, of total final demand in EU-27, per environmental impact category (only 9 impact categories with highest contribution to the CFI are shown to increase readability), 2010-2022, indexed values (2010 = 100). The big black line shows the total consumption footprint indicator.



Source: ETC CE calculations based on FIGARO (2024 Edition, 2010-2022 data).

There are no large changes in the contribution of sectors in the production networks to the CFI, nor are there large shifts in the contribution of the final demand categories. An exception is the change in inventories. This relatively small category that is part of EU-27 final demand shows large fluctuations. The category shows the change in the monetary value of inventories (both raw materials and products) of companies. Large changes are due to economic effects in global markets (e.g., changes in prices or economic expectations).

In the following sections, a more in-depth analysis is done for the consumption domains of housing, food, household goods, personal mobility, and services. To allow for such details, the use of EXIOBASE is necessary, as the FIGARO model provides insufficient details in the products/industry classification. The EXIOBASE results discussed below cover the period 2010-2021.

2.2.1 Housing

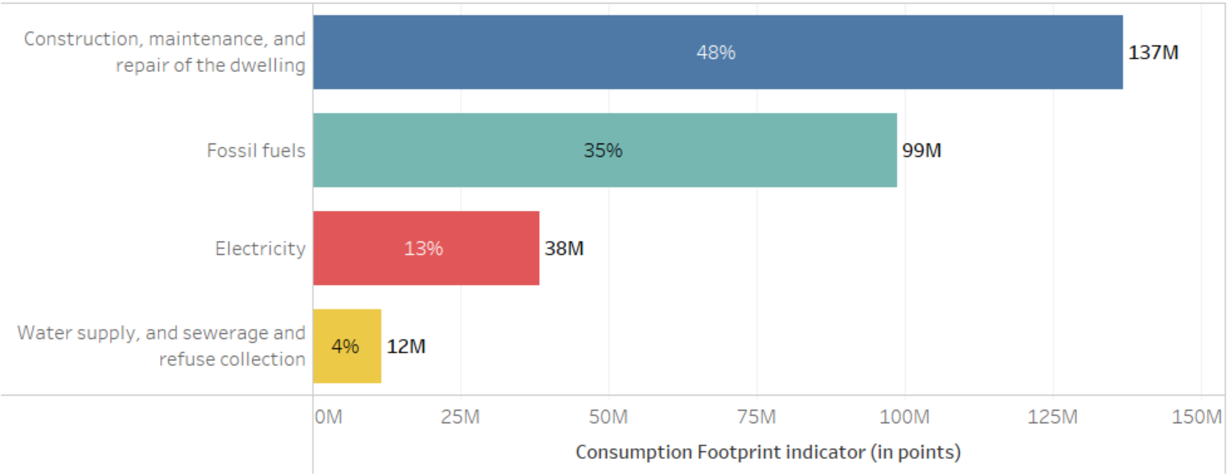
The consumption domain '**housing**' has a share of **34.1 % in the total CFI** excluding changes in inventories (2021) and is composed of four main categories:

- Construction, maintenance, and repair of the dwelling;
- Use of fossil fuels;
- Electricity; and
- Water supply, sewerage and refuse collection (including waste management).

The first category of construction is mainly linked to the final demand category of investments (73 %), to household consumption (16 %) and to consumption expenditures by governments (10 %). The remaining 1 % is linked to the consumption expenditures of non-profit institutions serving households (NPISHs). The construction and major renovations of dwellings and other constructions and infrastructure is part of the investments final demand category, while household and governmental consumption expenditures mainly encompass smaller renovations and maintenance activities. The other three categories are more directly linked to household consumption.

The CFI of housing represents 30.6% of the total CFI in 2021 (287 million points). 48 % of this impact is related to the construction, maintenance, and repair of the dwelling, 35 % to fossil fuels, 14 % to electricity and the remaining 4 % to water supply, sewerage and refuse collection (see Figure 2.7).

Figure 2.7: CFI of total final demand in EU-27, consumption domain housing, 2021.



Source: ETC CE calculations based on Exiobase v3.8.2.

The CFI related to fossil fuels can be broken down into solid fuels (24 %), gas (9 %), liquid fuels (9 %) and the direct emissions by households (48 %). This last category is related to the environmental impacts of households during the use (burning) of the fossil fuels mainly for heating purposes. The others are environmental impacts resulting from the mining and production of the fuels. The relatively high environmental impact of solid fuels is due to the high resource depletion caused by mining of solid fuels (FRD).

Households use energy for various purposes: space and water heating, space cooling, cooking, lighting and electrical appliances and other end-uses (mainly covering uses of energy by households outside the dwellings themselves). The results for 2021 show that space heating is responsible for 64 % of the total energy consumption, followed by water heating (15 %), lighting and electrical appliances (14 %) and cooking (6 %) (Eurostat, 2023).

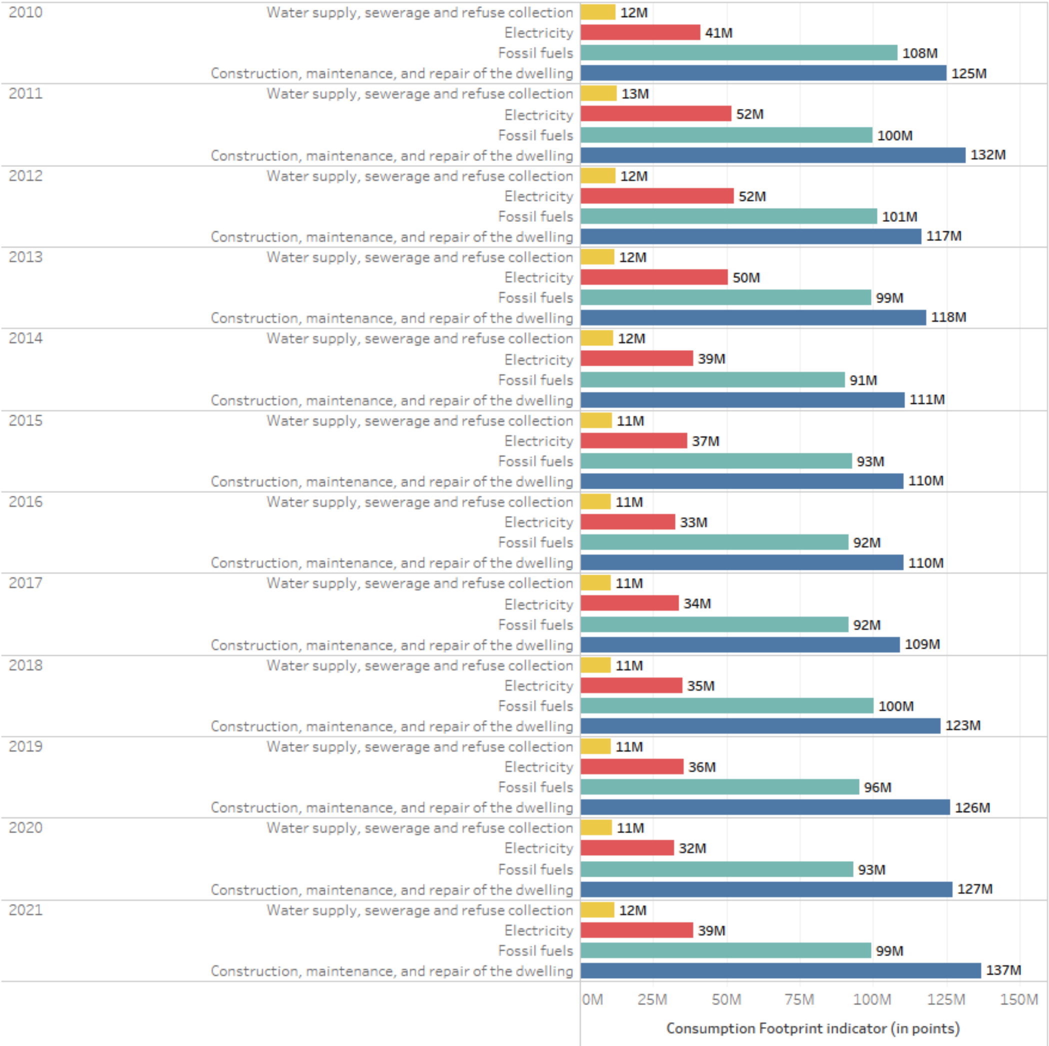
The CFI related to water supply, sewerage and refuse collection can be broken down into water supply and sewerage (42 %) and refuse collecting including waste treatment (58 %).

Figure 2.5 shows the contribution of the individual environmental impact categories to the CFI of housing (1st bar). The largest contribution results from resource use, fossils (FRD, 29 %), followed by particulate matter (PM, 19 %), climate change (CC, 18 %) and resource use, minerals and metals (MRD, 15 %). The impact from FRD is linked to the mining of fossil fuels required for construction, maintenance, and repair of the dwelling and for heating purposes and to the mining of fossil fuels for electricity production. PM is only linked to construction, maintenance, and repair of the dwelling, and to fossil fuels. MRD is only linked to the construction, maintenance, and repair of the dwelling. CC is related to all four subcategories.

In the period 2010-2021 the **CFI of housing** shows first a decrease CFI with 15 % between 2010 and 2017, followed by an increase with 17 % between 2017 and 2021. The contribution from the smallest category

(4.1 %), water supply, sewerage and refuse collection is stable over time. The Consumption Footprint of both electricity and fossil fuels decrease with 6 % and 8 % respectively. As consumption volumes are increasing, the effect of decarbonisation of the energy system is visible (visible via a decrease in FRD and CC). The impacts of construction, maintenance, and repair of the dwelling first decrease with 13 % from 2010 to 2017 and then increase with 26 % between 2017 and 2021.

Figure 2.8: CFI of total final demand in EU-27, consumption domain housing, 2010-2021.



Source: ETC CE calculations based on Exiobase v3.8.2.

In the period 2010-2021 the environmental impacts originating from inside the EU cover about 60 % of the total CFI. The remaining 40 % originates from outside the EU. Except for an increase in the EU impacts in the period 2015-2017 with a peak of 69% in 2016, there are no substantial changes in the EU vs. non-EU impact.

The CFI from **construction, maintenance, and repair of the dwelling** shows a more fluctuating pattern in the 2010-2021 period. In the period 2010-2017 the Consumption Footprint decreased, mainly thanks to environmental efficiency improvements in the production networks of building products and shifts to building materials with a lower environmental footprint. Although consumption levels already increased from 2014 onwards (both via investments in dwellings and infrastructure), the effect on the Consumption Footprint was limited as the efficiency gains and a different mix in building products outweighed the effect of increased consumption. From 2017 onwards the CFI increases as the even bigger increase in consumption and resulting effect on environmental impacts is no longer outweighed by the efficiency gains CFI.

The efficiency gains mainly reduced the effect on climate change (CC), particulate matter (PM), resource use, fossils (FRD) and resource use, minerals and metals (MRD). All these gains were outweighed by increased consumption except for CC, leading to a net-zero effect, and for FRD, resulting in a small environmental gain.

The Consumption Footprint from **fossil fuels** decreases over the full period, except with a peak in 2018 and 2021. In both years the peak is mainly due to an increase in consumption in combination with a different mix of supplying countries. Overall, the decrease is the result from a shift to fossils fuels with a lower environmental footprint, i.e. a combination of a different mix of fossil fuel types and improved environmental efficiency in the production networks. This decrease even outweighed the higher impact from the increased consumption level. The household demand, which largely determine the demand for fossil fuels in total EU-27 final use, show a small increasing trend. The net effect on the different environmental impact categories is zero, except for FRD and CC. Although consumption increased, the overall Consumption Footprint indicator decreased due to environmental gains in FRD (-10 %) and CC (- 18 %).

The Consumption Footprint from **electricity** decreases in all years, except for a large increase in 2011 and 2021. In both these years the increase is mainly due to an increase in consumption in combination with a different mix of supplying countries. Overall, the decrease is the result from mainly a shift to electricity products that have a lower environmental footprint (e.g., electricity from renewables). This decrease is not outweighed as the consumption levels for electricity (mainly from households) remained stable over time and even show a small decreasing trend. A strive towards less energy intensive products partly explains this decreased consumption volume (e.g., driven by the Ecodesign for Sustainable Products Regulation). The net effect on the different environmental impact categories is zero, except for fossil resource use and climate change. Although consumption increased, the Consumption Footprint indicator decreased due to environmental gains in FRD (-5 %) and climate change (-15 %). The reduction of the CFI is induced by increased investments in renewable energy CFI.

Overall, in the period 2010-2021 the Consumption Footprint indicator of housing remained at 287 million points both in 2010 and in 2021. The net effect for individual environmental impacts is mainly increasing, except for FRD (-7 %) and climate change (-9 %). Largest increases are noted for PM (+5 %), MRD (+10 %) and human toxicity, non-cancer (HTOX_nc, +26 %). The technological efficiency gains, the shift to cleaner and renewable technologies, and consuming more environmentally friendly alternatives do have an effect on the results, however these environmental gains are almost completely countered by the increase in consumption levels (except for a decreasing demand for electricity), especially by the significant growth in construction from 2014 onwards.

2.2.2 Food

The consumption domain '**food**' has a share of **20.2 % in the total CFI** excluding changes in inventories (2021) and is composed of eleven categories:

- Bread and cereals;
- Meat;
- Fish;
- Milk, cheese and eggs;
- Fruit and vegetables;
- Oils and fats;
- Sugar (including sugar, jam, honey, chocolate and confectionery);
- Beverages;
- Tobacco;

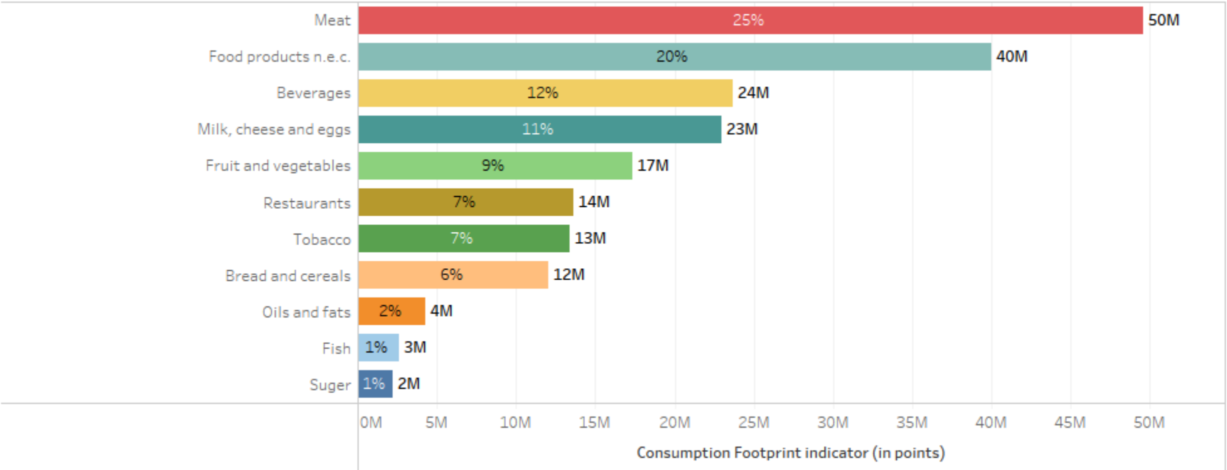
- Restaurants (including accommodations services, cafés, and canteens); and
- Food products not elsewhere classified (n.e.c.).

This last category is a rest-category containing all food products which cannot be attributed to one of the other categories, mainly because they are composed of multiple food products. Prepared meals are an example of a food product included in this rest category.

Animal products link to the categories meat, and milk, cheese, and eggs. Also oils and fats, food products n.e.c., and restaurants include animal products, but it is not possible to disaggregate these categories into animal products and non-animal products. The consumption area of food is almost completely covered by consumption expenditures by households.

The CFI of food is **responsible for 20.2 %** of the total CFI in 2021 (equalling 202 million points). 25 % of this impact is related to meat consumption, 20 % to food products n.e.c., 12 % to beverages (including both non-alcoholic and alcoholic beverages), 11 % to milk, cheese and eggs, 9% to fruit and vegetables, 7% to accommodation services, cafés, canteens and restaurants, 7% to tobacco, 6% to bread and cereals, 2% to oils and fats and both 1 % to fish consumption and to the consumption of sugar, jam, honey, chocolate and confectionery (see Figure 2.9).

Figure 2.9: CFI of total final demand in EU-27, consumption domain food, 2021.



Source: ETC CE calculations based on Exiobase v3.8.2.

The CFI related to animal food products is at least 39 % of the consumption domain food. Also considering the restaurants, oils and fats and the food products n.e.c. the impact increases to 130 million points, however, this is an overestimate as other non-animal products are also part of these categories.

Figure 2.5 shows the contribution of the individual environmental impact categories to the CFI. Compared to the other consumption areas a larger variety of environmental impacts contributes to the CFI of food. The environmental impacts with the highest contribution to the CFI are particulate matter (PM, 18 %), followed by climate change (CC, 15 %), acidification (AC,15 %), water use (WU, 12 %), eutrophication, terrestrial (TEU, 12 %), land use (LU, 9 %), and resource use, fossils (FRD, 8 %).

Significant differences in environmental impacts exist between the product groups within the food consumption area. AC and TEU are more related to the animal product groups of meat and milk, cheese, and eggs. WU is mainly linked to bread and cereals, fruit and vegetables, and to the food products n.e.c. The impact on FRD is mainly triggered by beverages, restaurants, and the food products n.e.c., as these categories involve more production steps requiring energy. PM, CC and LU are related to all categories without high or low outliers.

The trend in the period 2010-2021 shows first a decrease, by 10 %, in the CFI from 197 million points in 2010 to 177 million points in 2016, and an increase, by 14 %, to 202 million points in 2021. The contribution from meat products is stable over time (ca. 43-46 million points), with an increase in 2020 and 2021, respectively, by 11 % and 14 % compared to 2019. The decrease in the period 2010-2016 and the increase to 2021 in the CFI is mainly due to similar trends in food products n.e.c., beverages, and bread and cereals, as shown in Figure 2.10. The CFI of fruit and vegetables, and oils and fats show an increasing trend. The impacts related to fish and sugar, jam, honey, chocolate, and confectionery are rather stable in the 2010-2021 period. The environmental impacts resulting from milk, cheese, and eggs and tobacco show a more fluctuating pattern without consistent increasing or decreasing trend.

In the period 2010-2021 the environmental impacts originating from inside the EU fluctuate between 44 % and 53% of the total CFI. The remaining impacts originate from outside the EU.

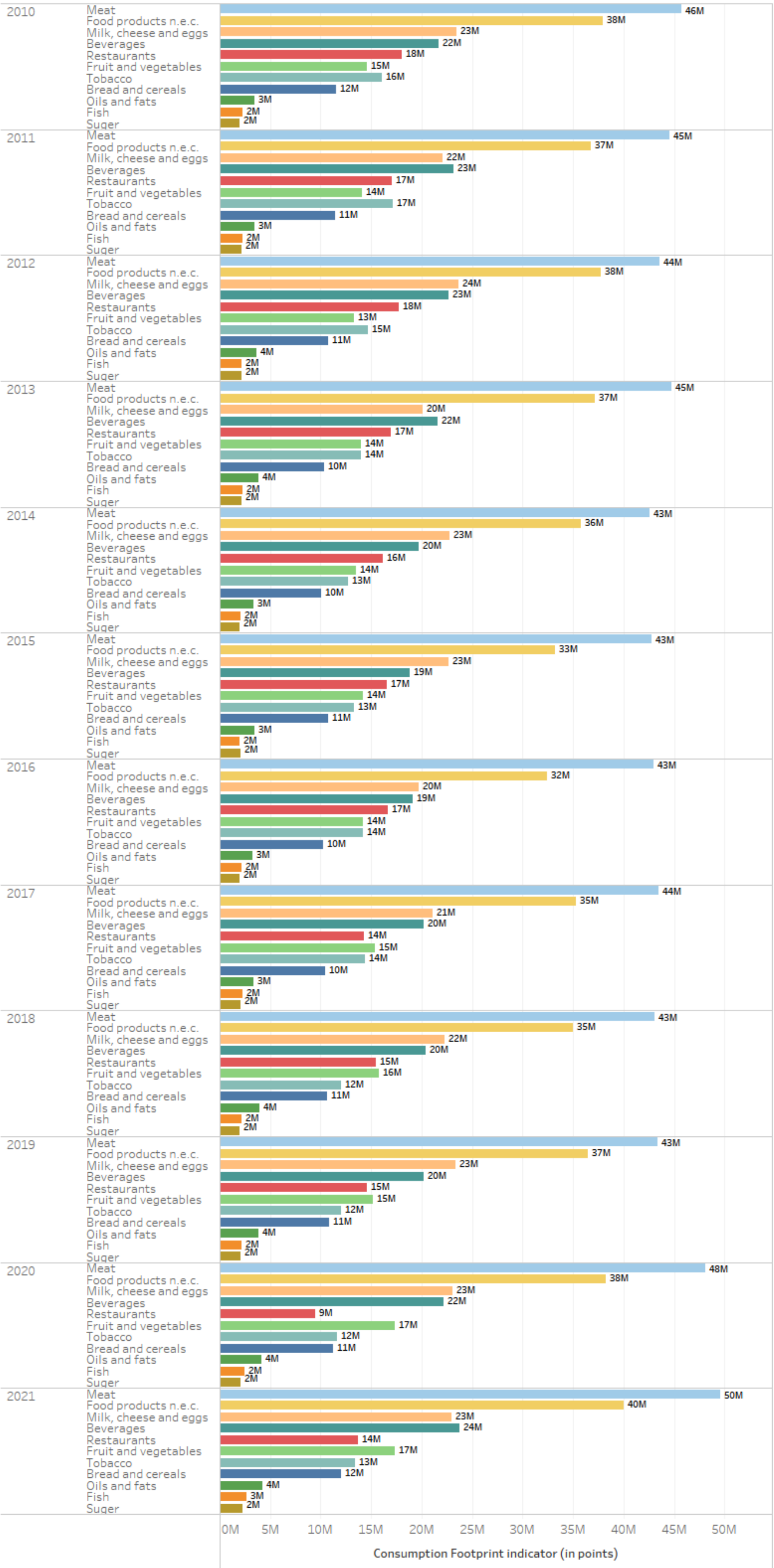
The CFI of **meat** products is rather stable in the period 2010-2019. In 2020 and 2021 the impact increased respectively, by 11 % and 14 % compared to 2019. In 2020 and 2021 the consumption volumes on meat products are much higher compared to volumes in 2010 until 2019. Likely as a result of COVID CRISIS, expenditures on restaurants went down drastically and are partly covered by increased consumption of food products directly. The decrease in expenditures on restaurants are partially outweighed by an increase in expenditures, especially on pig and poultry meat (but also on fruit and vegetables). The increase in 2021 is caused by increased consumption volumes. In the period 2010-2019 the CFI remained stable due to two counteracting effects: increasing consumption volumes and improved environmental efficiency in the production networks. The individual environmental impacts all show a comparable trend, resulting in an increase in impacts comparing 2021 with 2010, except for resource use, fossils (FRD) and acidification (AC) which have a net zero effect in this period.

The CFI of **food products n.e.c.** decreased by 15 % in the 2010-2016 period, after which it increased again by 23 % (2016-2021 period). In the period 2010-2015 there is a small consumption volume decrease. In the period 2015-2021 the consumption volume increased significantly (except for 2018 and 2021). Changes in the production networks lead to lower environmental impacts in the whole period. Overall, these improvements are amplified by decreased consumption in the period 2010-2015, however in the period 2015-2021 the increased consumption and the shift to products with a higher environmental footprint could not be outweighed by these environmental efficiency gains. The individual environmental impacts show a net zero effect between 2010 and 2021 for resource use, fossils (FRD), particulate matter (PM), eutrophication, terrestrial (TEU), and acidification (AC). Notwithstanding the huge reduction in climate change (CC) due to the improvements in the production networks, the increased consumption results in a net increase.

The same trend and drivers apply to the CFI of **beverages** and **bread and cereals**. The decrease in the period 2010-2016 (-12 % for beverages, and -11 % for bread and cereals) is thanks to environmental efficiency improvements in the production networks and the small degrowth in consumption volume combined with the shift towards products with a higher environmental footprint. In the period 2016-2021 the CFI of beverages and bread and cereals increased (+24 % for beverages and +28 % bread and cereals) mainly due to significantly increasing consumption volumes. All individual environmental impacts linked to the consumption of beverages showed an increase between 2010 and 2021, except FRD which shows a net zero effect. The impact of bread and cereals also increases for most individual environmental impact categories, except for FRD, resource use, minerals and metals (MRD), AC and TEU.

The CFI of **milk, cheese, and eggs** is fluctuating in the period 2010-2021 without having a clear upward or downward trend. Overall, the effect on the CFI and on the individual impact categories is nullified by the combined effect of efficiency gains and increased consumption. The fluctuating pattern is explained by the many fluctuations in the consumption volumes for milk, cheese, and eggs.

Figure 2.10: CFI of total final demand in EU-27, consumption domain food, 2010-2021.



Source: ETC CE calculations based on Exiobase v3.8.2.

The increase (+19 %) of the CFI related to **fruit and vegetables** is primarily caused by increased consumption and a shift in consumption to products with a higher environmental footprint. Noted is a large increase in the consumption volume of fruit and vegetables in 2020. The environmental gains from the improvements in production networks and efficiency is insufficient to cover for the increased consumption. The increase in the CFI is to a large extend related to an increased environmental impact for water use (WU) and land use (LU).

The CFI related to **restaurants** is showing a decreasing trend (-24 %) with a notable drop in 2020, for which the Covid crisis was responsible. Overall, the environmental efficiency improvement in the production network related to products consumed in restaurants, but also a shift towards products with a lower environmental footprint have led to this downward trend. This effect is visible in all individual environmental impact categories.

Overall, in the period 2010-2021 the Consumption Footprint indicator of food increased by 3 %. This net effect is the result of a small increase of LU and WU (mainly related to fruit and vegetables) and a small environmental gain from resource use, fossils (FRD). The gains are mainly due to the decreased impact via technology efficiency gains across all consumption domains and a decreasing consumption volume of tobacco and the lack of an increase in consumption of milk, cheese, and eggs, and food products n.e.c., but these gains are outweighed by the increased impacts due to increasing consumption volumes, mainly from meat consumption, from fruit and vegetables, and from beverages.

2.2.3 Personal mobility

The consumption domain ‘**personal mobility**’ has a share of **19.0 % in the total CFI** excluding changes in inventories (2021) and is composed of four categories:

- Fuels and lubricants including public transport (road, rail, water and air travel): electricity use for e-vehicles is not part of this category but included in the housing consumption area. Public transport and tickets for private transport (water, air, rail, and road transport) are accounted for in this product group. It was not possibly to disaggregate these categories. The impact resulting from consumptive expenditures at travel agencies are included in a separate category;
- Vehicles, including cars, motorbikes, bikes, campers, etc.;
- Travel agencies, including holiday packages containing transport and hotel services; and
- Maintenance and repair of personal transport equipment.

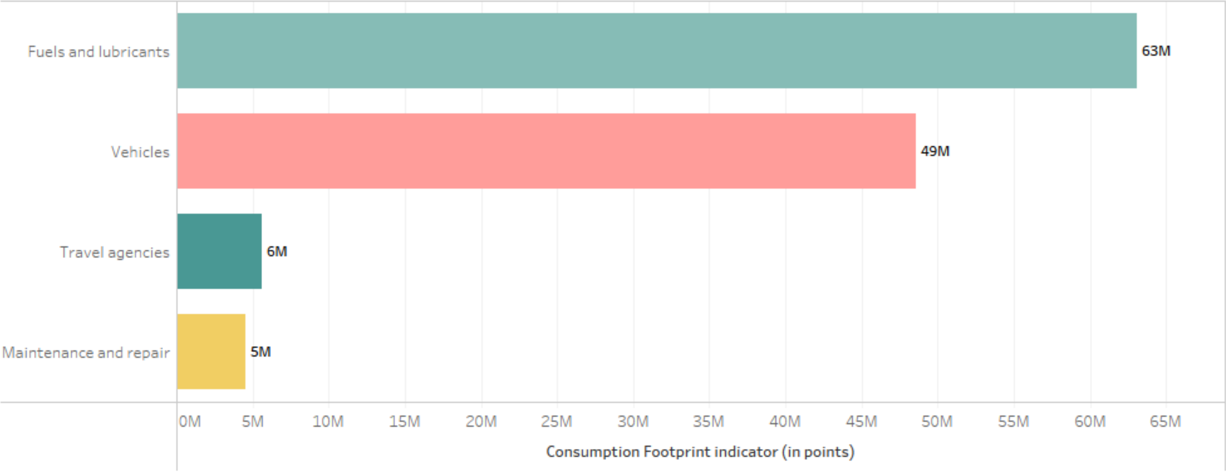
The CFI of personal mobility is **122 million points** in 2021. 52 % is related to fuels and lubricants, 40 % to vehicles, 5 % to travel agencies, and 4 % to maintenance and repair of personal transport equipment (Figure 2.11).

Figure 2.5 shows the contribution of the environmental impact categories to the CFI (3rd bar for personal mobility). The composition shows a larger contribution from resource use, fossils (FRD), climate change (CC), and resource use, minerals and metals (MRD). Also, the contributions from particulate matter (PM) and human toxicity, non-cancer (HTOX_nc) are relatively high. The higher impact from FRD, CC, and PM result from fuels and lubricants, while the higher impact from MRD and HTOX_nc mainly result from the production of vehicles.

The trend in the period 2010-2021 shows first a decrease by 18 % from 2010 to 2015, and an increase to 2021 by 17 %. The CFI in 2020 shows a drop by 8 % compared to 2019. In this period the CFI of fuels and lubricant is decreasing, with a lower value in 2020, while the trend in the CFI for vehicles shows a significant increase from 2016/2017 onwards (Figure 2.12).

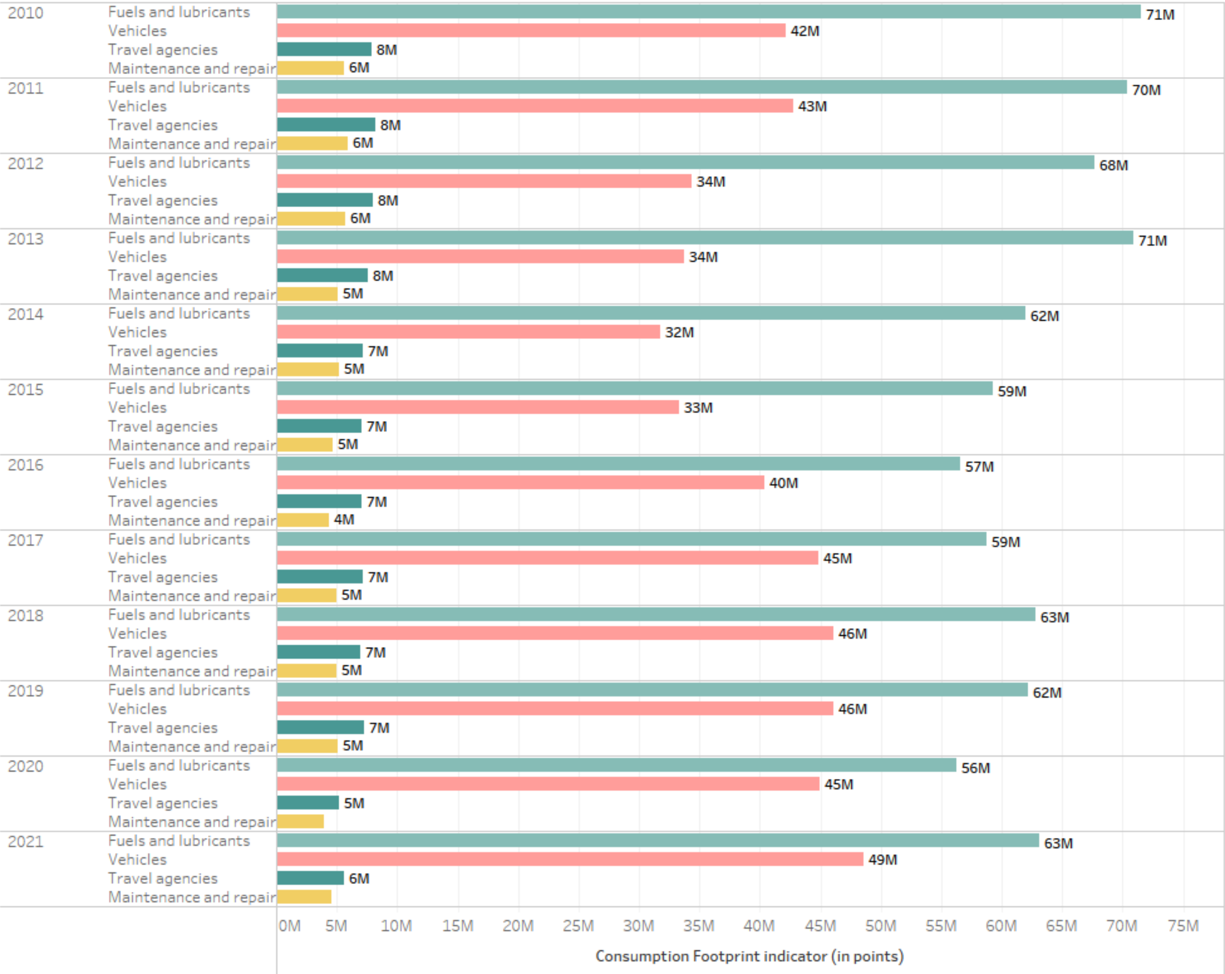
In the period 2010-2021 the environmental impacts originating from inside the EU fluctuate around 40 % of the total CFI, with a temporary increase in the period 2015-2017 to 50% in 2016. The EU share for vehicles is only 30 %, while this is 52 % for fuels and lubricants (or even only 26 % excluding direct emissions).

Figure 2.11: CFI of total final demand in EU-27, consumption domain personal mobility, 2021.



Source: ETC CE calculations based on Exiobase v3.8.2.

Figure 2.12: CFI of total final demand in EU-27, consumption domain personal mobility, 2010-2021.



Source: ETC CE calculations based on Exiobase v3.8.2.

The CFI of **fuels and lubricants** show a decrease in the period 2010-2021 by 12 %. The decrease is the result of environmental gains in the production networks of fuels, lubricants, and public transport. The gains are mainly related to efficiency improvements, and to a lower extend, different sourcing. The consumption volumes of fuels and lubricant are fairly stable over time. The net decrease in the CFI is related to a large decrease in fossil resource use and climate change (CC).

The CFI of **vehicles** increases in the 2010-2021 period with 15 %. In the first part of this period, until 2013, consumption volume decreased by ca. 10 %, mainly via a decrease in demand from household. Next to household demand, almost half the demand for vehicles originates from the gross fixed capital formation final use category (e.g., company vehicles). In combination with improved environmental efficiency this resulted in a substantial decrease (-20 %) of the CFI. Up to 2019 consumption volumes increased and are in 2019 even 24 % larger compared to the 2010 consumption volume. The 2020 drop in consumption volume (-10 %) did not recover in 2021 as it remained at the same level. The CFI of vehicles followed the same pattern, without substantial drop in 2020 (nor in 2021). Overall, the effect of the consumption increase is larger than the environmental efficiency gains. Although this opposite effect resulted in a net negative effect on resource use, fossils (FRD), a large increase is found for particulate matter (PM), FRD and human toxicity, non-cancer (HTOX_nc).

The CFI of **travel agencies** and **maintenance and repair** are relatively stable in the 2010-2021 period, except for a substantial decrease in 2020 as a result of the Covid crisis.

2.2.4 Household goods

The consumption domain '**household goods**' has a share of **12.7 % in the total CFI** excluding changes in inventories (2021) and is composed of six categories:

- Household appliances, including electric equipment, tableware, glassware and accessories;
- Furniture, including furniture and furnishings;
- Pharma, including pharmaceutical products and equipment for personal care;
- IT, including information processing equipment, televisions and communication equipment;
- Paperware, including books, newspapers, and periodicals; and
- Fertilisers.

The CFI of household goods is **167 million points** in 2021. 50 % is related to the household appliances, 17 % to furniture, 15 % to pharma, 12 % to IT, 4 % to paperware, and 1 % to the use of fertilisers by households (Figure 2.13).

35 % of the CFI of pharma is related to appliances and equipment, the remaining 65 % is related to pharmaceutical and medical products and products for personal care.

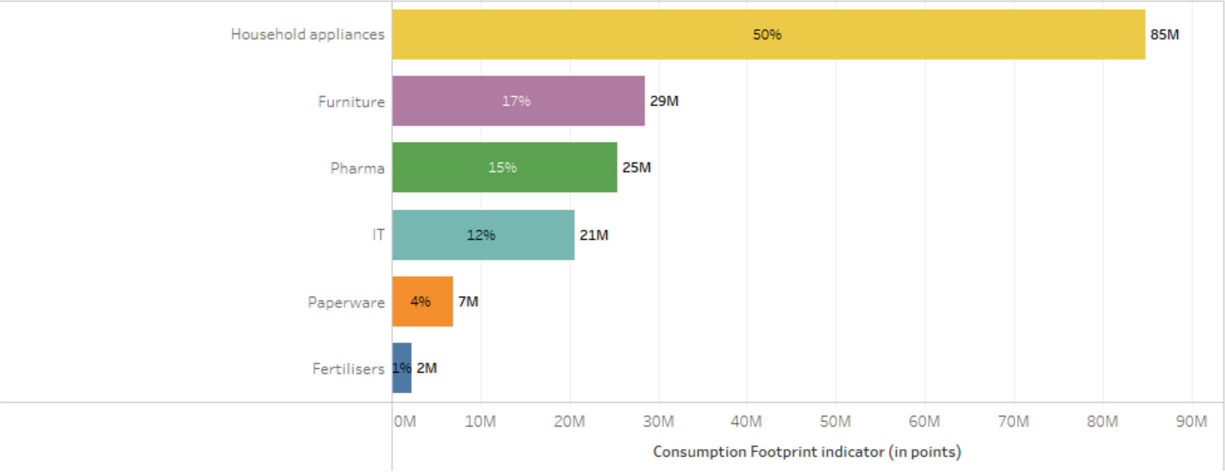
The bulk of CFI of household goods (71 % of the total CFI of household goods) is related to electric and electronic appliances and equipment. It is the sum of all appliances and equipment within household appliances (5 % of this impact is related to glassware, tableware, and other accessories), 35 % of the impact from pharma and the impact related to IT.

Note that electricity use is not included in this consumption domain. The use of electricity needed to run these appliances (and the impact thereof) is part of the housing consumption domain. This consumption domain only includes the production network and related impact that is behind these goods. The impacts resulting from waste management activities are also part of the housing consumption domain (i.e., water supply, sewerage and refuse collection).

Figure 2.5 shows the contribution of the environmental impact categories to the CFI (4th bar shows household goods). Compared to the other consumption areas, the environmental impacts from human toxicity, non-cancer (HTOX_nc, 10 %) are high. Other influential impact categories are resource use, fossils

(FRD, 26 %), particulate matter (PM, 17 %), resource use, minerals and metals (MRD, 16 %), and climate change (CC, 15 %).

Figure 2.13: CFI of total final demand in EU-27, consumption domain household goods, 2021.



Source: ETC CE calculations based on Exiobase v3.8.2.

No significant differences in environmental impacts exist between the product groups within the household goods consumption area. Only a higher impact of land use (LU) is noted for furniture, due to the use of (and production of) wood products.

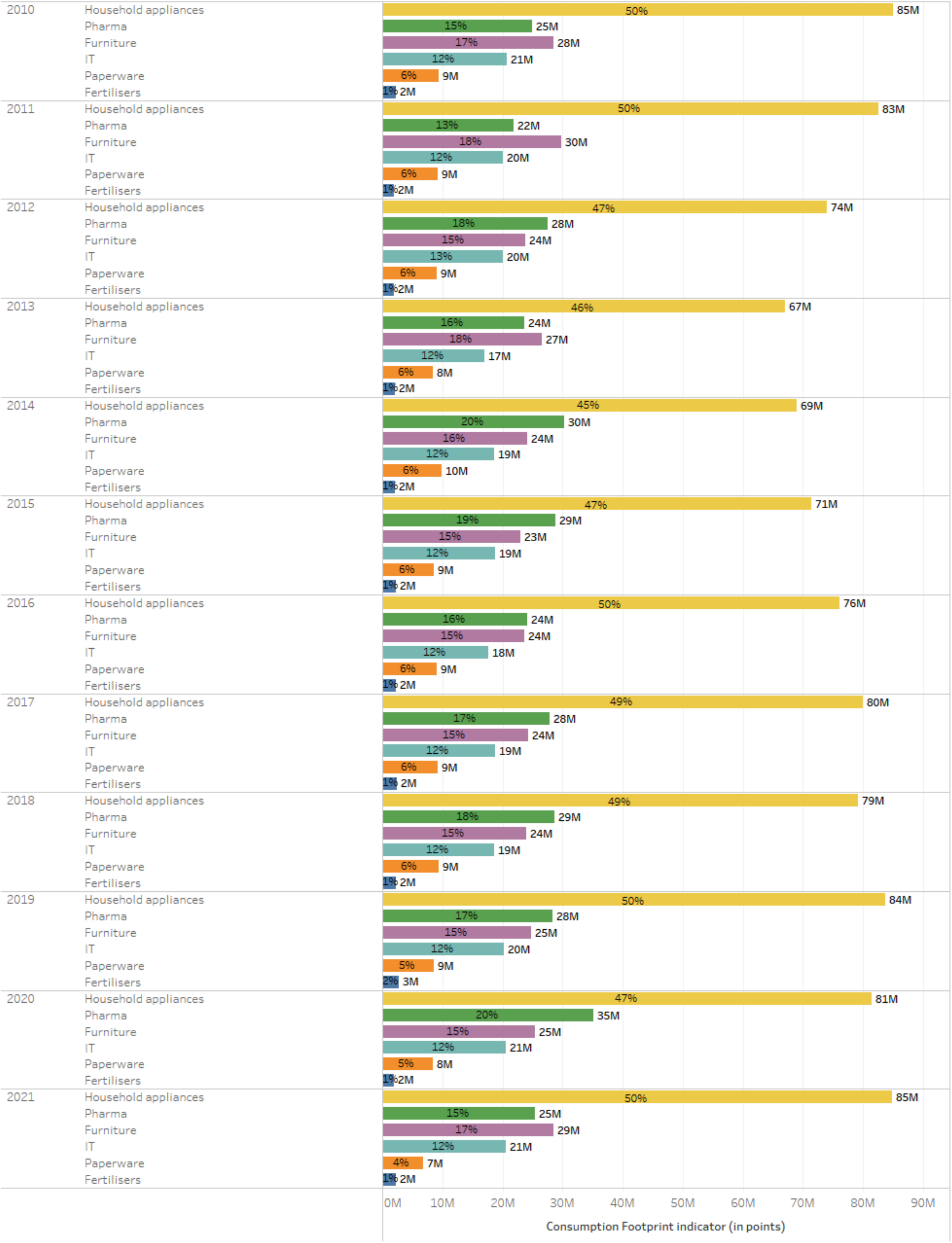
The trend in the period 2010-2021 shows first a 16 % decrease in the CFI from 2010 to 2013, and an increase by 19 % until 2020. The CFI decreased in 2021 by 3 %. The trend is mainly determined by a comparable trend in household appliances (Figure 2.14). The lower value in 2021 results from a drop in the CFI related to pharma.

In the period 2010-2021 the environmental impacts originating from inside the EU generally fluctuate around 25% of the total CFI, with a temporary increase in the period 2015-2017 to 30% in 2016.

The CFI of **household appliances** (84.8 million points in 2021) are a combination of household demand and investments and show a decrease in the CFI by 21 % in the period 2010-2013. In the period 2013-2021 it increases by 26 %, with a drop in 2020 by 4 %. These changes follow the same changes in the final demand volume, but they less pronounced because they are countered by improvements in the environmental efficiency in the upstream production networks. In the 2010-2013 period, the demand volume remained stable resulting in a decrease of the CFI for household appliances. The decrease of the CFI in 2020 is the result of a decrease in the final demand volume.

The impact related to **furniture** is around 23-25 million points, with higher values of 27-30 million points in 2010, 2011, 2013 and 2021. The trend in the consumption volume on furniture products can only partly explain the trend in the CFI of furniture. The steady increase in the consumption volume being outweighed by increased environmental efficiency gains explains the relatively stable CFI. A significant drop in the consumption volume explains the lower CFI in 2012. Shift in production networks in 2014 and 2015 explain the lower values from 2014 onwards. After a drop in 2020, the consumption volume increased significantly in 2021 resulting in a higher CFI for this year.

Figure 2.14: CFI of total final demand in EU-27, consumption domain household goods, 2010-2021.



Source: ETC CE calculations based on Exiobase v3.8.2.

In the period 2010-2021 the net effect on the CFI on household appliances and furniture is very small, but it is the result of a substantial increase in the consumption volume. The increase in the consumption volume in the household goods consumption area is the highest compared to the other consumption areas. Its effect on the CFI is outweighed by environmental efficiency improvements in the production networks of household goods. The decrease is a combined effect of efficiency improvements and changes in the production networks (sourcing from other countries and input substitutions). Almost half of the effect is a decrease in the resource use, fossils (FRD).

The CFI of **pharma** and **IT** is showing varying values in the 2010-2021 period, without clear trend. Both an increase in the consumption volume and a shift in the product mix have an upward effect on the CFI. The effect is countered by environmental gains due to shifts in the production networks and some efficiency gains. For pharma, most of the costs and benefits are a result in changes in the resource use, minerals and metals (MRD), while for IT the changes are mostly related to MRD, FRD and to CC.

The impacts related to **paperware** and **fertilisers** is stable around 9 and 2 million points, respectively.

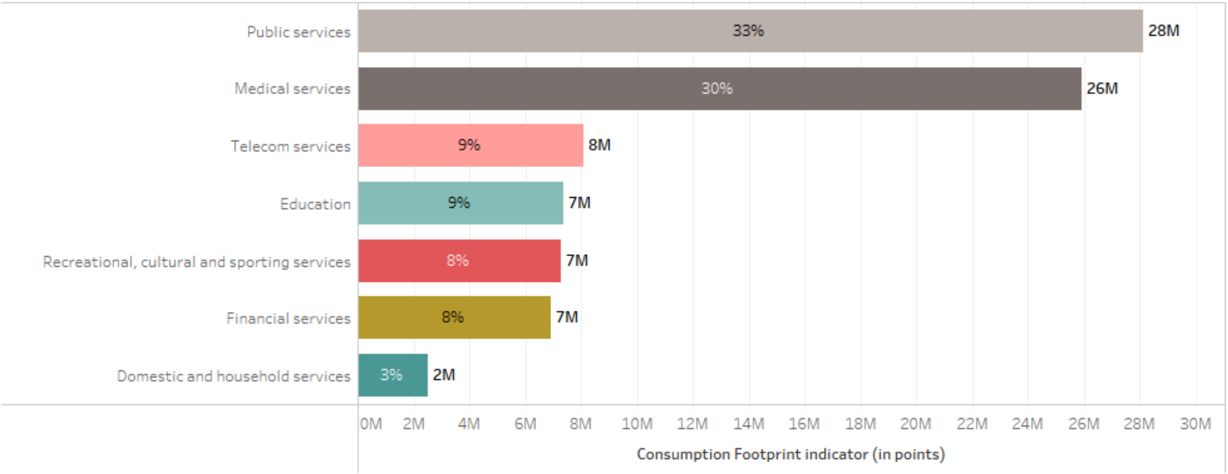
2.2.5 Services

The consumption domain '**services**' has a share of **11.7 % in the total CFI** excluding changes in inventories (2021) and is composed of seven categories:

- Public services, mainly provided by governments, like public administration and defence, and social work;
- Medical services, mainly provided by governments and household expenditures, cover all health services. Consumption of medical products are also included, expect for those directly paid for by households;
- Telecom services, largely paid by household directly, encompass postal and telecom services;
- Education, mainly provided by governments;
- Recreational, cultural, and sporting services, largely paid by household directly;
- Financial services, fully paid for by households including financial intermediation and insurances; and
- Domestic services and household services.

The CFI of personal mobility is **88 million points** in 2021. 33 % is related to public services, 30 % to medical services, 9 % to telecom services, to education, and to recreational, cultural, and sporting services, 8 % to financial services, and 3 % to domestic and household services (Figure 2.15).

Figure 2.15: CFI of total final demand in EU-27, consumption domain services, 2021.



Source: ETC CE calculations based on Exiobase v3.8.2.

Figure 2.5 shows the contribution of the environmental impact categories to the CFI (the 5th bar shows the composition for services). The composition shows a larger contribution from resource use, fossils (FRD), climate change (CC), and resource use, minerals and metals (MRD). No significant differences in environmental impacts exist between the product groups within the consumption area of services.

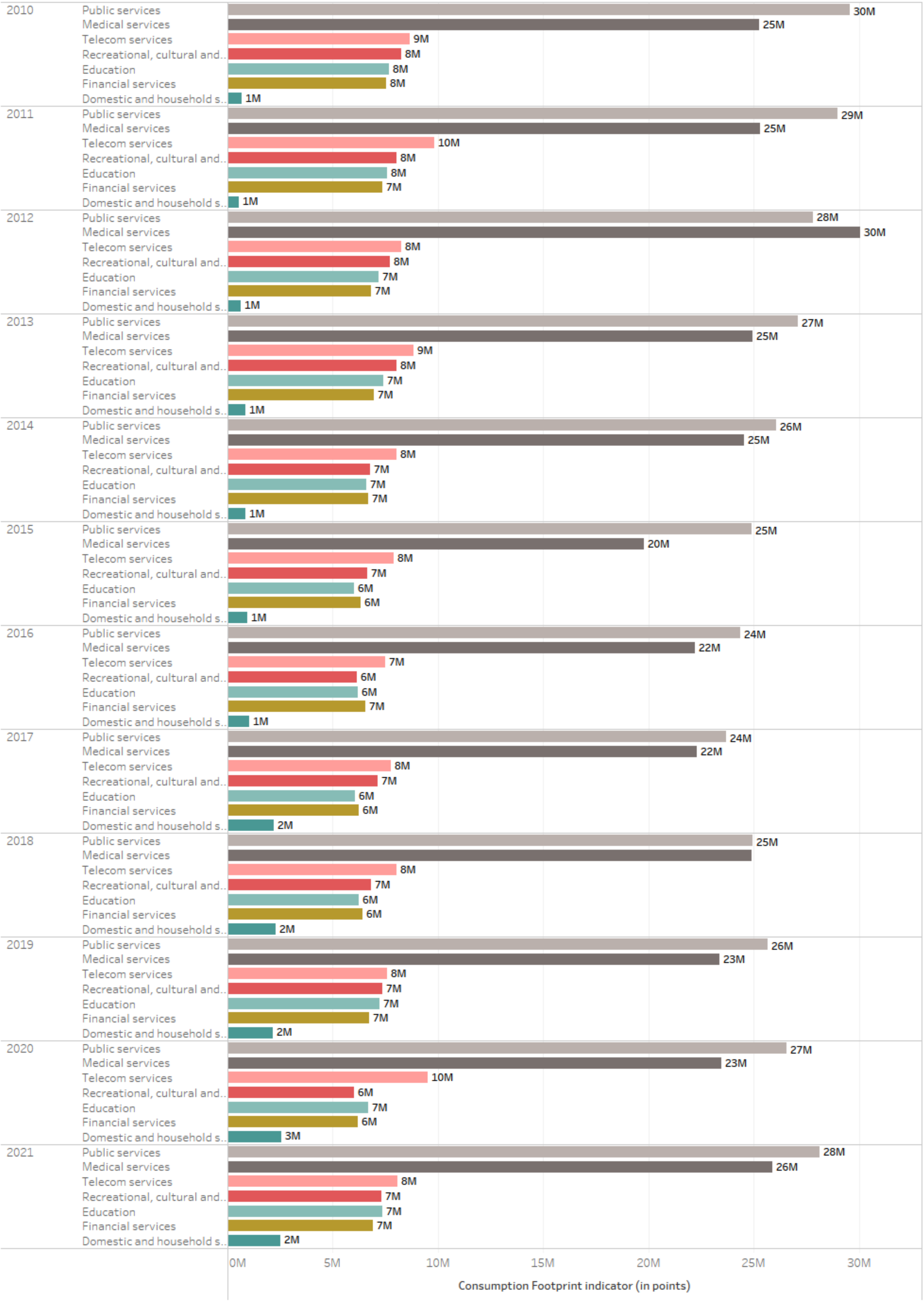
The trend in the period 2010-2021 shows first a decrease in the CFI by 17 % in 2010 to 2015, and an increase by 19 % until 2021. The same pattern is found for public services. No clear pattern is visible for the CFI related to medical services.

In the period 2010-2021 the environmental impacts originating from inside the EU cover about 42 % of the total CFI, with a temporary increase in the period 2015-2017 to 50% in 2016.

The CFI of **public services** show a decrease of 20 % in the period 2010-2017 after which it increased again by 19 % until 2021. The growth in the consumption volume for public services is relatively stable in the 2010-2018 period and increased afterwards. Remarkable is that the environmental gains from increase efficiency are much bigger in the first part of this time series compared to the second part of the time series. Therefor the trend in the CFI of public services decreased until 2017 but increased in the 2017-2021 period. Overall, the net decrease is related to FRD and CC.

The varying annual results of the CFI of **medical services** show no clear pattern. With a relatively steady increase in the consumption volume, the fluctuations in the CFI are related to large changes in production networks, mainly due to changes in sourcing (either from different countries or the sourcing of different inputs).

Figure 2.16: CFI of total final demand in EU-27, consumption domain services, 2010-2021.



Source: ETC CE calculations based on Exiobase v3.8.2.

3 Planetary boundaries

Key messages:

- Key message 3.1: Current EU consumption already leads to an overshoot of Earth's safe operating space, e.g., in the areas of particulate matter pollution, climate change, and fossil and mineral resource depletion. Impacts for ecotoxicity, land use, and photochemical ozone formation are found within a zone of increasing risk. Especially concerning climate change, Europe needs to urgently lower its consumption footprint at a fast pace to avoid crossing irreversible tipping points of the climate system.
- Key message 3.2: Consumption areas contributing most to this overshoot vary by impact category, but are largely triggered by consumption in **housing, food, and personal mobility (together these consumption areas make up around 73 % of overall environmental impacts)**. For example, for climate change the sole impact from housing already overshoots the save operating space by factor of 4.6, food by factor 2.7 and personal mobility by factor 2.6. For impact categories such as non-cancer human toxicity, fossils resource depletion, and mineral resource depletion **household goods** consumption is relevant as well.
- Key message 3.3: Different normative choices of 'downscaling' PBs to European citizens exist and can influence the magnitude of the allocated boundaries. Furthermore, uncertainties related to the choice of the planetary boundary proxy indicators and the underlying data to derive environmental footprints exist. Policy makers should be aware of such methodological choices and uncertainties when interpreting the above results.

3.1 Planetary Boundaries framework

European production and consumption patterns are putting unprecedented pressures on the environment, e.g., in terms of climate change, pollution, and land-use changes (see previous chapter). At the same time, the EU has articulated its goal of living well, within the ecological limits of our planet by 2050 (EC, 2014). However, for this to happen the EU and its individual member states would need science-based, quantitative targets and thresholds to benchmark environmental impacts associated with production and consumption. Such thresholds and targets could track the evolution of EU environmental impacts against a set of pre-defined environmental thresholds and highlight whether EU policies are able to keep us within (or bring us back into) safe Earth system boundaries.

Against this background, the planetary boundaries framework[6] (Rockström et al., 2009b) defines and quantifies the safe operating space for a range of key environmental and ecological processes. The reference state from which Earth system thresholds are derived is the stable Holocene period, during which human civilization could arise, develop, and thrive. Several updates to the initial framework and boundaries published in 2009 (Rockström et al., 2009b) have been put forth until today including in 2015 (Steffen et al., 2015b) and 2023 (Richardson et al., 2023; Rockström et al., 2023). The results from these analyses highlight that an increasing number of planetary boundaries have been surpassed since 2009 (Figure 3.1).

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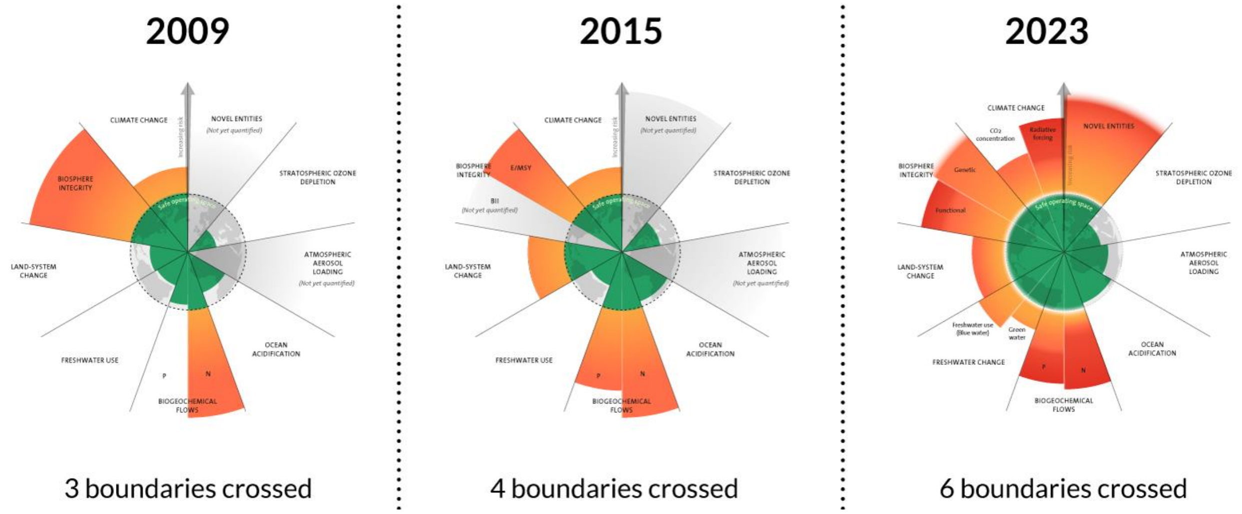
[6] Planetary boundaries are a framework to illustrate limits to the impacts of human activities on the Earth system beyond which nature may not be able to self-regulate anymore. Crossing these limits carries a high likelihood that the Earth system might leave the stable Holocene period. The framework relies on scientifically-derived control variables for each boundary which are frequently updates as new insights and data become available (see the following webpage for a summary of the framework: https://www.stockholmresilience.org/research/planetary-boundaries.html).

Figure 3.1: The evolution of the planetary boundaries' framework



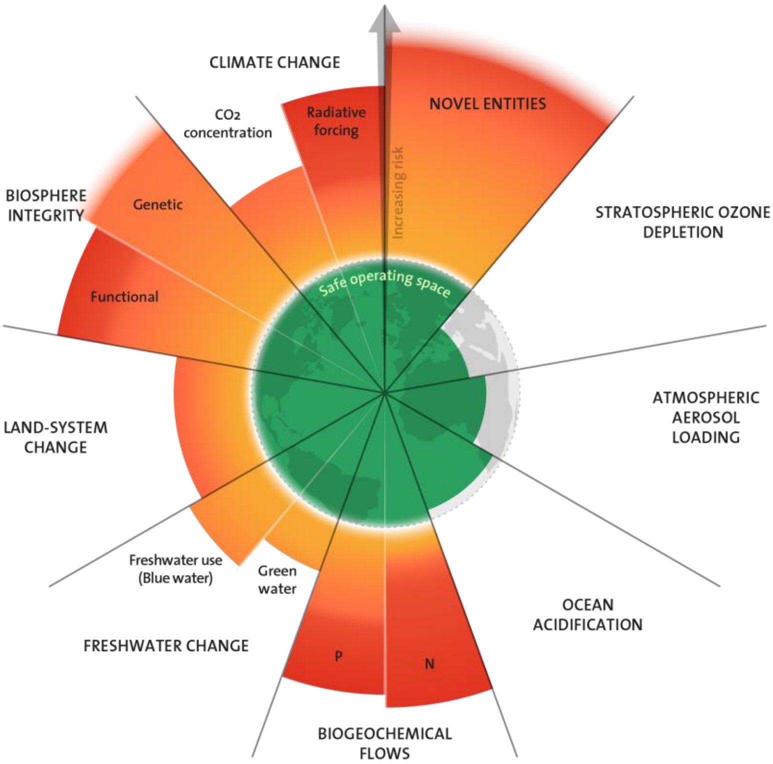
Source: Azote for Stockholm Resilience Centre, Stockholm University. Based on (Richardson et al., 2023; Steffen et al., 2015b; Rockström et al., 2009b). Licenced under CC BY-NC-ND 3.0).

The planetary boundaries framework identifies nine critical Earth system processes or 'planetary boundaries' that, if crossed, could lead to abrupt environmental changes and jeopardize human well-being. These nine dimensions are seen as fundamental processes that regulate the stability and resilience of the Earth system. For each of these boundaries, control variables are defined that capture the most important anthropogenic-induced changes at the planetary scale (Richardson et al., 2023). The boundaries and respective control variables used in the most recent update of the framework (Richardson et al., 2023) include:

- Climate change (atmospheric greenhouse gas (GHG) concentration)
- Biosphere integrity (genetic diversity and functional integrity)
- Stratospheric ozone depletion (ozone concentration)
- Ocean acidification (pH level)
- Biogeochemical flows (nitrogen (N) and phosphorus (P) flows)
- Land system change (are of forested land (percentage of area remaining))
- Freshwater use (disturbance of blue water flow and green water availability)
- Atmospheric aerosol loading (AOD) (interhemispheric difference in AOD)
- Novel entities (release of synthetic chemicals into the environment)

For each of these boundaries, scientists determined a 'safe operating space' or a threshold beyond which there is an increased risk of causing irreversible damage to the Earth's systems. These thresholds were intended to guide policy decisions and prevent crossing critical tipping points. According to the latest analysis from 2023 (Richardson et al., 2023), a total of six out of nine planetary boundaries have already been surpassed and ocean acidification is approaching its planetary boundary (Figure 3.2).

Figure 3.2: The 2023 update to the Planetary boundaries



Source: Azote for Stockholm Resilience Centre, based on analysis in (Richardson et al., 2023). Licensed under CC BY-NC-ND 3.0.

In the figure, the green zone is the safe operating space (below the boundary). Areas in orange represent increasing risk and red highlights the high-risk zone where stable Earth system conditions are transgressed with high confidence. The outer part of the wedges for the novel entities and the genetic diversity dimension of the biosphere integrity boundaries are blurred because they have not yet been quantified (novel entities) or are associated with large uncertainties (loss of genetic diversity).

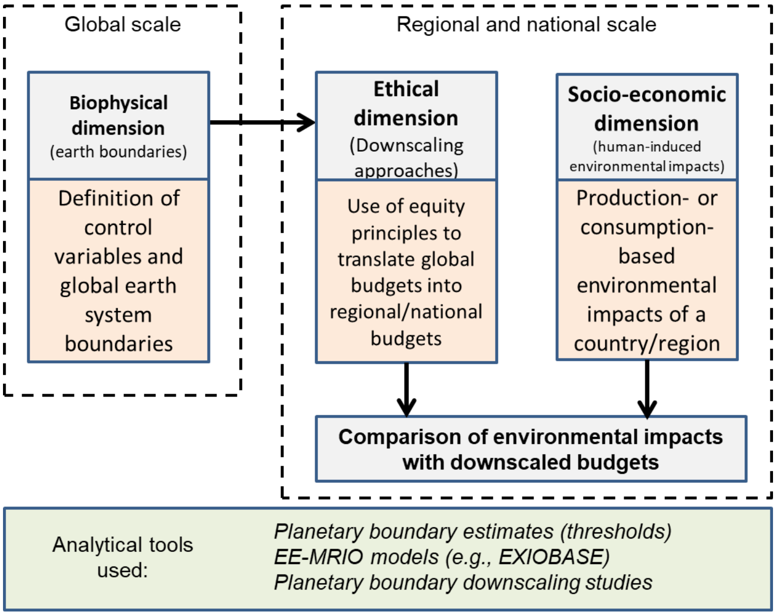
The Planetary Boundaries framework recognizes that boundaries are interconnected with each other and that exceeding one boundary can increase the risk of crossing others (e.g., deforestation can impact both the biosphere integrity and the biogeochemical flows boundaries). Therefore, more sophisticated Earth system models are required to capture geosphere-biosphere-anthroposphere interactions in the future (Richardson et al., 2023).

3.2 Deriving science-based targets at regional and country level

3.2.1 Downscaling approaches

The planetary boundaries discussed in the previous chapter are estimated at the global and for some dimensions also at the regional level (e.g., biogeochemical flows of N and P). Transforming global boundaries into regional or national limits requires addressing the biophysical, socio-economic, and ethical dimensions of the individual environmental dimensions under investigation (Häyhä et al., 2016) (Figure 3.3).

Figure 3.3: Conceptual framework for translating the planetary boundaries to national or regional scales



Source: Own figure based on (Häyhä et al., 2016; UBA, 2021)

- **Biophysical dimension:**

The planetary boundaries framework was originally designed to formulate global boundaries and expressed using biophysical ‘control variables’ indicating the biophysical state of a specific process (e.g., atmospheric CO_2 concentrations in ppm for climate change). However, the spatial heterogeneity of the underlying biophysical processes requires quantification of boundary values also at sub-global level for some boundaries. Häyhä and colleagues (Häyhä et al., 2016) discuss implications on the translation of global boundaries to national or regional scales by making the following distinctions:

1) For *global systemic processes,* the absolute magnitude of the pressure determines the impact on the Earth system, independently of where the pressure takes place. This includes the following processes: climate change, ocean acidification, stratospheric ozone depletion, and novel entities. Direct perturbations push the Earth system away from the Holocene baseline state.

2) For *global cumulative processes,* human activities that cause impacts at the regional or local scale alter the Holocene baseline state by changing the interconnections between different Earth system components (i.e., atmosphere, ocean, and biosphere). Human made impacts may cascade through the Earth system causing global-scale impacts. Processes in this category include: biosphere integrity, land-system change, freshwater change, biogeochemical flows of phosphorus and nitrogen, and atmospheric aerosol loading.

In this study, planetary boundary control variables from the scientific literature are used (see below) to provide estimates of biophysical Earth system boundaries/thresholds. These represent either an absolute or a yearly budget which can be further downscaled using different ethical dimensions (e.g., per capita allocation) and compared with the consumption-based environmental impacts (socio-economic dimension).

- **Socio-economic dimension (impacts from production and consumption):**

In a globalized world, environmental pressures and subsequent impacts can occur during different stages of the value chain. Through global trade, the environmental impacts may occur in different countries around the world and a footprint perspective discussed in chapter 2 (EEA Consumption Footprint) allows accounting for the environmental impacts of Europe’s consumption. Häyhä and colleagues argue that for applying the planetary boundaries concept as a global sustainability framework, *downscaled boundaries* *need to be compared with the consumption-based impacts (footprint perspective)* (Häyhä et al., 2016). Only by doing so can the indirect environmental impacts in other world regions which are associated with consumption (global trade) be accounted for. While the perspective of using consumption-based impacts is gaining tractability among the scientific community, it is not yet widespread in policy making from our experience.

In our study, we use estimates for the EEA Consumption Footprint from chapter 2 which is based on environmentally extended input output (EEIO) calculations. The FIGARO MRIO database was used for the overall analysis, while the EXIOBASE MRIO database provided more detailed data for the different consumption domains until 2021 as discussed in section 2.2.1-2.2.5.

- **Ethical dimension:**

The principle of *'common but differentiated responsibility'* accounts for the varying circumstances and capacities of countries to deal with environmental issues. Firstly, countries differ in their stages of economic development and, hence, the pressures historically and today put on the environment. Industrialized countries such as in the EU have a long history of extracting natural resources and causing environmental impacts such as climate change and are, therefore, responsible for a larger share of already existing environmental degradation than countries with lower levels of economic development. Secondly, due to their economic development, countries such as in the EU are better able to cope with such environmental problems than lesser developed countries. Discussion on distributive fairness of environmental problems is prevalent, e.g., in the climate discussions.

In order to translate global budgets into national contexts, the ethical dimension has to be considered. Depending on the ethical principle chosen, different national budgets can be derived. The following approaches are discussed in the literature[7]:

Equality (per-capita allocation)

This approach assumes that each human being has equal rights and responsibilities. In the climate discussions, this approach refers to all people having equal rights to use the atmosphere (Lucas and Wilting, 2018).

This approach requires national and global population figures (immediate equal per capita allocation (IEPC)) or future population estimates (equal cumulative per capita allocation (ECPC)). Using this approach leads to larger budgets being allocated to countries with a high population. For example, the remaining global carbon budget to not exceed global warming of > ~1.5°C (IPCC, 2018) might be downscaled to the EU-27 or a single country based on the regional/national population compared to the world population. For example, according to an EEA-FOEN study around 8.1 % (average) of global limits are allocated to the EEA country territory (consisting of the 33 member countries of the EEA) using this approach (EEA and FOEN, 2020).

Sovereignty (grandfathering)

This approach is also referred to as 'acquired rights' and states that countries have the right to use natural resources and the ecological space as "justified by established customs and usage" (Lucas and Wilting, 2018). For example, global greenhouse gas (GHG) emission allowances would be allocated proportional to current national emission levels.

This approach requires data on the national and global environmental impacts (e.g., from the EEA consumption footprint for the EU and planetary boundaries literature for global impacts). Using this approach attributes larger budgets to countries with already high environmental impacts. For example,

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[7] Note that the following summary of allocation principles is largely based on details given in the report by (Lucas and Wilting, 2018) with example calculation results for the EEA member countries territory taken from (EEA and FOEN, 2020).

around 11.4 % (average) of global limits are allocated to the EEA country territory using this approach (EEA and FOEN, 2020).

Capability

This approach refers to the capacity of a country to contribute to coping with / solving environmental issues. It is sometimes also referred to as the ‘ability to pay’. In this approach, not the global budget but instead the global reduction target (i.e., the difference between current global environmental impacts and the defined boundary) is allocated across countries (Lucas and Wilting, 2018). Therefore, it can only be applied to planetary boundaries that have already been surpassed. The weighting can take place considering the national vs. global per capita gross domestic product (GDP). This means that the richer the country, the lower annual budget it would be allocated. For example, only 5.9 % (average) of global limits are allocated to the EEA country territory using this approach (EEA and FOEN, 2020).

This approach requires data on GDP and population. The approach is based on work by Berg and colleagues (Van den Berg et al., 2020) and is used to allocate required GHG reduction efforts to countries according to their capacity.

Right to development

This approach refers to the needs of countries to meet the needs of their people. In climate policy, it considers the least capable countries to being allowed less ambitious reduction targets. It is linked to the capability principle (above) as countries with higher economic power and level of development could be allocated less resources as they have already achieved a decent level of wellbeing.

According to Lucas and Wilting (Lucas and Wilting, 2018), this approach can use data on the ‘Responsibility Capability Index (RCI)’[8]. This index considers indicators of responsibility and capacity, together with macro-economic data to define the development need for individual countries in each year (estimated by way of a development threshold). Further details on the RCI can be found on their webpage. For example, only 4.1 % (average) of global limits are allocated to the EEA country territory using this approach (EEA and FOEN, 2020).

Needs

The European Environment Agency (EEA) together with the Federal Office for the Environment (FOEN) published a study (EEA and FOEN, 2020) which implements a ‘needs’ approach (amongst others) to allocate resource budgets to people considering population weighted by age (equivalency between adults and children), travel time to major cities (accessibility), and food nutrient adequacy (nutrition). This reflects that people have different needs for resources access, e.g., due to their age, household size, or their living location. For example, about 7.1 % (average) of global limits are allocated to the EEA country territory using this approach (EEA and FOEN, 2020).

Responsibility

This approach takes into consideration the relative contribution of individual countries to environmental impacts (‘polluter pays principle’). For this, it considers the historical contributions to an environmental impact.

Resource efficiency

According to this approach the allocation of a global budget based on where the highest efficiency gains are expected. The global budget is allocated based on equal resource efficiency. For this, an efficiency parameter has to be developed for each of the planetary boundary dimensions. Lucas and Wilting apply the concept to biogeochemical flows where the efficiency parameter is based on the amount of N or P released per area (Lucas and Wilting, 2018).

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[8] https://climateequityreference.org/

The choice of the allocation principle depends is normative and depends on the policy background and research question of the specific case.

3.2.2 Selected studies applying allocation approaches to derive planetary boundaries at country and regional scale

A number of case studies exist to date on the application of the global planetary boundaries framework to the regional or national policy context (selected examples include (EEA and FOEN, 2020; Sala et al., 2020; Häyhä et al., 2018, 2016; Lucas and Wilting, 2018; Lucas et al., 2020)).

For example, the EEA and FOEN published the study *"Is Europe living within the limits of our planet?"* in which multiple allocation approaches for downscaling biogeochemical flows (P and N), land system change, and freshwater use to the EU-level were investigated (EEA and FOEN, 2020). The downscaling principles included equality, human needs, right to development, sovereignty, and capability. European environmental footprints were derived using MRIO analysis with environmental extensions. The ethical dimension 'right to development' results in the lowest European share of the global limit, whereas 'sovereignty' allocated more of the global budget to Europe. Environmental footprints surpass the limits for biogeochemical flows (both P and N) and land system change, but not for freshwater use[9].

The Joint Research Centre (JRC) of the European Commission has operationalized the planetary boundaries concept together with environmental thresholds derived from absolute sustainability assessment in the context of the LCA-based *EU CFI* (Sala et al., 2020; Sanye Mengual and Sala, 2023) which is used, e.g., to monitor the circular economy[10] and the 8th Environment Action Programme[11]. Planetary boundaries and other environmental thresholds were downscaled to the EU-27 and individual EU member states on a per-capita basis ('equality approach'). The EU Consumption Footprint transgressed several environmental thresholds such as, e.g., climate change, land use, and particulate matter emissions. However, it should be noted that the environmental thresholds developed per LCA impact categories for the JRC consumption footprint, do only partly overlap with the original planetary boundaries framework by (Rockström et al., 2009a; Steffen et al., 2015b; Rockström et al., 2023; Richardson et al., 2023).

Furthermore, several studies at national level have attempted to incorporate the planetary boundaries concept into their monitoring and policy making such as, for example, for the *Netherlands* (Lucas and Wilting, 2018), *Sweden* (Nykvist et al., 2013; Swedish EPA, 2021), *Germany* (UBA, 2021; Nuss et al., 2023), *Switzerland* (Dao et al., 2015, 2018), the *EU* (Hoff et al., 2014, 2017; Häyhä et al., 2018) (please note that this is not a comprehensive summary of the literature).

EEA Eionet Working Group Planetary Boundaries[12]

The EEA has enacted a working group on planetary boundaries in 2022 consisting of several member countries of the European Environment Information and Observation Network (EIONET)[13]. The goal of this working group is to provide a platform for like-minded countries with an interest in applying the planetary boundaries framework in environmental policy making at national level. Current efforts include, e.g., the screening of country-level efforts for assessing environmental footprint indicators and comparisons with planetary boundaries, exchange of best practices, work towards harmonizing the different approach, and providing a forum for discussion of improvements to the methodologies and for keeping track of research developments.

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[9] The nitrogen cycle was exceeded for all allocation principles, while the phosphorus cycle and land system change were exceeded for all allocation principles except 'sovereignty. The limit for freshwater use is not exceeded for any ethical dimension investigated in the study (EEA and FOEN, 2020).

[10] https://ec.europa.eu/eurostat/web/circular-economy/monitoring-framework

[11] https://environment.ec.europa.eu/publications/monitoring-framework-8th-environment-action-programme_en

[12] https://forum.eionet.europa.eu/eionet-working-group-planetary-boundaries/

[13] https://www.eionet.europa.eu/

Table 3.1: Overview of selected examples of studies that downscale planetary boundaries to the national or regional level.

Study	Geographical focus	Downscaling approach	Planetary Boundaries	Reference
Is Europe living within the limits of our planet?	33 EEA member countries	Equality, human needs, right to development, sovereignty, and capability	P and N cycles, land system change, freshwater use. Case study Switzerland on biosphere integrity (genetic diversity)	(EEA and FOEN, 2020)
Environmental sustainability of European production and consumption assessed against planetary boundaries	EU-27 and member states	Equality	16 life-cycle impact assessment (LCIA) categories from the EU Consumption Footprint	(Sala et al., 2020)
“Living well, within the limits of our planet”? Measuring Europe’s growing external footprint	EU	Equality	Climate change, water sue, land use, biodiversity loss, biogeochemical cycles (P and N)	(Hoff et al., 2014)
Bringing EU policy into line with the Planetary Boundaries	EU	Equality	Climate change, land use, biogeochemical flows (N and P), freshwater use, biosphere integrity	(Hoff et al., 2017)
Operationalizing the concept of a safe operating space at the EU level – first steps and explorations	EU	Equality	Climate change, land use, biosphere integrity, biogeochemical flows (N and P), freshwater use, novel entities	(Häyhä et al., 2018)
Environmental Limits and Swiss Footprints Based on Planetary Boundaries National environmental limits and footprints based on the Planetary Boundaries framework: The case of Switzerland	Switzerland	Equality	Climate change, ocean acidification, biogeochemical flows (N and P) losses, land use, biodiversity loss	(Dao et al., 2015) (Dao et al., 2018)
Using planetary boundaries to support national implementation of environment-related sustainable development goals	Netherlands	Sovereignty, equality, capability, efficiency	Climate change, land use, biogeochemical flows (N and P), biodiversity loss	(Lucas and Wilting, 2018)
National Environmental Performance on Planetary Boundaries	Sweden	Equality	Climate change, biogeochemical cycles (N and P), freshwater use, land use, stratospheric ozone depletion, biodiversity loss	(Nykvist et al., 2013)
Living within the limits of our planet – a Swedish perspective	Sweden	Equality, needs, right to development, sovereignty, capability*	Biogeochemical cycles (N and P), land use, freshwater use	(Swedish EPA, 2021)
Preliminary study on approaches and concepts for linking the "Planetary Boundaries" concept with the use of abiotic raw materials	Germany	Equality, right to develop, sovereignty (grandfathering), historical responsibility	Climate changes, land use, freshwater use, biogeochemical cycles (N and P)	(UBA, 2021)

*analogous to (EEA and FOEN, 2020)

This table with relevant literature highlights that (1) the equality approach is most widely used in the literature and (2) the application of the planetary boundaries framework in policy-related literature (e.g., reports by EU or national government institutions) is gaining in relevance.

3.3 Science-based targets for the EU-27 and comparison with the results from Chapter 2

This chapter applies the LCIA-based planetary boundaries from the Joint Research Centre (Sala et al., 2020) to benchmark environmental impacts calculated in chapter 2 using the EEA consumption footprint. We also discuss uncertainties associated with the JRC planetary boundaries method used.

3.3.1 JRC approach to benchmark environmental impacts

In order to compare the EEA consumption footprint discussed in chapter 2 with environmental thresholds, we apply the pre-defined LCIA-based planetary boundaries from the JRC per impact category (Sala et al., 2020) (Table 3.2).

Table 3.2: Planetary boundaries adopted to the environmental footprint (EF) method for each impact category

Abbr.	**Impact category**	**Indicator**	**Unit**	**PB**	**PB per capita* (2022)**
CC	Climate Change	Global warming potential (GWP100)	kg CO_2-eq	6.81E+12	8.56E+02
MEU	Eutrophication (marine)	Fraction of nutrients reaching marine end compartments (N)	kg N-eq	2.01E+11	2.53E+01
FEU	Eutrophication (freshwater)	Fraction of nutrients reaching freshwater compartments (P)	kg P-eq	5.81E+09	7.31E-01
TEU	Eutrophication (terrestrial)	Accumulated exceedance (AE)	molc N-eq	6.13E+12	7.71E+02
AC	Acidification	Accumulated exceedance (AE)	molc H^+-eq	1.00E+12	1.26E+02
LU	Land use	Soil erosion	kg soil loss	1.27E+13	5.01E+05
WU	Water use	Deprivation-weighted water consumption	m^3 world eq	1.82E-14	2.29E+04
PM	Particulate matter	Impact on human health	Disease incidence	5.16E+05	6.49E-05
POF	Photochemical ozone formation	Tropospheric ozone concentration increase	kg NMVOC-eq	4.07E+11	5.12E+01
HTOX_c	Human toxicity, cancer	Comparative toxic units for humans	CTUh	9.62E+05	1.21E-04
HTOX_nc	Human toxicity, non-cancer	Comparative toxic units for humans	CTUh	4.10+E06	5.16E-04
ECOTOX	Ecotoxicity, freshwater	Comparative toxic units for ecosystems	CTUe	1.31E+14	1.65E+04
FRD	Resource use, fossil	Abiotic resource depletion – fossil fuels (ADP-fossil)	MJ	2.24E+14	2.82E+04
MRD	Resource use, minerals and metals	Abiotic resource depletion (ADP ultimate reserves)	Kg Sb-eq	2.19E+08	2.75E-02

*Downscaled by dividing with the world population of 7.952 billion people in 2022[14].

Note: Ionizing radiation and ozone depletion are excluded as they are not covered in the EEA consumption footprint calculation due to missing elementary flow data/environmental extensions.

Source: (Sala et al., 2020).

These boundaries are only partly based on the planetary boundaries concept with several thresholds derived from literature on environmental carrying capacity such as, e.g., by Bjorn and colleagues (Bjørn and Hauschild, 2015; Bjørn et al., 2015). Comparing these boundary values on a per capita basis (using the 2022 global population figures) to the per capita consumption footprint in the same year for the EU-27 allows calculating the extent to which individual thresholds have been surpassed by EU consumption (Figure 3.4). The magnitude of the results presented here are comparable to the 'Final Consumption I/O' results from Sala et al. (2020) (see the supporting information table SM3 in Sala et al. (2021): Overall, the results here show the same conclusion regarding an overshoot in planetary boundaries for HTOX_nc, PM, POF, CC, FRD and MRD.

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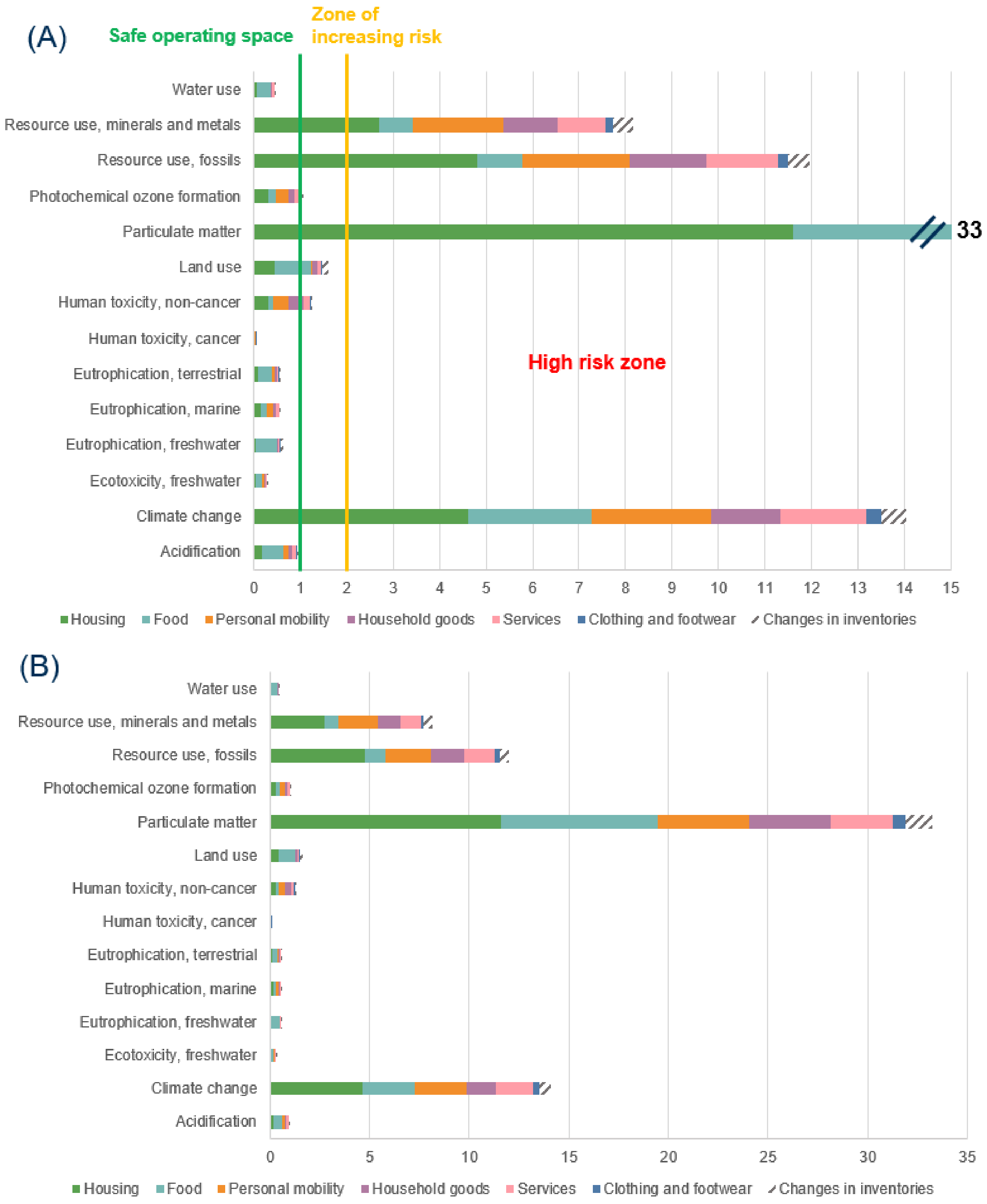
[14] https://data.worldbank.org/indicator/SP.POP.TOTL

Figure 3.4: Comparison of the EEA consumption footprint results (chapter 2) against environmental thresholds published by (Sala et al., 2020) using a per-capita equal allocation approach.



Note: Due to the large magnitude by which PM surpasses the planetary boundary, the bottom figure (B) shows the full scale, while the top figure (A) "zooms in" to the other impact categories. Please see the previous table for the full name of each impact category.

However, differences in results exist compared to other methods, e.g., the LCA-based results. Different explanations are possible: due to the cut-off of activities in the LCA model, a different (and more extended) set of elementary flows in the LCA model, etc.

Impacts in the high-risk zone

The comparison of the EEA consumption footprint by consumption domain (Figure 3.4) highlights that the boundaries climate change (CC; factor 14), particulate matter (PM; factor 33), fossils resource use (FRD; factor 12), and mineral resource use (MRC; factor 8) are being surpassed and found in a high-risk zone, i.e., they are found at a factor of 2 or more by which the planetary boundaries have been transgressed.

Particulate matter (PM)

This impact category looks at the impact on human health by using the concept of 'acceptable environmental burden' of disease (Vargas-Gonzalez et al., 2019). The boundary is based on PM levels per m^3 of air considered 'safe' by the World Health Organization (WHO) accounting also for natural average (background) concentrations. Note that different calculation methods can be applied to derive an estimate of the LCIA-based planetary boundary for PM in disease incidence to align with the units of the environmental footprint (EF) impact assessment method. We use the global value of 5.16E+05 disease incidence which is converted, using 2022 population figures, into 6.49E-05 disease incidence/person.

With a total impact of 2.2E-03 disease incidence/person in 2022, the impact of EU citizens is found about 33 times above the downscaled per capita boundary. Main contributing consumption areas include housing (mainly from the combustion of fossil fuels), food (largely linked to the consumption of animal products), household goods (mainly resulting from the production of appliances), and personal mobility (mainly tail-pipe emissions from combustion vehicles). In fact, the housing consumption domain alone transgresses the EU allocated PM boundary by almost 12 times. PM is mainly linked to energy, energy-intensive production processes (like construction materials and appliances) and livestock (linked to dairy products and meat production).

We note that the boundary value can significantly change depending on the estimation approach used. For example, (Sala et al., 2020) provide four different proxy indicator results ranging from 8.68E+00 to 3.12E+06 disease incidence (with a value of 5.16E+05 used in the study). This means that the absolute result obtained provides only a first insight and can significantly change depending on the planetary boundary value chosen (however, the threshold would be transgressed using any of those planetary boundaries).

Climate change (CC)

The planetary boundary for this impact category is based on the 2 °C target, which aims to limit global warming to 2 °C above pre/industrial levels. The converted GWP100 boundary value from (Bjørn and Hauschild, 2015) of 6.81+12 kg CO_2-eq is used and converted into a per capita threshold of 856 kg CO_2-eq/person/year in 2021.

With a total consumption-based impact of 12 tons CO_2-eq/person in 2022 for the EU-27, the climate threshold has been surpassed by a factor of 14. Consumption areas contributing the bulk to climate change impacts include housing, food, and personal mobility (e.g., burning of fossil fuels in these consumption areas or GHG-emissions from land use in the food sector). EU citizens need to drastically reduce their carbon footprint in order to return back into a safe operating system for climate change.

Note that the 2 °C target used for this assessment will likely still lead to irreversible changes in the Earth system. Using a more stringent target, such as 1W/m^3 (equal to a temperature increase of 1.06 °C above preindustrial era) (Rockström et al., 2009b) or the widely used 1.5 °C target in climate policy (Rogelj et al., 2016), in a precautionary approach would result in an even larger overshoot for the climate change boundary in 2022. Therefore, the absolute magnitude of overshoot is largely influenced by the boundary value chosen for climate change.

Fossil resource depletion (FRD) and mineral resource depletion (MRD)

Planetary boundaries for resources (raw materials) use are not readily available from the literature as these would need to be derived, e.g., by considering environmental implications of raw materials extraction and provisioning or by using scenario outcomes on future raw material demands (e.g., in climate protection pathways. However, for the LCIA-based planetary boundaries study Sala and colleagues used as a first proxy the "factor 2" concept which assumes that global raw material consumption needs to be reduced by 50% to achieve environmental sustainability (Sala et al., 2020). Note, however, that this is a normative assumption and other reduction targets could be used (e.g., based on future material demands compatible with climate neutrality pathways (Nuss et al., 2021) or based on aspects of materials criticality). In our study, no adaptations were made to these global boundary values of 2.24E+12 MJ-eq. (considering global use of fossil fuels) and 2.19E+08 kg Sb-eq. (considering global extraction rates and ultimate reserves for minerals[15]) (Sala et al., 2020).

Use of fossil raw materials (i.e., coal, oil, natural gas) was 337 GJ-eq. per person in 2022. The boundary value of 28.2 GJ-eq. per person implies that EU citizens consume fossil fuels above their fair share (by a factor of ca. 12). Main contributors include energy-intensive consumption areas such as housing (both for fuel demand for heating and the energy intensive production of building materials), household goods (due to energy intensive production processes), and personal mobility.

Similarly, the consumption of mineral resources is with 0.23 kg Sb-eq. per capita by a factor of about 8 times above the determined planetary threshold. Main consumption areas that contribute to mineral resource depletion include household goods (e.g., use of metals in appliances), housing (e.g., use of construction materials such as steel), and personal mobility (e.g., use of metals in car manufacturing).

It is important to emphasize again that the choice of the boundary values for resources based on the factor 2 concept is normative. Using other concepts (e.g., factor 5 (Weizsacker et al., 2009) or methods to derive resource budgets (Desing et al., 2020)) could result in significantly different boundary values. Therefore, the uncertainty associated with the resource-related planetary boundary assessments is considered very high. Furthermore, for fossil raw materials the use of the climate change impact category and boundary value seems more appropriate given that an Earth system threshold can be transparently derived from the scientific literature.

Environmental impacts within the zone of increasing risk:

Impacts with regard to human toxicity, non-cancer (HTOX_nc) (factor 1.2), land use (LU) (factor 1.6), and photochemical ozone formation (POF) (factor 1.1) are found within a zone of increasing risk, i.e., between a factor of 1 and 2 by which the planetary boundaries have been transgressed.

Human toxicity, non-cancer (HTOX_nc)

The boundary value for this impact category is based on the environmental burden approach of (Vargas-Gonzalez et al., 2019; Bjørn and Hauschild, 2015) and expressed in comparative toxic units for humans (CTUh). The boundary is surpassed by a factor of 1.2 mostly due to consumption of household goods, housing, and mobility. The production of household appliances, construction materials and vehicles are related to emissions to air linked to this environmental impact category.

Land use (LU)

Land use in the JRC assessment framework differs from the original planetary boundary control variable (which looks at the area of forested land as the percentage of original forest cover (Richardson et al.,

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[15] The choice of the reference substance, antimony, is arbitrary and used to obtain values in a common unit (i.e., kg antimony equivalents). Antimony is the first element alphabetically for which the necessary data on global extraction and ultimate reserves is available (Van Oers and Guinée, 2016).

2023)) and employs an ecological boundary on soil erosion using the LANCA method[16] (Sala et al., 2020). Environmental impact of EU consumption in 2022 are with a factor of 1.6 within the range of uncertainty, mostly due to the consumption domains food and housing.

Photochemical ozone formation (POF)

Finally, the threshold value for photochemical ozone formation looks at the tropospheric ozone concentration increase in kg non-methane volatile organic compounds (NMVOC)-equivalents (Sala et al., 2020). With a factor of 1.1, the consumption-based impacts of the EU are just within the area of uncertainty, mostly due to the consumption domains housing and personal mobility.

3.3.2 Discussion of uncertainties of the planetary boundaries concept

Uncertainty ranges for each boundary value

Uncertainties differ depending on the planetary boundary value chosen in the calculation (see above). For example, the choice of the factor 2 concept, by which resource use of fossil fuels and mineral raw materials would need to be reduced by 50 %, is a normative choice and using other choices would alter the results. Especially for particulate matter, the option chosen to derive the planetary boundary can influence the final value by several orders of magnitude (see the supporting information table SM2 in Sala et al. (2021)).

However, while the absolute magnate of planetary overshoot can vary depending on the choice of the boundary value chosen, the message generally remains the same, namely that the EU triggers unsustainable levels of environmental impacts (e.g., GHG emissions, air emissions, land use) and overconsumes fossil and mineral raw materials.

Uncertainty with downscaling (see EEA-FOEN study, Table 3.3)

Using the per capita allocation approach (equality) in the previous chapter leads to approximately 5.6 % of global impacts being allocated to the EU-27 (i.e., 446,735,291 people (EU-27$_{2022}$) / 7.952 billion people (global$_{2022}$) =5.6 %). In the EEA-FOEN study this share was at around 9.3% on average due to different population figures and as the EU-28 (incl. the UK) was considered (EEA and FOEN, 2020). Using a range of different allocation principles (equality, needs, right to development, sovereignty, and capability), the average shares allocated to the EU in EEA-FOEN study[17] varied between 4.1 % (right to development) to 11.4 % (sovereignty). This highlights that the choice of the downscaling approach chosen, can also have an important impact on the final results.

Uncertainties within the environmental footprint calculation

The underlying MRIO model FIGARO and EXIOBASE including its environmental extensions is associated with uncertainties. The coverage of the elementary flows is extensive, but still small compared to LCI-databases (e.g., see supplementary table A1 and A2 in Beylot et al. (2019) for a detailed comparison). Uncertainty ranges associated with environmentally relevant input and output parameters in the environmental footprint model can be estimated, for instance, using a semi-quantitative approach such as the PEDIGREE-matrix from LCA in which an uncertainty bound is associated with each input/output parameter. Using analytical approaches such as Monte-Carlo analysis could then allow to estimate an overall uncertainty bound for each environmental impact result. However, this could not yet be done in this project.

3.4 Conclusions

Global environmental impacts triggered by EU consumption lead to the overshoot of several planetary boundaries and environmental limits that can be captured using the JRC planetary boundary LCIA method (Sala et al., 2020). Consumption areas such as housing, food, and personal mobility contribute the bulk to

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[16] https://www.ibp.fraunhofer.de/en/expertise/life-cycle-engineering/applied-methods/lanca.html

[17] See table 3.3 in the EEA-FOEN study (EEA and FOEN, 2020).

this overshoot for a wide range of impact categories. Furthermore, the consumption of household goods triggers impacts with regard to mineral resource use and toxicity. While a number of uncertainties are associated, e.g., with the choice of the planetary boundary value, the selection of the downscaling method (to derive resource budgets at EU-level), and the underlying footprint method, the overall trend that the EU is significantly overshooting planetary boundaries (e.g., related to climate change and associated fossil resource use, air emissions, and land use), is still valid and policy makers and EU citizens need to act quickly to reduce the EU consumption footprint. The next chapter will discuss options to reduce the consumption footprint in a number of priority areas based on their impact contribution.

4 Sustainable consumption pathways

Key messages:

- Key message 4.1: Solution pathways to reduce Europe's consumption footprint in order to stay within the Earth's safe operating space, especially regarding climate change, particulate matter, land use, human toxicity, and resource use (chapter 3), require significant changes in the most impactful consumption domains including housing, food, person mobility and household goods and services.
- Key message 4.2: Solution pathways require a mix of approaches to reduce (absolute reduction in consumption), shift (replacement of unsustainable consumption options by more sustainable ones) and improve (efficiency improvement) consumption patterns. In this chapter, we give particular emphasis to the circular economy related approaches in the mix.
- Key message 4.3: A realistic view about what is needed to disseminate and scale up the approaches to deliver more sustainable consumption solution pathways requires analysing whether there are enough motivation, capability, and opportunity among people to change their consumption patterns in Europe.

4.1 Why European consumption patterns need to change – and fast!

As we have seen in previous chapters, there is an urgent need to change the consumption patterns in Europe. This is so because consumption levels related to key areas of people's lives, such as housing, food consumption, and personal mobility contribute to the crossing of essential Earth system limits considered safe in terms of resource use and impact regeneration to ensure the continuation of our lives as we know it today and are leading to an increased risk of causing irreversible damage to the Earth's systems.

Concretely, as shown in Chapter 2, the EU-27 Consumption Footprint indicator (CFI) has reached the level of 866 million points in 2022, registering an increase of 4 % in comparison to 2010. This overall trend resulted from a substantial decrease between 2010 and 2016 (-23 %), followed by a sharp increase between 2016 and 2022 (+35 %). The CFI per capita increased from 1.89 points per capita in 2010 to 1.94 point per capita in 2022. Despite the significant reduction in the CFI in the period from 2010 to 2016, the CFI is on the rise again ever since and, as discussed in Chapter 3, the current EU-27 Consumption Footprint indicator is still considered extremely high, as it exceeds the planetary boundaries several times for many types of impacts, such as for climate change (CC), particulate matter (PM), land use (LU), human toxicity (HTOX), and resource use (RD, both for fossil fuels and minerals). As there is great uncertainty about when tipping points could be reached and damages could become irreversible, it is crucial to drastically change current European consumption patterns.

Before exploring solution pathways, it is crucial to recap first what the most impactful consumption domains are, in order to build a solid basis to make the case around where the pathways need to focus on (i.e., to identify the leverage points from the perspective of overall environmental impacts as reflected with the aggregated consumption footprint score[18]). As demonstrated in Chapter 2, when analysing the consumption domains that contribute the most to the current CFI in 2022 (excluding changes in inventories), the largest share is attributed to housing (32.3 %), followed by food (23.1 %), personal mobility (17.8 %), household goods (12.7 %), services (11.8 %), and clothing and footwear (2.2 %).

With regards to **housing**, overall, the technological efficiency gains, the shift to cleaner and renewable technologies, and the fact that people in Europe are consuming more environmentally friendly alternatives are visible in the CFI results, but these environmental gains are annulled by the increase in consumption

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[18] Note that depending on the impact category investigated, the contributions by consumption area and, hence, leverage points to reduce these might be different. Here we use the normalized and weighted single score indicator from the ILCD impact assessment method as a starting point to identify sectors with the highest contributions to overall impacts.

levels (except for electricity demand), especially a significant growth in housing construction and fossil fuel-based energy demand from 2014 onwards. Also, apart from a decrease in climate change related impacts in the area due to a decrease in fossil resource use, all other environmental impact categories continue to increase. Remarkable is a decrease in the impact of electricity use, both due to gains in the production and the demand side. Overall, the decrease in the footprint of electricity is the result from a shift to electricity products that have a lower environmental footprint (e.g., increasing share of electricity production from renewables) and a decreasing trend in consumption volumes of electricity by households. A strive towards less energy intensive products partly explains this decreased consumption volume (e.g., driven by the Ecodesign for Sustainable Products Regulation).

The increasing final use volumes for construction in the EU-27 could partly be explained by increasing isolation and technical requirement (heat pumps, solar panels, etc.) that have a long-term beneficial effect via a reduced energy requirement. These effects should gradually become more visible in the future.

Overall, in the period 2010-2022 the CFI of **food** increased by 13.7 %. The gains are mainly due to the decreased impact via technology efficiency gains across all consumption domains and a decreasing consumption volume of tobacco and the lack of an increase in consumption of milk, cheese, and eggs, and food products n.e.c., but these gains are outweighed by the increased impacts due to increasing consumption volumes, mainly from meat consumption, from fruit and vegetables, and from beverages. Still, the increase in the consumption volume is less pronounced in the food consumption domain compared to the other ones.

With regards to **personal mobility**, the decrease in the CFI is the result of environmental improvements in the production network of fuels and lubricants and to a lesser extent in the production of vehicles. These gains were only partly outweighed by increased consumption volumes for vehicles, as level of consumption for fuels and lubricant is fairly stable over time.

When we look into the domain of **household goods**, in the 2010-2013 period these is a large decrease in the CFI which is mainly related to shifts in consumption patterns within the pharmaceutical products and a small reduction in demand for household appliances and goods as well as due to environmental efficiency improvements in the production networks of these appliances and furniture. Part of this gain is outweighed in the 2013-2022 period, mainly due to increased consumption volumes across all product groups.

Finally, in the **services** consumption domain, the decrease in the CFI prior to 2015 resulting from increased efficiency in production networks was compensated by increased consumption volumes of public, financial, and medical services in later years, forcing the CFI to rise again.

In this context, the following section will focus on these consumption domains as the main target areas of solution pathways to help Europe transition towards more consumption levels.

4.2 Solution pathways towards more sustainable consumption patterns

A mix of approaches to enable more sustainable consumption and behaviour patterns are needed in order to help Europe reduce its consumption footprint and adopt new ways of living that allow people to flourish and thrive within the Earth's safe operating system. In this chapter we explore different mixes of approaches by addressing the consumption domains with the largest contribution to the Consumption Footprint indicator (CFI), and we call them solution pathways.

Concretely, each solution pathway will focus on one consumption domain and will comprise of solutions to ***reduce***, ***shift*** and ***improve*** consumption patterns (Akenji et al., 2021) in that specific domain. Reduce solutions are understood as solutions that enable absolute reduction of consumption amounts of goods and services. Shift solutions refer to approaches that help replace unsustainable consumption options with more sustainable ones. And improve solutions encompass approaches that enable efficiency improvement without necessarily changing consumption amounts.

In this chapter, we give particular emphasis to the **circular economy related approaches** in the mix, and the reason for this is two-fold. On the one hand, the circular economy has been gaining more and more attention and dedicated efforts from different stakeholder groups around the globe. In this sense, we are keen to understand to which extent circular solutions play a critical role in the solution mix to reduce Europe's consumption footprint. On the other hand, most studies and initiatives on the circular economy overall are still framed from the perspective of production and business model solutions, while the role of people's behaviours and their relationship with products and their environment have been largely overlooked (Selvefors et al., 2019; van den Bergh et al., 2021). When looking into ways to reduce consumption footprints, however, it is inevitable to get closer to people's reality and account for people-centric approaches as well. Therefore, we see this as an opportunity to help address this research gap.

For the achievement of these sustainable consumption solution pathways to be realistic, this chapter proposes analysing also whether there is enough **motivation**, **capability**, and **opportunity** among people to adopt the solution pathways and change consumption patterns in Europe. This is based on Michie et al.'s COM-B model (Michie et al., 2011), which was originally designed for developing policies in the public health domain and its use has evolved towards its application in the promotion of sustainability strategies and policies in various sectors (Terlet et al., 2022).

According to the model, behaviour is shaped by three main determinants: capability, opportunity, and motivation (Michie et al., 2011). **Capability** is described as people's psychological and physical capacity to engage in the activity concerned, in this case, circular behaviours that support the transition towards sustainable consumption in Europe, including knowledge and skills. **Opportunity** is defined as all the factors that lie outside the individual that make the behaviour possible or prompt it, including infrastructure and the social context. **Motivation** is defined as all those brain processes that energize and direct behaviour, both rational and unconscious processes. The absence of any one of these factors is likely to put the desired behaviour change at risk. When thinking of interventions to reduce Europe's consumption patterns, which largely depend on changing consumption behaviours, triggering or changing any of these factors, separately or in combination, may yield better results.

4.2.1 Housing pathway: Shifting to renewable-based heating, cooling and electricity grid and enjoying smaller living spaces

What is this pathway about?

The number of households in Europe is still increasing due to population growth and an increase in one-person households, driving greater energy and material use as well as waste generation. Also, the average living space per person evolves. Living space per person in dwellings in Germany, for example, went from 34.9 m^2 in 1991 to 47.4 m^2 in 2022 (Statista, 2023). The amount of living space can also be measured as the average number of rooms per person: there were on average 1.6 rooms per person in the EU in 2021 (ESTAT, 2023c). Among the Member States, the largest number was recorded in Malta (2.3 rooms per person), followed by Belgium, Ireland, and the Netherlands (all 2.1 rooms).

Among the reasons behind this trend is the reduction of household size in Europe, an indicator that measures the average number of people living in the same home. In 1961, EU-15 had 92 million households with an average of 3.3 persons per household (ESTAT, 2023a). By 1995 the figure had risen to 148 million households with an average of 2.5 persons per household (ibid.). By 2021, household size in the EU decreased even further, reaching an average of 2.3 persons per household (ESTAT, 2023a).

As a result of this, in 2020, the European construction sector produced approximately 283 million tons of construction and demolition waste (ESTAT, 2023b), thus constituting one of the most substantial waste streams in Europe (ibid.). Buildings account for 40% of the EU's total energy consumption and 36% of its greenhouse gas emissions (EC, 2020) and the building and construction sector is responsible for over 35% of EU's total waste generation and 5-12% of national GHG emissions (EC, 2023b), therefore playing a pivotal role in Europe's transition towards a more sustainable CFI.

Besides changes in family structure in the EU, there is evidence that consumers tend to associate larger homes with higher status and quality of life (Foye, 2017), although increased living spaces do not necessarily equate to a higher quality of life, which stresses out an arising intriguing paradox between people's aspirations and the actual benefits they derive from it (Lagas et al., 2015). On the other hand, surplus space often remains underutilized, underscoring the plausibility for consumers to live more sustainably, efficiently, and happily within smaller living spaces (Cohen, 2021).

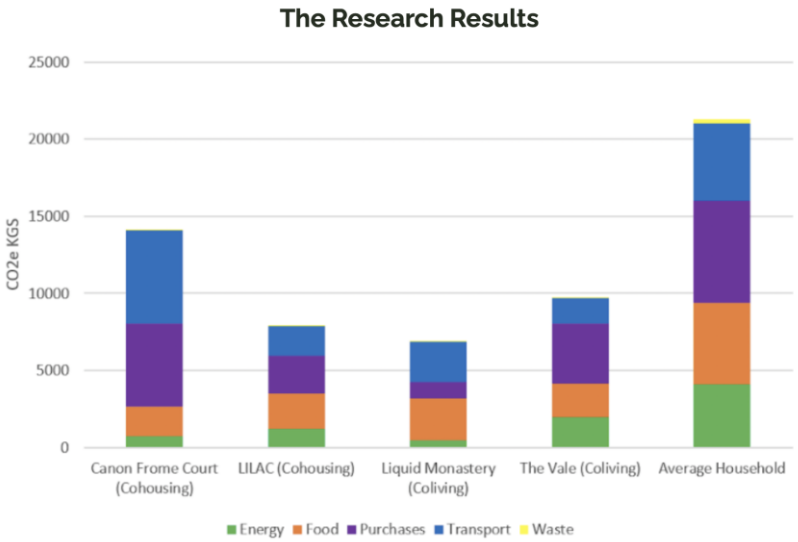
To reverse such patterns, the housing pathway explores a mix of strategies available to European consumers to reduce, shift and improve consumption patterns towards the adoption of more circular, sustainable housing solutions. Particular attention will be paid to solutions that help reducing the amount of living space per person, as increased consumption levels in the housing domain has been the main factor outweighing the efficiency gains registered in the sector in the past decade, as well those solutions that help reducing resource use and shifting towards renewable based sources of energy at home, due to the high impact associated to it.

Reduce solutions

Reduce solutions for housing encompass mainly shared living initiatives that aim to reduce the amount of living space and interventions to reduce energy consumption in homes. It goes well in line with what the IPCC report's Chapter 9 (Cabeza et al., 2022) calls sufficiency in buildings: measures that tackle the causes of GHG emissions by avoiding the demand for energy and materials over the lifecycle of buildings and appliances, based on long-term actions driven by non-technological solutions. Such actions would include the optimisation of the use of building, repurposing unused existing buildings, prioritising multi-family homes over single-family buildings, and adjusting the size of buildings to the evolving needs of households by downsizing dwellings. According to the report, at a global level, up to 17% of the carbon emission mitigation potential could be captured by 2050 through sufficiency interventions.

Particularly with regards to smaller and optimised living spaces, evidence shows that co-living and cohousing initiatives hold great potential to deliver relevant sustainability gains. For example, a case study conducted in the UK found that a co-living community's overall greenhouse gas emissions were 68% lower than the average household (Clark, 2021). In this study, two co-living communities and two cohousing communities were compared with an average UK household, and all four of them performed better in terms of carbon emissions. The reasons identified for this improved home performance are various, including the enabling infrastructure, e.g., to produce and optimise the use of renewable sources of energy, and shared use of common areas, living rooms, kitchens, and bathrooms, which led to less private living space per person and more efficient space heating and electricity usage (ibid.).

Figure 4.1: CO_2 emissions per household per year.



Source: Clark (2021).

Other studies in Europe have pointed in a similar direction. Lavagna et al. (2018) found that single-family houses are responsible for the highest share of impacts related to housing in Europe, as such homes usually have a greater floor area in comparison to multi-family dwellings. The use phase of single-family houses was found to be the most impacting lifecycle stage, due to the contribution of burning fossil fuels for heating and electricity production (ibid.).

Besides the environmental gains, analysis of multigenerational co-living initiatives has associated shared homes with health and social benefits, such as a lower risk of developing dementia among people over 50, and greater development of language, reading and social skills among children that spend time regularly with elderly people (Branson, 2020).

In the energy consumption reduction front, behavioural experiments have become smarter in fostering the uptake of relevant energy saving measures among citizens in their homes. For example, to effectively support homeowners in adopting energy-saving behaviours and reducing their bills, particularly in view of the rise in energy prices in the past couple of years, the UK Local Government Association, aware that the government was not effective in communicating energy-saving tips, taught residents of nine municipalities five low-cost energy-saving actions, in order to empower the residents to help their friends and family to implement these measures (LGA, 2019). The intervention promoted particularly five tips that cost little money and effort to implement and could save the resident more than £500.00 per year. As a result, the initiative found that sharing energy-saving tips increased by 39% the participants' energy-saving knowledge. Residents who participated in energy saving public training also appeared to be more likely to help their friends and family (89.3%) than those who did not participate (32.1%) (ibid.).

Shift solutions

Shift solutions would include opportunities to replace conventional, linear building infrastructure and practices with more circular ones.

One example of such solutions is the reuse of greywater (Circular Homes[19]). Greywater is wastewater from non-toilet plumbing systems, such as wash basins, washing machines or showers. It can be separated with retrofitting measures in existing buildings. Greywater can be treated using innovative nature-based

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[19] https://www.circularhomes.eu/circular-measures-and-products/

solutions for indoor application in multi-level green walls with minimum energy cost (<1.5kWh/m3) and disinfected using commercial O3/UV systems for >90% water reuse.

Another example would be to reuse existing building products and recycled materials (Circular Homes). Reusing existing building materials can reduce emissions, but also help to retain the value of buildings over their lifetime and support the local economy. To increase reuse, it is necessary to maximize the number of valuable materials recovered by increasing the acceptance of Construction and Demolition Waste CDW–based products. CDW-derived materials can be effectively reintroduced in the production cycles of concrete and timber components with a replacement rate of 50-85 %, helping to reduce the impacts of building in the same rate.

If the shift to renewable sources of energy at the household level are also considered a circular economy related solution in more broadly speaking terms, then it is also worthwhile exploring this shift here. In 2022, more than 22 % of the gross final energy consumed in the EU came from renewables (EEA, 2023b). However, while climate mitigation and energy policies have been effective in lowering carbon-intensive energy supply over time (e.g., in 2022 the EU's electricity sector was 50 % less GHG intensive than in 1990), high gas prices and nuclear shutdowns in 2022 resulted in more coal use in the generation mix (EEA, 2023a). The shift to renewable sources of energy at the household level played an important role in this process and it is important to scale it further in order to reduce the negative impacts of housing in the CFI.

Some rights and initiatives have removed obstacles and made it easier for people in Europe to consume renewable energy in their homes. One of them is the right to switch to a renewable electricity supplier without any charge for the change, and since 2019 also within 3 weeks' time (EC, 2023a).

Another important step was to enable consumers and local communities in Europe to become prosumers, in other words, the possibility to actively participate in the electricity market by producing their own electricity, consuming it, or selling it back to the grid (ibid.).

In some EU countries, energy consumers can use online price comparison tools to compare the prices of renewable electricity providers and have more transparency and certainty when making the shift (ibid.).

Improve solutions

In the efficiency side of the story, zero-waste building construction guidelines (Soharu et al., 2022) aim to minimize waste generated during the construction process, prioritize the reduction, reuse, and recycling of materials, create a closed-loop system, and therefore make use of high resource efficiency to minimize the environmental impacts of building construction. Key elements of zero-waste design are the material selection, the design for disassembly, the modularity of constructions, and their adaptability (ibid.).

In line with such principles, in a 2019 experiment employing the life cycle assessment methodology for single-family homes in Eastern Slovakia, three different approaches to building construction were tested and a significant reduction of nearly 60 % in CO_2 emissions between the most and the least sustainable approach employed was achieved (Moňoková and Vilčeková, 2019). House 1, featuring a fully built-up area of approximately 250 m^2 and constructed using conventional approaches and materials, exhibited a global warming potential of 1415 kg CO_2 per 1 m^2 (ibid.). In contrast, house 2, with a floor area of 120 m^2, and house 3, spanning around 60 m^2, adopted sustainable approaches with a strong focus on environmental and energy considerations (ibid.). House 2 emitted 548 kg CO_2 per 1 m^2, while House 3 demonstrated a significantly lower global warming potential, emitting around 828 kg CO_2 per 1 m^2 (ibid.). These emission reductions were attributed to the use of natural, eco-friendly, and recycled materials, as well as the incorporation of efficient energy sources such as heat pumps in houses 2 and 3 (ibid.).

Another interesting example is the Green Design Centre (GDC), situated in Bosnia and Herzegovina, which will serve as a multifunctional and demountable public information and education centre, designed to exemplify the principles of circular building construction within the context of the European circular economy model[20]. Aligned with zero-waste building construction guidelines, the GDC aims for a 93 % reduction in total construction waste and a 78% decrease in the utilization of raw materials through the refurbishment of an old military storage unit and its reversible building design (ibid.). With a planned design of 180 m^2, the GDC is strategically designed for dynamic functionality, transitioning seamlessly from an exhibition space to workshop areas or office space (ibid.). The building is based on a high reuse potential of its elements and components, ensuring disassembling and repurposing materials without generating waste, emphasizing efficient resource management, and reduced environmental impact (ibid.). The project will be assessed based on waste and material reduction indicators, as well as energy efficiency measures, thereby integrating material passports for the construction to embrace the principles of circularity (ibid.).

The Build Reversible in Conception (BRIC) project stands as an educational and transformable wooden building, primarily to explore circular building knowledge and skills to the construction sector. The project is a sustainable, scalable, and reversible construction, being assembled and disassembled on a yearly basis, minimizing waste during transformation and accompanied by functional changes (office, shop, laboratory) regularly (ibid.). BRIC places a strong emphasis on reversibility, transformability, sustainability, the incorporation of reclaimed materials, efficient resource management, and energy efficiency (ibid.). Using bio-based and renewable materials with a focus on wood and wooden derivates, the project replaced as much as possible petrochemical and mineral-based construction materials from regular construction processes (ibid.). Through Life Cycle Assessment and Analysis, BRIC reused 100 % of the materials for the three reconstructions and has cut 98 % of waste generation by the coordination between design and production, thereby saving approximately 42 kg CO_2eq compared to a non-circular approach (ibid.).

Discuss motivation, capability and opportunity needs and advancements

The table below brings a qualitative discussion of the level of motivation, capability, and opportunity among people in Europe to adopt more sustainable, circular solutions to reduce, shift and improve housing-related consumption levels in Europe, based on the examples presented above. Remind that capability is described as people's psychological and physical capacity to engage in the activity concerned, in this case, circular behaviours that support the transition towards sustainable consumption in Europe, including knowledge and skills, opportunity is defined as all the factors that lie outside the individual that make the behaviour possible or prompt it, including infrastructure and the social context; and motivation is defined as all those brain processes that energize and direct behaviour, both rational and unconscious processes. The absence of any one of these factors is likely to put the desired behaviour change at risk.

Table 4.1: Motivation, capability, and opportunity in the housing pathway.

	Motivation	**Capability**	**Opportunity**
Housing reduce solutions	**High-Low**	**Low**	**Low**
Housing shift solutions	**Medium**	**Medium**	**High**
Housing improve solutions	**Low**	**Low**	**Low**

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[20] https://www.bamb2020.eu/

Motivation among people to reduce energy consumption at home has increased particularly from 2022 onwards, as the Ukraine-Russia war had led to increased global energy prices, which has put a significant burden on households and led to a rising demand for local advice regarding energy consumption reduction (LGA, 2023). With regards to reducing living space, however, motivation still seem low to look for ways to reduce living space, as larger homes are still associated with higher status and quality of life (Foye, 2017). When it comes to the levels of capability and opportunity to engage with *reduce* solutions, both seem to be low, as such initiatives still seem to be very niche and learning how to save energy or engaging in a shared home project would require a high level of motivation to look for a chance to develop the right set of skills in order to engage with it. So there seems to be a crucial need to increase social and physical opportunity for people to engage with reduce solutions.

Shifting to renewable sources of energy at home is becoming more and more common among people in Europe, as it has been made easier and more affordable through private and public initiatives, including through an increased market availability of renewable energy suppliers. As evidence shows that the easier a task is, the more motivated people feel to perform it, these supporting factors probably contribute to an increased motivation among people to switch to renewable energy providers in their homes.

As initiatives around zero waste, circular homes are still limited in number, seeming to be something quite far away from people's realities, opportunity, capability, and motivation to adopt such solutions are all in need of investment and support.

4.2.2 Food pathway: Shifting to alternative types of plant-based food

What is this pathway about

Eating and food purchase patterns have been known for years to account for at least 25 % of the already oversized average carbon footprint of a European (Leppanen et al., 2012), similarly to its share in view of the entire European Carbon Footprint indicator (CFI), with the consumption of meat and dairy products accounting for most of these environmental impacts (as detailed in Chapter 2). Other food consumption related impacts are equally important, such as implications for human health (Staatsen et al., 2017) or working conditions in food production within and outside Europe.

In order to transition towards more sustainable, circular food consumption patterns in Europe, the EAT-Lancet Commission Summary Report (Willett et al., 2019) is helpful in pointing out the direction to go. The report states that in order for the global population to live sustainably and healthy by 2050, the global consumption of fruits, vegetables, nuts and legumes should double, and consumption of foods such as red meat and sugar should fall by more than 50 %. A diet rich in plant-based foods and with fewer animal-source foods confers both improved health and environmental benefits. Exploring solutions to enable this transition is the focus of this pathway.

Reduce solutions

Absolute reductions of animal product consumption in Europe are crucial in order to transition towards a more sustainable CFI for food. In this process, both holistic and more concrete circular economy related interventions have a relevant role to play, particularly with regards to reducing food waste.

Among the more holistic initiatives, Grow It Yourself[21], an initiative from Ireland, is an interesting one. They teach adults on how to plant and grow at least part of their food, and they developed the hypothesis that after three years in the food growing journey, people start not only growing about 70-80 kg of vegetables and saving about 500€ per year, but also adopting new food-related behaviours, such as

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[21] https://giy.ie/

wasting less food and eating more plant-based meals. This would have the potential of saving about 100 kg of CO_2 per year (ibid.).

Among the more concrete interventions, there is evidence that a smaller plate in buffets and restaurants leads to less food wasted, as people tend to put in their plates only what they really can eat. For example, the conscious plate initiative reduced plate size by 20 % among the restaurants that belong to the Ecobeneficios network, leading to a reduction of food waste by 50 %. When it comes to using social norms to avoid food waste behaviours, in Norway, placing a sign on the table of various hotel restaurants saying “Welcome back! Again! And again!” fostered the feeling that it was fine and acceptable to visit the menu table several times, thereby helping reduce food waste by 20.5 % (Lehner et al., 2016).

Another solution here would be food banks. By rescuing and redistributing surplus food from retailers and manufacturers, food banks are not only helping to feed those who are hungry but also reducing the amount of food that goes to waste. Food banks are an essential part of the solution to both of these problems, reducing food waste and helping communities in need (REFRESHCEO, 2023).

Shift solutions

Shift solutions would include opportunities to replace conventional, linear food consumption practices with more circular ones.

In this context, compost solutions can give a new life to organic waste that would otherwise end up in landfills. Rests of food, yard waste and stabilised blackwater from anaerobic digestion systems can be used as compost for local gardening. Through, for example, bio-digestion the bacteria break down organic waste, like food scraps and animal manure, producing biogas. Bacteria in the digester also produce organic, liquid bio-fertilizer. The bio-fertilizer flows freely so one can easily collect and use it on his/her own garden and crops (Circular Homes, 2023).

Improve solutions

When it comes to improving the level of efficiency of food consumption in Europe, technology has the power to reduce food waste in the supply chain significantly (REFRESHCEO, 2023). One of the key causes of food waste is a lack of visibility and control in the supply chain. Food traceability systems can help track the origin, journey, and quality of food products. These systems use various technologies, and with the help of these technologies, food suppliers can quickly identify where and when food is being wasted in the supply chain, enabling them to take corrective measures to prevent further waste.

Smart packaging is another innovative technology that can help reduce food waste in the supply chain. This technology uses sensors to monitor the quality and freshness of food products and alert consumers when food is about to spoil. It can also keep track of the temperature and humidity, making sure that food is stored and moved in the best conditions. Furthermore, smart packaging can help prevent food waste by extending the shelf life of food products ((REFRESHCEO, 2023).

Motivation, capability and opportunity needs and advancements

The table below brings a qualitative discussion of the level of motivation, capability and opportunity among people in Europe to adopt more sustainable, circular solutions to reduce, shift and improve food-related consumption levels in Europe, based on the examples presented above.

Table 4.2: Motivation, capability, and opportunity in the food pathway.

	Motivation	Capability	Opportunity
Food reduce solutions	High	Low	Medium-Low
Food shift solutions	Low	Low	Low
Food improve solutions	High	Low	Medium-Low

Overall, capability and opportunity regarding the above-described solutions pathways is low, which is demonstrated by the huge amounts of food still wasted in the EU - nearly 57 million tonnes of food waste (127 kg/inhabitant) are generated annually with an associated market value estimated at 130 billion euros (EC Library Guides, 2023). Only through broadening social norms around food waste avoidance and developing market solutions to optimise the consumption of food we would achieve a higher degree of opportunity. The increasing recognition of society's moral and social obligation to curb food waste is fostering greater motivation to do so, but the lack of the proper skills and opportunities to do that in everyday contexts hinder people to act according to this positive motivation.

4.2.3 Personal mobility: Shifting to less often and shorter international flights as well as to non-motorised mobility options for commuting

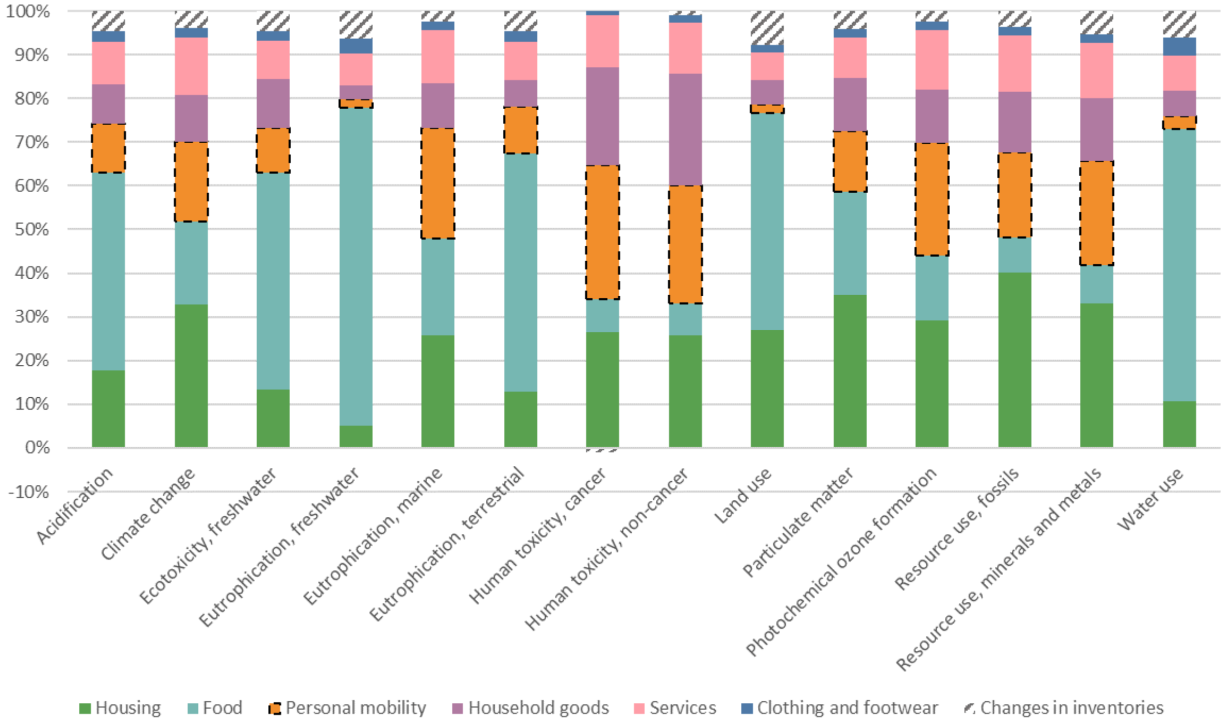
What is this pathway about

With the exception of a drop in 2020 due to the COVID-pandemic and associated lockdowns, personal mobility in the EU27 has been steadily increasing for passenger cars, air transport, railways, and tram and metros over the last 2.5 decades (EC, 2023c).

Personal mobility contributes between 2-31 % to the environmental impact categories underlying the consumption footprint (Figure 4.2). Environmental impacts are highest for human toxicity (cancer and non-cancer, HTOX_C and human toxicity, non-cancer, resp. 31% and 27%), photochemical ozone formation (POF, 26 %), marine eutrophication (MEU, 25 %), and resource use, minerals and metals (MRD, 24%). The share of personal mobility in the total CFI is stable over time (ca. 17.8-21 %). In addition, the impacts resulting from the production and use of fuels and lubricants is decreasing (-12 %), but the impacts from the production of vehicles is increasing (+15 %). These trends align with the trends in consumption (increased consumption for vehicles, and stable consumption for fuels and lubricant) in combination with improved efficiency gains in the production networks.

Globally, materials are responsible for around 55 % of the emissions related to vehicle production (Hertwich, 2021). This in turn means that circular economy policies aiming at a reduction of material requirements can be an important lever also in climate mitigation within the vehicles production sector.

Figure 4.2: Contribution of consumption areas to the environmental impact categories of the EEA consumption footprint.



Source: ETC CE calculations based on FIGARO (2024 Edition, 2010-2022 data).

Within the consumption area of personal mobility in 2021, roughly 52 % of all impacts to the total consumption footprint (single score) are due to the use of fuels and lubricants (incl. public transport and other private transport), 40 % due to the production of vehicles (cars, bikes, etc.), 5 % due to travel agencies, and 4 % due to maintenance and repair (see section 2.2.4). These results highlight immediately that the largest leverage points to reduce environmental impacts are associated with (1) an energy transition toward electrification and GHG-neutral fuels using renewable power, and (2) due to modal shifts, transport avoidance, and improvement of sector-wide energy and resource efficiency.

More specifically, it is important to systematically transform the mobility sector through a combination of different changes and policy measures including:

(1) a modal shift (e.g., from individual person mobility to public transport or car sharing),
(2) transport avoidance (e.g., home-office instead of driving to the office),
(3) improvement of sector-wide energy and resource efficiencies, and
(4) an energy transition from current internal combustion engines to electrical drivetrains and replacement of fossil fuels with GHG-neutral alternatives (e.g., via Power-to-X pathways)[22].

The first three changes above can be referred to as a transition of the transport system, while the fourth bullet point refers to an energy transition in transport.

The following sections discuss required changes for personal mobility in some depths and systematize these according to the reduce-shift-improve framework used in this chapter. We source required changes

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[22] Note that due to currently much higher efficiencies of electrical drivetrains and lower costs compared to GHG-neutral fuels, e.g., used in traditional combustion engines, the PtX pathways should only be implemented in applications which cannot be electrified (e.g., heavy freight transport such as via ships or air transport).

in the mobility sector from studies including, e.g., the UBA RESCUE study, which investigated necessary changes for the automobile sector until 2050 in order to transform Germany into a GHG-neutral and resource-efficient economy (Günther et al., 2019), and material efficiency measures investigated by the International Resource Panel (IRP) to lower GHG-emissions associated with passenger cars (IRP, 2020). The latter study highlights that material efficiency strategies could reduce GHG emissions from the material cycle of passenger cars and operational energy use by around 30-40% in EU-countries such as Italy, France, and Germany by 2050 (the study looked specifically at the G7 countries as well as China and India) (IRP, 2020).

Reduce solutions

Materials demand due to personal vehicle use can be reduced by moving towards **smaller and lighter vehicles**, while still providing the same transportation service to people. The vehicle size and therefore overall vehicle mass also determines the fuel economy, i.e., the overall amount of energy (in the form of fuels or power) required for driving the vehicle, which (as shown above) is responsible of about half of all environmental impacts. However, it should be noted that current trends develop in the opposite direction with more heavy vehicles on the roads, globally (Cozzi and Petropoulos, 2023).

Material substitution for light-weighting in vehicles can include the use of, for instance, aluminium, carbon-fibre, magnesium, or high-strength steel for conventional steel (IRP, 2020). The IRP notes that, while some of these materials might lead to more emissions during the production phase, this can be offset during the use-phase due to the better fuel-efficiency of lighter vehicles. On the other hand, additional costs due to the use of alternative materials such as carbon-fibre can occur and there might be recycling challenges. Depending on the assumptions, some significant reductions in material requirements (in the body) can be associated with this strategy (up to -50 %) (Öko-Institut et al., 2016; Purr et al., 2019).

The need for primary raw materials can also be lowered by aiming for **higher yields in manufacturing, reuse and recycling** of vehicle parts of single materials embedded in them. For example, the IRP highlights that remanufacturing vehicle parts such as engines and tyres can reduce emissions by 70-90 % compared to virgin components (IRP, 2018, 2020). However, this may be mainly relevant for heavy-duty vehicles today.

The shift toward electric mobility will require an increasing number of batteries and charging infrastructures. To date, recycling of battery materials (e.g., lithium, cobalt, etc.) is limited as the amount in use (in the anthropogenic stock) is too low to satisfy increasing demands. However, as electric vehicles are increasingly used in Europe, there will be more batteries reaching their end-of-life that need to be properly collected and recycled to lower demand for primary raw materials.

Shift solutions (upper R strategies)

Avoiding the need for personal mobility via shifting to more sustainable alternatives such as, e.g., public transport, creating walkable neighbourhoods, allowing for home-office based work (where feasible), or implementing car sharing schemes can help to reduce the need for people to purchase a vehicle in the first place. Modal shifts towards low-carbon mobility together with transport avoidance are central to reduce environmental impacts of personal mobility. Incentives are required to shorten travel distances, e.g., by changing settlements and transport networks and to increasingly cover these with more sustainable modes of transportation (e.g., public transport and railway networks, or e-mobility where needed).

For this to take place, policy makers need to implement proper carbon pricing on fossil fuels and environmentally harmful subsidies need to be removed (e.g., the tax diesel privilege, commuter tax relieves for personal vehicles, or company car allowances) (Günther et al., 2019).

Furthermore, demand-side changes can take place by making local and domestic travel more attractive than international trips (e.g., by providing a well-functioning public transport and railway system and offering varied options for vacations within the region). The EU could aim at making inner-EU travel possible via train so that no domestic flights are required (as these are found to have a significant impact compared to train travel on a per person-km basis).

More intensive use of existing vehicles through car sharing schemes and ride sharing have been found to reduce the vehicle stock required for providing transport demands by people (IRP, 2020). The largest reductions in GHG emissions are observed by changing modes of vehicle use including ride sharing and car sharing, and by shifting to smaller vehicles (IRP, 2020). This is due to the fact that such demand-side changes reduce the demand for both materials and energy during the vehicle use.

Finally, freight transport needs to be electrified where possible, e.g., by shifting toward electrified lorries/trucks or moving freight transport toward railway systems (this applies to all sectors as freight transport is part of the background system when calculating the EEA consumption footprint). For airplanes, fuels based on renewable power via PtX routes need to be provided to further decarbonize the sector.

Improve solutions

The transportation sector needs to be fully decarbonized by electrification (sector coupling) and the use of GHG neutral fuels via PtX-pathways (Günther et al., 2019). This is one of the largest leverage points as fuels are responsible for about half of all environmental impacts from the sector (see section 2.2.4).

The demand for critical materials and those that are associated with adverse social implications (e.g., cobalt from DRC Congo) can be reduced by investing into research and development and switching to alternative battery types (Gourley et al., 2020) and considering sustainable sourcing approaches.

Discuss motivation, capability and opportunity needs and advancements

The table below brings a qualitative discussion of the level of motivation, capability and opportunity among people in Europe to adopt more sustainable, circular solutions to reduce, shift and improve personal mobility-related consumption levels in Europe, based on the examples presented above.

Table 4.3: Motivation, capability, and opportunity in the personal mobility pathway.

	Motivation	**Capability**	**Opportunity**
Mobility reduce solutions	Medium-Low	Low	Low
Mobility shift solutions	Low	Low	Medium-Low
Mobility improve solutions	Medium-Low	Low	High-Medium

Overall, the motivation, capability and opportunity regarding the above-described solutions pathways is low. Only through broadening market supply of electric vehicles and improving charging infrastructure leads to a higher degree of opportunity. The rise of sharing platforms is also contributing to this. Also, increasing fuel costs might give rise to more motivation.

5 Conclusions and outlook

Overall, the EU-27 Consumption Footprint indicator (CFI) is considered high, as it exceeds the planetary boundaries for several types of impacts, such as impacts on climate change and land use (see Chapter 3). Between 2010 and 2022, the CFI increased by around 4%. This overall trend resulted from a substantial decrease between 2010 and 2016 (-23 %), followed by a sharp increase between 2016 and 2022 (+35 %).

The impacts of consumption **follow the pattern of changes in the domestic final use volumes of EU-27. Overall, we see an upward trend in consumption volume (almost +10 %, in constant prices) in the 2010-2022 period, however, the impacts of consumption only increase by 4 % in this period**. During the period 2013-2016, there was a widening gap between the two indicators. This gap reflects the reductions in the Consumption Footprint per unit of consumption volume due to improved production efficiency, reduced environmental impacts and structural changes in global production networks. While this illustrates the importance of environmental improvements in production networks, they are insufficient for cancelling out the consequences of increasing consumption volumes in the EU-27 and achieving absolute decoupling of the impacts from consumption volumes. Notable is that **the relative decoupling is mainly the result of a downward trend in the climate change indicator and fluctuations in the fossils and minerals resource use categories**.

Striving towards reductions in the environmental footprint requires a speeding up of environmental improvements in production networks that focus on all environmental impact categories, but also putting more emphasis on **reducing final consumption volumes and shifting consumption to products with a lower environmental footprint**.

The Consumption footprint indicator is analysis at the level of the individual consumption domains:

- With regards to **housing**, overall, the technological efficiency gains, the shift to cleaner and renewable technologies, and the fact that people in Europe are consuming more environmentally friendly alternatives are visible in the CFI results, but these environmental gains are annulled by the increase in consumption levels (except for electricity demand), especially a significant growth in housing construction and fossil fuel-based energy demand from 2014 onwards. Also, apart from a decrease in climate change related impacts in the area due to a decrease in fossil resource use, all other environmental impact categories continue to increase. Remarkable is a decrease in the impact of electricity use, both due to gains in the production and the demand side. Overall, the decrease in the footprint of electricity is the result from a shift to electricity products that have a lower environmental footprint (e.g., increasing share of electricity production from renewables) and a decreasing trend in consumption volumes of electricity by households. A strive towards less energy intensive products partly explains this decreased consumption volume (e.g., driven by the Ecodesign for Sustainable Products Regulation). The increasing final use volumes for construction in the EU-27 could partly be explained by increasing technical requirements (isolation, heat pumps, solar panels, etc.) that have a long-term beneficial effect via a reduced energy requirement. These effects should gradually become more visible in the future.
- Overall, in the period 2010-2022 the Consumption Footprint indicator of **food** increased by 14 % in this period. The gains are mainly due to the decreased impact via technology efficiency gains across all consumption domains and a decreasing consumption volume of tobacco and the lack of an increase in consumption of milk, cheese, and eggs, and food products n.e.c., but these gains are outweighed by the increased impacts due to increasing consumption volumes, mainly from meat consumption, from fruit and vegetables, and from beverages. Still, the increase in the consumption volume is less pronounced in the food consumption domain compared to the other ones.
- When we look into the domain of **household goods**, in the 2010-2013 period these is a large decrease in the CFI which is mainly related to shifts in consumption patterns within the pharmaceutical products and a small reduction in demand for household appliances and goods as well as due to environmental efficiency improvements in the production networks of these

appliances and furniture. Part of this gain is outweighed in the 2013-2022 period, mainly due to increased consumption volumes across all product groups.

- With regards to **personal mobility**, the decrease in the CFI is the result of environmental improvements in the production network of fuels and lubricants and to a lesser extent in the production of vehicles. These gains were only partly outweighed by increased consumption volumes for vehicles, as level of consumption for fuels and lubricant is fairly stable over time.
- In the **services** consumption domain, the decrease in the CFI prior to 2015 resulting from increased efficiency in production networks was compensated by increased consumption volumes of public, financial, and medical services in later years, forcing the CFI to rise again.

For each impact category, the current footprints of European consumption can be measured against the European planetary boundaries. **Current EU consumption already leads to an overshoot of Earth's safe operating space for multiple impact categories**, e.g., in the areas of particulate matter pollution, climate change, and fossil and mineral resource depletion. Impacts for non-cancer human toxicity, land use, and photochemical ozone formation are found within a zone of increasing risk. Especially concerning climate change, Europe needs to urgently lower its consumption footprint at a fast pace to avoid crossing irreversible tipping points of the climate system. The consumption areas contributing most to this overshoot vary by impact category but are largely triggered by consumption in **housing, food, and personal mobility (together these consumption areas make up around 75 % of overall environmental impacts)**. For example, for climate change the sole impact from housing already overshoots the save operating space by factor of 4.6, food by factor 2.6 and personal mobility by factor 2.6. For impact categories such as human toxicity and mineral resource depletion also **household goods** consumption is relevant.

Different normative choices of 'downscaling' planetary boundaries to European citizens exist and can influence the magnitude of the allocated boundaries. Transforming global boundaries into regional or national limits requires addressing the biophysical, socio-economic, and ethical dimensions of the individual environmental dimensions under investigation.

Furthermore, **uncertainties** related to the choice of the planetary boundary proxy indicators and the underlying data to derive environmental footprints exist. Policy makers should be aware of such methodological choices and uncertainties when interpreting the results presented in this report. While a number of uncertainties are associated, e.g., with the choice of the planetary boundary value, the selection of the downscaling method (to derive resource budgets at EU-level), and the underlying footprint method, that could be tackled by further research, the overall trend that the EU is significantly overshooting planetary boundaries (e.g., related to climate change and associated fossil resource use, air emissions, and land use), is still valid and policy makers and EU citizens need to act quickly to reduce the EU consumption footprint.

The report discusses different options to reduce the consumption footprint in a number of priority areas based on their impact contribution. Solution pathways to reduce Europe's consumption footprint in order to stay within the Earth's safe operating space, especially regarding climate change, particulate matter, land use, human toxicity, and resource use (chapter 3), require significant changes in the most impactful consumption domains including housing, food, personal mobility and household goods and services. These solution pathways require a mix of approaches to **reduce** (absolute reduction in consumption), **shift** (replacement of unsustainable consumption options by more sustainable ones) and **improve** (efficiency improvement) consumption patterns. In this report, we give particular emphasis to the circular economy related approaches in the mix. A realistic view about what is needed to disseminate and scale up the approaches to deliver more sustainable consumption solution pathways requires analysing whether there are enough **motivation, capability, and opportunity** among people to change their consumption patterns in Europe.

Reflecting on the key messages from this report highlights the urgency and scale of the required changes in our current consumption patterns. Current EU consumption already leads to an overshoot of Earth's safe operating space for multiple impact categories, and the current trend shows still increasing environmental impacts. This message does not change even considering the different uncertainties that accompany the results.

From a methodological perspective, it is possible to expand this work to EU-27 MS-level in the future. The screening of country-level efforts for assessing environmental footprint indicators and comparisons with planetary boundaries by the EEA Eionet Working Group Planetary Boundaries will provide a solid basis for further improving and expanding this concept across EEA member states.

6 List of abbreviations

Abbreviation	**Name**	**Reference**
AC	Acidification	
CC	Climate change	
CEAP	Circular Economy Action Plan	
CFI	Consumption Footprint Indicator	
CO_2	Carbon dioxide	
CO_2-eq.	Carbon dioxide equivalent	
CTUe	Comparative toxic unit for ecosystems	
CTUh	Comparative toxic unit for humans	
e.g.	*Exempli gratia* (for example)	
EC	European Commission	
ECOTOX	Ecotoxicity freshwater	
EEA	European Environment Agency	eea.europa.eu
EE-MRIO	Environmentally extended multi-region input-output model	
EF	Environmental footprint	
ETC CE	ETC Circular economy and resource use	eionet.europa.eu/etcs/etc-ce
EU-27	European Union (2020-composition)	
EUR	Euro	
FEU	Eutrophication, freshwater	
FOEN	Federal Office for the Environment (Switzerland)	
FRD	Resrouce use, fosils	
GDP	Gross domestic product	
GHG	Greenhouse gas	
Gt	Gigatonne (10^9 tonnes)	
HTOX_c	Human toxicity, cancer	
HTOX_nc	Human toxicity, non-cancer	
i.e.	*id est* (that is)	
IR	Ionising radiation	
kg	Kilogram	
LCA	Life cycle analysis	
LU	Land use	
m^3	Cubic metre	
MEU	Eutrophication, marine	
MJ	Megajoule (10^6 joules)	
mol H+ eq.	Unit of mole of H+ equivalents	
mol N-eq.	Unit of mole of N equivalents	
mol	Mole (SI unit)	
MRD	Resrouce use, minerals and metals	
N	Nitrogen	
NACE	Statistical classification of economic activities in the European Community	
NMVOC	Non-methane volatile organic compound	
NMVOC-eq.	Non-methane volatile organic compound equivalent	
ODP	Ozone depletion	
P	Phosphorous	
PB	Planetary boundaries	
PJ	Petajoule (10^{15} joules)	
PM	Particulate matter	
POF	Photochemical ozone formation	
Pt	point	

PtX	power-to-X (heat, fuels, chemicals)
Sb	Antimony
Sb-eq.	Antimony equivalent
SI	International System of Units
TEU	Eutrophication, terrestrial
W/m^2	Thermal transmittance
WU	Water use

7 References

Akenji, L., et al., 2021, '1.5 Degree Lifestyles: Towards a fair consumption space for all' (https://hotorcool.org/wp-content/uploads/2021/10/Hot_or_Cool_1_5_lifestyles_FULL_REPORT_AND_ANNEX_B.pdf) accessed 5 December 2023.

Beylot, A., et al., 2019, 'Assessing the environmental impacts of EU consumption at macro-scale', *Journal of Cleaner Production* 216, pp. 382-393 (DOI: 10.1016/j.jclepro.2019.01.134).

Bjørn, A., et al., 2015, 'Strengthening the link between life cycle assessment and indicators for absolute sustainability to support development within planetary boundaries', *Environmental Science and Technology* 49(11), pp. 6370-6371 (DOI: 10.1021/acs.est.5b02106).

Bjørn, A. and Hauschild, M. Z., 2015, 'Introducing carrying capacity-based normalisation in LCA: framework and development of references at midpoint level', *The International Journal of Life Cycle Assessment* 20(7), pp. 1005-1018 (DOI: 10.1007/s11367-015-0899-2).

Branson, A., 2020, 'Is multi-generational living the future of housing?' (https://ww3.rics.org/uk/en/modus/built-environment/homes-and-communities/all-together-now--mult-igenerational-living.html) accessed 5 December 2023.

Cabeza, L. F., et al., 2022, 'Buildings', in: *Climate Change 2022 - Mitigation of Climate Change*, Cambridge University Press, pp. 953-1048.

Circular Homes, 2023, 'Circular Measures and Products | circularhomes.eu' (https://www.circularhomes.eu/circular-measures-and-products/) accessed 15 December 2023.

Clark, D. P., 2021, 'COP26, and how coliving can help mitigate the climate crisis', Conscious Coliving (https://www.consciouscoliving.com/cop26-and-how-coliving-can-help-mitigate-the-climate-crisis/) accessed 5 December 2023.

Cohen, M. J., 2021, 'New Conceptions of Sufficient Home Size in High-Income Countries: Are We Approaching a Sustainable Consumption Transition?', *Housing, Theory and Society* 38(2), pp. 173-203 (DOI: 10.1080/14036096.2020.1722218).

Cozzi, L. and Petropoulos, A., 2023, 'Global SUV sales set another record in 2021, setting back efforts to reduce emissions',.

Dao, H., et al., 2015, *Environmental limits and Swiss footprints based on Planetary Boundaries*, UNEP/GRID–Geneva and University of Geneva, Geneva (https://www.bafu.admin.ch/dam/bafu/en/dokumente/wirtschaft-konsum/externe-studien-berichte/naturvertraeglichesmassundschweizerfussabdrueckegestuetztaufplan.pdf.download.pdf/environmental_limitsandswissfootprintsbasedonplanetaryboundaries.pdf) accessed 2 October 2023.

Dao, H., et al., 2018, 'National environmental limits and footprints based on the Planetary Boundaries framework: The case of Switzerland', *Global Environmental Change* 52, pp. 49-57 (DOI: 10.1016/j.gloenvcha.2018.06.005).

Desing, H., et al., 2020, 'A circular economy within the planetary boundaries: Towards a resource-based, systemic approach', *Resources, Conservation and Recycling* 155, p. 104673 (DOI: 10.1016/j.resconrec.2019.104673).

EC, 2014, *Living well, within the limits of our planet 7th EAP – the new general Union environment action programme to 2020* (https://op.europa.eu/en/publication-detail/-/publication/0a50d4db-cb35-43aa-8c33-3b06a3a57597) accessed 25 September 2023.

EC, 2020, 'Energy efficiency in buildings' (https://commission.europa.eu/news/focus-energy-efficiency-buildings-2020-02-17_en) accessed 5 December 2023.

EC, 2023a, 'Access to and use of energy services', Your Europe (https://europa.eu/youreurope/citizens/consumers/energy-supply/access-use-energy-services/index_en.htm) accessed 5 December 2023.

EC, 2023b, 'Buildings and construction' (https://single-market-economy.ec.europa.eu/industry/sustainability/buildings-and-construction_en) accessed 5 December 2023.

EC, 2023c, *EU transport in figures: Statistical pocketbook 2023*, Publications Office of the European Union, Luxembourg (https://op.europa.eu/en/publication-detail/-/publication/493b2403-7157-11ee-9220-01aa75ed71a1) accessed 4 December 2023.

EC Library Guides, 2023, 'EC Library Guides: EC Library Guide on food waste: Introduction' (https://ec-europa-eu.libguides.com/food-waste/introduction) accessed 15 December 2023.

EEA, 2023a, 'Greenhouse gas emission intensity of electricity generation in Europe' (https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emission-intensity-of-1) accessed 5 December 2023.

EEA, 2023b, 'Share of energy consumption from renewable sources in Europe' (https://www.eea.europa.eu/en/analysis/indicators/share-of-energy-consumption-from) accessed 5 December 2023.

EEA and FOEN, 2020, *Is Europe living within the limits of our planet? An assessment of Europe's environmental footprints in relation to planetary boundaries*, Joint EEA/FOEN Report, EEA Report No 1/2020, European Environment Agency and Federal Office for the Environment (https://www.eea.europa.eu/publications/is-europe-living-within-the-planets-limits) accessed 3 September 2020.

ESTAT, 2023a, Average household size (EU-SILC survey), (https://ec.europa.eu/eurostat/databrowser/view/ILC_LVPH01__custom_3603397/bookmark/table?lang=en&bookmarkId=5d2c2746-642e-498b-9699-33fd2f99b666) accessed 5 December 2023.

ESTAT, 2023b, Generation of waste by waste category, hazardousness and NACE Rev. 2 activity, (https://ec.europa.eu/eurostat/databrowser/view/env_wasgen__custom_8847675/default/table?lang=en) accessed 5 December 2023.

ESTAT, 2023c, Housing in Europe - Size of housing, (https://ec.europa.eu/eurostat/cache/digpub/housing/bloc-1b.html?lang=en) accessed 5 December 2023.

Eurostat, 2023, 'Disaggregated final energy consumption in households - quantities (NRG_D_HHQ)' (https://ec.europa.eu/eurostat/databrowser/view/NRG_D_HHQ__custom_2920041/bookmark/table?lang=en&bookmarkId=63f72d98-a0e8-4cb6-b21c-1c2049e23a37) accessed 12 October 2023.

Foye, C., 2017, 'The Relationship Between Size of Living Space and Subjective Well-Being', *Journal of Happiness Studies* 18(2), pp. 427-461 (DOI: 10.1007/s10902-016-9732-2).

Gourley, S. W. D., et al., 2020, ‘Breaking free from cobalt reliance in lithium-ion batteries’, *Iscience* 23(9).

Günther, J., et al., 2019, *Resource-Efficient Pathways towards Greenhouse-Gas- Neutrality – RESCUE*, German Environment Agency (UBA) (https://www.umweltbundesamt.de/en/rescue/summary_report) accessed 12 November 2019.

Häyhä, T., et al., 2016, ‘From Planetary Boundaries to national fair shares of the global safe operating space — How can the scales be bridged?’, *Global Environmental Change* 40, pp. 60-72 (DOI: 10.1016/j.gloenvcha.2016.06.008).

Häyhä, T., et al., 2018, *Operationalizing the concept of a safe operating space at the EU level — first steps and explorations*, Stockholm Resilience Centre, Stockholm, Sweden (http://www.stockholmresilience.org/publications/artiklar/2018-07-03-operationalizing-the-concept-of-a-safe-operating-space-at-the-eu-level---first-steps-and-explorations.html) accessed 10 August 2018.

Hertwich, E., 2021, ‘Increased carbon footprint of materials production driven by rise in investments’, (DOI: 10.31235/osf.io/n9ecw).

Hespul, 2021, *Game of Showers: encouraging students to save water* (https://www.cscp.org/wp-content/uploads/2021/12/AoC_Hespul.pdf) accessed 5 December 2023.

Hoff, H., et al., 2014, *Living well, within the limits of our planet? Measuring Europe’s growing external footprint*, Working Paper 2014-05, Stockholm Environment Institute, Stockholm, Sweden (https://mediamanager.sei.org/documents/Publications/SEI-WP-2014-05-Hoff-EU-Planetary-boundaries.pdf) accessed 8 June 2019.

Hoff, H., et al., 2017, ‘Bringing EU Policy into Line with the Planetary Boundaries, SEI Policy Brief’, *Stockholm Environment Institute, Stockholm*.

Ibáñez-Rueda, N., et al., 2023, ‘Towards a sustainable use of shower water: Habits and explanatory factors in southern Spain’, *Sustainable Water Resources Management* 9(4), p. 121 (DOI: 10.1007/s40899-023-00905-3).

IPCC, 2018, *Global Warming of 1.5°C: IPCC Special Report on Impacts of Global Warming of 1.5°C above Pre-industrial Levels in Context of Strengthening Response to Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*, Cambridge University Press, Cambridge.

IRP, 2018, *Re-defining Value – The manufacturing Revolution. Remanufacturing, Refurbishment, Repair and Direct Reuse in the Circular Economy*, United Nations Environment Programme.

IRP, 2020, *Resource efficiency and climate change: material efficiency strategies for a low-carbon future*, United Nations Environment Programme, Nairobi.

Lagas, P., et al., 2015, ‘Regional quality of living in Europe’, *REGION* 2(2), pp. 1-26 (DOI: 10.18335/region.v2i2.43).

Lavagna, M., et al., 2018, ‘Benchmarks for environmental impact of housing in Europe: Definition of archetypes and LCA of the residential building stock’, *Building and Environment* 145, pp. 260-275 (DOI: 10.1016/j.buildenv.2018.09.008).

Lehner, M., et al., 2016, ‘Nudging – A promising tool for sustainable consumption behaviour?’, *Journal of Cleaner Production* 134, pp. 166-177 (DOI: 10.1016/j.jclepro.2015.11.086).

Leppanen, J. M., et al., 2012, *Scenarios for sustainable lifestyles 2050: from global champions to local loops. Future scenarios for new european social models with visualisations. SPREAD Sustainable Lifestyles 2050* (https://www.cscp.org/wp-content/uploads/2016/05/Scenarios-for-Sustainanle-Lifestyles_2050.pdf).

LGA, 2019, *Building cohesive communities. An LGA guide*, Local Government Association, UK (https://www.local.gov.uk/sites/default/files/documents/10.31%20Community%20cohesion%20guidance_04.2.pdf) accessed 5 December 2023.

Lucas, P. L., et al., 2020, 'Allocating planetary boundaries to large economies: Distributional consequences of alternative perspectives on distributive fairness', *Global Environmental Change* 60, p. 102017 (DOI: 10.1016/j.gloenvcha.2019.102017).

Lucas, P. and Wilting, H., 2018, *Using planetary boundaries to support national implementation of environment-related Sustainable Development Goals*, Report No 2748, Netherlands Environmental Assessment Agency, The Hague, Netherlands (https://www.pbl.nl/sites/default/files/downloads/Using_planetary_boundaries_to_support_national_implementation_of_environment-related_Sustainable_Development_Goals_-_2748.pdf) accessed 1 September 2019.

Mengual, S. E. and Sala, S., 2023, *Consumption Footprint and Domestic Footprint: Assessing the environmental impacts of EU consumption and production*, Publications Office of the European Union, Luxembourg (https://publications.jrc.ec.europa.eu/repository/handle/JRC128571) accessed 25 September 2023.

Michie, S., et al., 2011, 'The behaviour change wheel: A new method for characterising and designing behaviour change interventions', *Implementation Science* 6(1), p. 42 (DOI: 10.1186/1748-5908-6-42).

Moňoková, A. and Vilčeková, S., 2019, 'Environmental impact analysis of five family houses in Eastern Slovakia through a life cycle assessment', *Selected Scientific Papers - Journal of Civil Engineering* 14(1), pp. 81-92 (DOI: 10.1515/sspjce-2019-0009).

Nuss, P., et al., 2021, 'Monitoring framework for the use of natural resources in Germany', *Resources, Conservation and Recycling* 175, p. 105858 (DOI: 10.1016/j.resconrec.2021.105858).

Nuss, P., et al., 2023, 'Monitoring the consumption footprint of countries to support policy-making: An assessment of data availability in Germany', *Journal of Industrial Ecology* n/a(n/a) (DOI: 10.1111/jiec.13412).

Nykvist, B., et al., 2013, *National environmental performance on planetary boundaries — a study for the Swedish Environmental Protection Agency*, Report No 6576, Stockholm Resilience Centre and Stockholm Environment Institute, Stockholm, Sweden (https://www.naturvardsverket.se/Documents/publikationer6400/978-91-620-6576-8.pdf) accessed 6 August 2019.

Öko-Institut, et al., 2016, *Renewbility III -Optionen einer Dekarbonisierung des Verkehrssektors*, Berlin, Darmstadt, Freiburg (https://www.oeko.de//fileadmin/oekodoc/RenewbilityIII_Endbericht.pdf) accessed 4 December 2023.

Purr, K., et al., 2019, *Wege in eine ressourcenschonende Treibhausgasneutralität - RESCUE*, Umweltbundesamt, Dessau-Roßlau.

REFRESHCEO, 2023, 'What Food Banks Are Doing to Save Money and Feed People?' (https://www.refreshcoe.eu/how-food-banks-are-reducing-food-waste-and-helping-communities.html) accessed 15 December 2023.

Richardson, K., et al., 2023, ‘Earth beyond six of nine planetary boundaries’, *Science Advances* 9(37), p. eadh2458 (DOI: 10.1126/sciadv.adh2458).

Rockström, J., et al., 2009a, ‘A safe operating space for humanity’, *Nature* 461(7263), pp. 472-475 (DOI: 10.1038/461472a).

Rockström, J., et al., 2009b, ‘A safe operating space for humanity’, *Nature* 461(7263), pp. 472-475 (DOI: 10.1038/461472a).

Rockström, J., et al., 2023, ‘Safe and just Earth system boundaries’, *Nature* 619(7968), pp. 102-111 (DOI: 10.1038/s41586-023-06083-8).

Rogelj, J., et al., 2016, ‘Differences between carbon budget estimates unravelled’, *Nature Climate Change* 6(3), pp. 245-252 (DOI: 10.1038/nclimate2868).

Sala, S., et al., 2020, ‘Environmental sustainability of European production and consumption assessed against planetary boundaries’, *Journal of Environmental Management* 269, 110686 (DOI: 10.1016/j.jenvman.2020.110686).

Sala, S., et al., 2021, ‘Corrigendum to “Environmental sustainability of European production and consumption assessed against planetary boundaries’, *Journal of Environmental Management* 281, 111904 (DOI: doi.org/10.1016/j.jenvman.2020.111904).

Sanye Mengual, E. and Sala, S., 2023, *Consumption footprint and domestic footprint: assessing the environmental impacts of EU consumption and production*, JRC Science for Policy Report, European Commission, Joint Research Centre, Publications Office of the European Union, Luxembourg (https://data.europa.eu/doi/10.2760/3878) accessed 4 July 2023.

Selvefors, A., et al., 2019, ‘Use to use – A user perspective on product circularity’, *Journal of Cleaner Production* 223, pp. 1014-1028 (DOI: 10.1016/j.jclepro.2019.03.117).

Soharu, A., et al., 2022, ‘An Approach Towards Zero-Waste Building Construction’, Advances in Construction Materials and Sustainable Environment, Singapore, 2022.

Staatsen, B., et al., 2017, *Exploring triple-win solutions for living, moving and consuming that encourage behavioural change, protect the environment, promote health and health equity* (https://inherit.eu/wp-content/uploads/2017/06/INHERIT-Report-A4-Low-res_s.pdf) accessed 5 December 2023.

Statista, 2023, ‘Dwelling living space per inhabitant Germany’, Statista (https://www.statista.com/statistics/1414973/living-space-per-inhabitant-dwellings-germany/) accessed 5 December 2023.

Steffen, W., et al., 2015a, ‘Planetary boundaries: Guiding human development on a changing planet’, *Science* 347(6223), p. 1259855 (DOI: 10.1126/science.1259855).

Steffen, W., et al., 2015b, ‘Planetary boundaries: guiding human development on a changing planet’, *Science* 347(6223), p. 1259855 (DOI: 10.1126/science.1259855).

Swedish EPA, 2021, Questionnaire to Member States for providing information into the Early Warning analyses – Sweden.

Terlet, J., et al., 2022, *Considerations for policy and colaboration on sustainable behaviours Insights from a European Policy Roundtable,* Behaven (https://www.behaven.com/media/site/f103d8fd04-

1661369837/considerations_for_policy_and_collaboration_on_sustainable_behaviours_16.06.2022.pdf)
.

UBA, 2021, *Vorstudie zu Ansätzen und Konzepten zur Verknüpfung des „Planetaren Grenzen" Konzepts mit der Inanspruchnahme von abiotischen Rohstoffen/Materialien (eng;. Preliminary study on approaches and concepts for linking the 'Planetary Boundaries' concept with the use of abiotic raw materials)*, Dessau-Roßlau (https://www.umweltbundesamt.de/en/publikationen/vorstudie-zu-ansaetzen-konzepten-zur-verknuepfung) accessed 25 September 2023.

Van den Berg, N. J., et al., 2020, 'Implications of various effort-sharing approaches for national carbon budgets and emission pathways', *Climatic Change* 162, pp. 1805-1822.

van den Bergh, J., et al., 2021, 'Designing an effective climate-policy mix: accounting for instrument synergy', *Climate Policy* 21(6), pp. 745-764 (DOI: 10.1080/14693062.2021.1907276).

Van Oers, L. and Guinée, J., 2016, 'The Abiotic Depletion Potential: Background, Updates, and Future', *Resources* 5(1), p. 16 (DOI: 10.3390/resources5010016).

Vargas-Gonzalez, M., et al., 2019, 'Operational Life Cycle Impact Assessment weighting factors based on Planetary Boundaries: Applied to cosmetic products', *Ecological Indicators* 107, p. 105498 (DOI: 10.1016/j.ecolind.2019.105498).

Weizsacker, E. U. von, et al., 2009, *Factor Five: Transforming the Global Economy through 80% Improvements in Resource Productivity*, Routledge.

Willett, W., et al., 2019, 'Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems', *The Lancet* 393(10170), pp. 447-492 (DOI: 10.1016/S0140-6736(18)31788-4).

Annex 1: Methodology and data for the CFI

The calculation of the EU-27 Consumption Footprint indicator Ok.is based on an adopted version of the environmentally extended multiregional input-output model Exiobase. This Annex provides a description of the model Exiobase, followed by the calculation methodology and the modifications done to the Exiobase model. A last part is added on the composition and description of the consumption domains used throughout this report.

The model FIGARO:

FIGARO (the 2024 FIGARO edition): The EU inter-country supply, use and input-output tables (developed by Eurostat and the JRC) are part of official EU statistics (2010-2022 data). The FIGARO tables are benchmarked against the most recent macroeconomic aggregates and respect the same quality standards as official statistics and are released annually by Eurostat (T-2). The tables present the relationship between the EU27 and 18 non-EU countries plus a rest of world region, covering 64 industries (NACE rev.2 classification).

Extension data in FIGARO: Air emissions accounts are collected under Regulation (EU) No 691/2011 on European Environmental Economic Accounts. Air emission accounts are compiled according to the system of environmental economic accounting and can therefore be readily combined with input-output tables for further analysis (assuming the use of industry-by-industry tables). The data on employment for each EU Member State at the level of 64 industries (based on NACE Rev. 2) are expressed in numbers of persons employed. These data are collected via the European system of accounts (ESA 2010) transmission programme and are available on Eurostat's website [nama_10_a64_e]. Note that these data sources are restricted to EU-27 data (and in addition UK-data), but do not cover data for non-EU countries.

The model EXIOBASE (description from the EXIOBASE-website)

EXIOBASE 3 (version 3.8.2; October 2021[23]) provides a time series of environmentally extended multi-regional input-output (EE MRIO) tables ranging from 1995 to a recent year (currently 2022) for 44 countries (28 EU Member States plus 16 major economies) and five rest of the world regions. EXIOBASE 3 builds upon the previous versions of EXIOBASE by using rectangular supply-use tables (SUT) in a 163 industry by 200 products classification as the main building blocks. The tables are provided in current, basic prices (EUR million).

EXIOBASE 3 is the culmination of work in the FP7 DESIRE project and builds upon earlier work on EXIOBASE 2 in the FP7 CREEA project and EXIOBASE 1 of the FP6 EXIOPOL project. These databases are available at the official EXIOBASE website.

A special issue of Journal of Industrial Ecology (Volume 22, Issue 3) describes the build process and some use cases of EXIOBASE 3. This includes the article by Stadler et. al 2018 describing the compilation of EXIOBASE 3. Further information (data quality, updates, etc.) can be found in the blog post describing a previous release at the Environmental Footprints webpage.

The original EXIOBASE 3 data series end in 2011. Additional years are estimated based on a range of auxiliary data, but mainly trade and macro-economic data which (currently) go up to 2022 when including IMF expectations. So, care must be taken in use of the data.

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[23] Stadler, Konstantin, Wood, Richard, Bulavskaya, Tatyana, Södersten, Carl-Johan, Simas, Moana, Schmidt, Sarah, Usubiaga, Arkaitz, Acosta-Fernández, José, Kuenen, Jeroen, Bruckner, Martin, Giljum, Stefan, Lutter, Stephan, Merciai, Stefano, Schmidt, Jannick H, Theurl, Michaela C, Plutzar, Christoph, Kastner, Thomas, Eisenmenger, Nina, Erb, Karl-Heinz, … Tukker, Arnold. (2021). EXIOBASE 3 (3.8.2) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.5589597

The calculation methodology

The global distribution of pressures and effects related to final the consumption of households have been calculated using an extended multiregional input model based on input-output data. For this purpose, environmentally extended product-by-product tables were used. The calculation started from the following identities:

$$x = A \cdot x + y \qquad (1)$$

where x is the total output vector, A the matrix of direct input coefficients (or matrix of technological coefficients), and y is the final demand vector. Solving the model for output gives:

$$x = (I - A)^{-1} \cdot y = L \cdot y \qquad (2)$$

with identity matrix I, and matrix L the Leontief inverse also known as the multiplier matrix or matrix of direct and indirect output requirements per unit produced for final demand. The Leontief model implies the following assumptions: prices are fixed in the short term, input coefficients are constant regardless of output or final demand level changes, structure of the economy is taken to be constant, at least in the reported period.

The direct environmental effects of national production are the result of the sum of the direct effects associated with each unit produced in each industry:

$$E^T = \sum_1^n E_t = \sum_1^n e_t^{int} = \langle e^{int} \rangle \cdot x \qquad (3)$$

where E^T is the total environmental or socio-economic effect associated with the corresponding amounts of the final output x and e^{int} is the environmental or socio-economic effect intensity vector. Each element of e^{int} represents the amount of the effect directly caused by the production of a product group. By multiplying the environmental pressure per output unit (measured in physical units per euro worth of output) by the total output of each industry (measured in EUR), defined by equation (2), an environmentally extended input-output model is created:

$$E^T = \langle e^{int} \rangle \cdot x = \langle e^{int} \rangle \cdot (I - A)^{-1} \cdot y \qquad (4)$$

in which E^T is the vector of total environmental pressures associated with the corresponding amounts of the products groups finally used (vector y) and e^{int} the environmental pressure intensity vector. Each element of e^{int}represents the amount of the environmental pressure directly caused by the production of a product group. Each element of e^{int} is allocated to a sector-region combination, which, for example, allows to derive the EU-27 shares in the total footprint.

Modifications to the Exiobase model

To develop a time-series dataset of environmental impacts for the EU-27, we applied several adjustments to the EXIOBASE dataset. The goal of these adjustments is to improve the data of the model in respect of our purpose to calculate the Consumption Footprint for the EU-27. The modifications include:

- An update of the material extraction data;
- Integration of Eurostat's EU-27 consumption statistics; and
- Ad-hoc changes to erase outliers in the environmental or socio-economic effect intensity vector.

A shortcoming of the Exiobase is that the end years of the real data in the extension tables vary and are therefore not completely up to date. It means that the extension tables are based on real data till a certain year and then the extension coefficients (i.e., the environmental impact per monetary unit of sectoral output) are kept constant. This means that, after the data series based on real data end, the footprint calculations only capture changes in environmental impacts due to changes in output volumes. Changes in environmental efficiency per unit of output are not captured. The end years of the extension tables are:

2015 for energy, 2019 all greenhouse gases (nonfuel, non-carbon dioxide are nowcasted from 2018), 2013 for material use, and 2011 for most others, land, and water.

The material extraction data are overwritten to match, at country level, with the UNEP Global Material Flows Database[24] (including 13 material categories). The extensions on domestic extraction used in EXIOBASE are overwritten to match with the total domestic extraction per material category, per year and per country from the UNEP-database. Per material category the sectoral distribution at country level available from EXIOBASE remains unchanged. This means that per material category and per country the totals are overwritten, but the allocation to the sectors of extraction remains unchanged.

The integration of EU-27 consumption statistics from Eurostat is needed to fully include trends in EU-consumption over whole period (1995-2021). For each final demand category, a different dataset is used:

- Consumption expenditures by households: the data at country level and per year shows the consumption expenditures by households for 61 consumption domains (including categories for (sub-)totals). The data is taken from the NAMA_10_CO3_P3 (last update: 05/06/2023) dataset from Eurostat.
- Consumption expenditures by governments: The data at country level and per year shows the total level of consumption expenditures by governments. The allocation to product categories from Exiobase remains unchanged, but the totals at country level are overwritten by the data taken from the GOV_10A_EXP (last update: 27/04/2023) from Eurostat. A correspondence matrix supports the allocation from the Eurostat classification of consumption domains into the classification of consumption domains employed in this report.
- Gross fixed capital formation: The data at country level and per year shows the total level of gross fixed capital formation. The allocation to product categories from Exiobase remains unchanged, but the totals at country level are overwritten by the data taken from the NAMA_10_AN6 (last update: 07/06/2023) from Eurostat.
- Consumption expenditures by non-profit institutions serving households: The data at country level and per year shows the total level of consumption expenditures from non-profit institutions serving households. The allocation to product categories from Exiobase remains unchanged, but the totals at country level are overwritten by the data taken from the NAMA_10_GDP (last update: 07/06/2023) from Eurostat.
- Changes in valuables and inventories: The data at country level and per year shows the total level of changes in valuables and inventories. The allocation to product categories from Exiobase remains unchanged, but the totals at country level are overwritten by the data taken from the NAMA_10_GDP (last update: 08/06/2023) from Eurostat.

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[24] Global Material Flows Database | Resource Panel (https://www.resourcepanel.org/global-material-flows-database)

Table A.1: The data, last updates, and dissemination of data from Eurostat which are used to modify the consumption expenditures data in Exiobase.

Name	Online data code	Currently available data	Dissemination of data
Final consumption expenditures of **households**, **non-profit institutions serving households**, **governments**, **gross fixed capital formation**	nama_10_gdp	1995-2022 (last update 23/10/2023; at MS-level)	T+2 and T+9 months
Final consumption expenditures of **households** by consumption purpose	nama_10_co3_p3	1995-2021 (last update 26/10/2023; at MS-level)	T+9 and T+21 months
General **government** expenditure by function (COFOG)	gov_10a_exp	1995-2021 (last update 21/07/2023; at MS-level)	T+14 months, frequent updates after validations
Gross fixed capital formation by AN_F6 asset type	nama_10_an6	1995-2022 (last update 23/10/2023; at MS-level)	T+2 and T+9 months

The ad-hoc changes to overwrite outliers in the environmental or socio-economic effect intensity vector include manual correctios to outlier values.

Application of the Environmental Footprint

Applying the methodology as described above gives individual results for each environmental extension, for each country for each year available from the FIGARO and EXIOBASE dataset. A disaggregation into sectoral contributions, final demand categories and consumption domains remains possible.

The global distribution of pressures and effects related to the final EU-27 consumption have been calculated using an extended multiregional input model (industry-by-industry tables). The calculation is based on the following formula:

$$E_{ind}^{T} + E_{dir}^{T} = \langle e^{int} \rangle . x + E_{dir}^{T} = \langle e^{int} \rangle . (I - A)^{-1} . y + E_{dir}^{T}$$

with:

- E_{ind}^{T}: environmental footprint (indirect impacts)
- E_{dir}^{T}: environmental footprint (direct impacts generated by final demand)
- $\langle e^{int} \rangle$: environmental effect intensity vector, the amount of the effect directly cased by the production of a product group
- x: sectoral (monetary) output
- $(I - A)^{-1}$: Leontief inverse, representing the economic structure of the supply chain network
- y: final demand, EU-27

The scope includes both indirect and direct impacts/resource use. The indirect impacts/resource use covers impacts upstream the global production network. It covers impacts from all kinds of activities, for example, manufacturing, agriculture, and transport. The direct impacts/resource use covers impacts directly generated by households. For example, the burning of fuels for heating houses or driving a car.

Applying the formula gives individual results for each environmental extension available from the FIGARO and Exiobase datasets. In a next step, these extensions are translated into the 16 environmental impact categories according from the Environmental Footprint (EF) method 3.1. Translating the 528 unique environmental extension lines into the 16 impact categories of the EF-method requires a conversion through characterization factors.

An important remark here is that the EF method defines characterization factors for more emissions and resources extracted than available in the extension tables for FIGARO and Exiobase. For some environmental impacts, like climate change, the coverage is quite complete. For other impacts however, like toxicity, the extension tables only include a very limited selection of emissions. No information, and thus no extension lines, is available to estimate the impact categories ozone depletion and ionising radiation.

The consumption footprint refers to the environmental and climate impacts resulting from the consumption by EU citizens of goods and services, whether produced within or outside the EU. To monitor the EU's consumption footprint, this indicator uses a single score that represents all types of impacts on the environment and climate caused by consumption of goods and services by EU citizens. The conversion of the 16 impact categories into a single score refers to the final step which normalizes and weights (factors in Table A.2) the different environmental impact categories. To calculate the Consumption Footprint (expressed in point, Pt) in one aggregated score. The normalization and weighting allow to express all environmental impacts into a single score.

Table A.2: Normalisation and weighting factors of the Environmental Footprint methodology 3.1.

EF Impact Category	Unit	Normalization factor (EF-method 3.1)	Weighting factor
Climate change	kg CO2 eq	7553.0832	0.2106
Ozone depletion	kg CFC11 eq	0.0523484	0.0631
Ionising radiation	kBq U-235 eq	4220.1634	0.0501
photochemical ozone formation	kg NMVOC eq	40.859198	0.0478
Particulate Matter	disease inc.	0.0005954	0.0896
Human toxicity, non-cancer	CTUh	0.0001287	0.0184
Human toxicity, cancer	CTUh	1.725E-05	0.0213
Acidification	mol H+ eq	55.569541	0.062
Eutrophication, freshwater	kg P eq	1.6068521	0.028
Eutrophication, marine	kg N eq	19.545182	0.0296
Eutrophication, terrestrial	mol N eq	176.755	0.0371
Ecotoxicity, freshwater	CTUe	56716.586	0.0192
Land use	Pt	819498.18	0.0794
Water use	m3 depriv.	11468.709	0.0851
Resource use, fossils	MJ	65004.26	0.0832
Resource use, minerals and metals	kg Sb eq	0.0636226	0.0755

The calculation of the EU-27 Consumption Footprint covers the period 1995-2021.

The consumption domains

Seven consumption domains, i.e., areas of consumption, are distinguished when looking at EU-27 final demand. They are:

- **food** – food, drink, and hotels and restaurants, etc;
- **clothing and footwear**;
- **housing** – dwellings, heating, hot water and electricity, including investment in dwellings by households;
- **personal mobility**;
- **household goods** – household equipment, appliances, and information and communications technology (ICT);
- **services** – health, education, finance, postal services, and recreation; and
- **changes in inventories** – changes in inventories and valuables.

The consumption domains as defined in this report follow the Eurostat COICOP-classification and are aggregated to ensure comprehensive analysis and easy comparison between a limited number of large consumption domains in Europe. With a focus on household consumption, it is straightforward and common sense to include all goods and services bought by households in the analysis. This includes all expenditure by households, such as energy bills, expenditure at supermarkets, and spending on insurance.

There is also consumption expenditure by governments, which also serves households and as such is taken into consideration in our analysis as well. This category covers the provision of services to the community by governments, for example, education, health, the justice system, defence, and police. The consumption expenditures by governments follow the COFOG-classification. The 10 divisions of the COFOG-classification correspond to two consumption domains as defined in this report: housing and services. Environmental production, housing and community amenities are linked to the housing consumption domain, and general public services, defence, public order and safety, economic affairs, health, recreation, culture and religion, education and social production to the services consumption domain.

Furthermore, expenditure of non-profit institutions serving households (NPISH) can be attributed to households. It covers sports clubs, unions, churches, charities, etc. helping members of the community. The total volume of expenditure by NPISH is linked to the COICOP classification, using the allocation matrix from JRC (Beylot et al., 2019).

Investment in, for example, infrastructure, machinery, and equipment has no link or at least no direct link to current household consumption. Therefore, the gross fixed capital formation is allocated to a separate category "capital investments".

Table A.3: Allocation table for FIGARO.

	Food	**Housing**	**Personal mobility**	**Household goods**	**Services**	**Clothing and footwear**
FIGARO commodities (in nomenclature op products)						
Products of agriculture, hunting and related services	100%	0%	0%	0%	0%	0%
Products of forestry, logging and related services	3%	72%	0%	25%	0%	0%
Fish and other fishing products; aquaculture products; support services to fishing	100%	0%	0%	0%	0%	0%
Mining and quarrying	0%	91%	9%	0%	0%	0%
Food, beverages and tobacco products	100%	0%	0%	0%	0%	0%
Textiles, wearing apparel, leather and related products	0%	0%	0%	0%	0%	100%
Wood and products of wood and cork, except furniture; articles of straw and plaiting materials	3%	72%	0%	25%	0%	0%
Paper and paper products	0%	0%	0%	100%	0%	0%
Printing and recording services	0%	0%	0%	100%	0%	0%
Coke and refined petroleum products	0%	30%	71%	0%	0%	0%
Chemicals and chemical products	0%	26%	7%	54%	7%	6%
Basic pharmaceutical products and pharmaceutical preparations	0%	0%	0%	40%	60%	0%
Rubber and plastic products	0%	67%	0%	21%	12%	0%
Other non-metallic mineral products	0%	79%	0%	21%	0%	0%
Basic metals	0%	100%	0%	0%	0%	0%
Fabricated metal products, except machinery and equipment	0%	36%	0%	64%	0%	0%
Computer, electronic and optical products	0%	0%	0%	100%	0%	0%
Electrical equipment	0%	0%	4%	96%	0%	0%
Machinery and equipment n.e.c.	0%	8%	0%	92%	0%	0%
Motor vehicles, trailers and semi-trailers	0%	0%	100%	0%	0%	0%
Other transport equipment	0%	0%	0%	100%	0%	0%
Furniture and other manufactured goods	0%	0%	0%	100%	0%	0%

Repair and installation services of machinery and equipment	25%	25%	0%	25%	0%	25%
Electricity, gas, steam and air conditioning	0%	100%	0%	0%	0%	0%
Natural water; water treatment and supply services	0%	100%	0%	0%	0%	0%
Sewerage services; sewage sludge; waste collection, treatment and disposal services; materials recovery services; remediation services and other waste management services	0%	100%	0%	0%	0%	0%
Constructions and construction works	0%	100%	0%	0%	0%	0%
Wholesale and retail trade and repair services of motor vehicles and motorcycles	0%	0%	100%	0%	0%	0%
Wholesale trade services, except of motor vehicles and motorcycles	24%	32%	12%	15%	13%	5%
Retail trade services, except of motor vehicles and motorcycles	24%	32%	12%	15%	13%	5%
Land transport services and transport services via pipelines	0%	0%	100%	0%	0%	0%
Water transport services	0%	0%	100%	0%	0%	0%
Air transport services	0%	0%	100%	0%	0%	0%
Warehousing and support services for transportation	0%	0%	100%	0%	0%	0%
Postal and courier services	0%	0%	0%	0%	100%	0%
Accommodation and food services	76%	15%	0%	0%	9%	0%
Publishing services	0%	0%	0%	100%	0%	0%
Motion picture, video and television programme production services, sound recording and music publishing; programming and broadcasting services	0%	0%	0%	0%	100%	0%
Telecommunications services	0%	0%	0%	0%	100%	0%
Computer programming, consultancy and related services; Information services	0%	0%	0%	0%	100%	0%
Financial services, except insurance and pension funding	0%	0%	0%	0%	100%	0%
Insurance, reinsurance and pension funding services, except compulsory social security	0%	0%	0%	0%	100%	0%
Services auxiliary to financial services and insurance services	0%	0%	0%	0%	100%	0%
Real estate services	0%	100%	0%	0%	0%	0%
Legal and accounting services; services of head offices; management consultancy services	0%	43%	0%	33%	24%	0%
Architectural and engineering services; technical testing and analysis services	0%	43%	0%	33%	24%	0%
Scientific research and development services	0%	0%	0%	0%	100%	0%
Advertising and market research services	0%	0%	0%	0%	100%	0%
Other professional, scientific and technical services and veterinary services	0%	0%	0%	0%	100%	0%
Rental and leasing services	0%	43%	0%	33%	24%	0%
Employment services	0%	43%	0%	33%	24%	0%
Travel agency, tour operator and other reservation services and related services	0%	43%	0%	33%	24%	0%
Security and investigation services; services to buildings and landscape; office administrative, office support and other business support services	0%	43%	0%	33%	24%	0%
Public administration and defence services; compulsory social security services	0%	1%	0%	0%	99%	0%
Education services	0%	0%	0%	0%	100%	0%
Human health services	0%	0%	0%	0%	100%	0%
Residential care services; social work services without accommodation	0%	0%	0%	0%	100%	0%
Creative, arts, entertainment, library, archive, museum, other cultural services; gambling and betting services	0%	0%	0%	0%	100%	0%
Sporting services and amusement and recreation services	0%	0%	0%	0%	100%	0%
Services furnished by membership organisations	0%	50%	0%	30%	20%	0%
Repair services of computers and personal and household goods	0%	0%	0%	0%	100%	0%
Other personal services	0%	0%	0%	0%	100%	0%
Services of households as employers; undifferentiated goods and services produced by households for own use	0%	0%	0%	0%	100%	0%
Services provided by extraterritorial organisations and bodies	0%	0%	0%	0%	0%	0%

Table A.4: Allocation table for EXIOBASE.

	Food	Housing	Personal mobility	Household goods	Services	Clothing and footwear
EXIOBASE commodities (in nomenclature of industries)						
Cultivation of paddy rice	100%	0%	0%	0%	0%	0%
Cultivation of wheat	100%	0%	0%	0%	0%	0%
Cultivation of cereal grains n.e.c.	100%	0%	0%	0%	0%	0%
Cultivation of vegetables, fruit, nuts	100%	0%	0%	0%	0%	0%
Cultivation of oil seeds	100%	0%	0%	0%	0%	0%
Cultivation of sugar cane, sugar beet	100%	0%	0%	0%	0%	0%
Cultivation of plant-based fibers	67%	0%	0%	0%	0%	33%
Cultivation of crops n.e.c.	100%	0%	0%	0%	0%	0%
Cattle farming	100%	0%	0%	0%	0%	0%
Pigs farming	100%	0%	0%	0%	0%	0%
Poultry farming	100%	0%	0%	0%	0%	0%
Meat animals n.e.c.	100%	0%	0%	0%	0%	0%
Animal products n.e.c.	100%	0%	0%	0%	0%	0%
Raw milk	100%	0%	0%	0%	0%	0%
Wool, silk-worm cocoons	100%	0%	0%	0%	0%	0%
Manure treatment (conventional), storage and land application	100%	0%	0%	0%	0%	0%
Manure treatment (biogas), storage and land application	100%	0%	0%	0%	0%	0%
Forestry, logging and related service activities (02)	3%	72%	0%	25%	0%	0%
Fishing, operating of fish hatcheries and fish farms; service activities incidental to fishing (05)	100%	0%	0%	0%	0%	0%
Mining of coal and lignite; extraction of peat (10)	0%	100%	0%	0%	0%	0%
Extraction of crude petroleum and services related to crude oil extraction, excluding surveying	0%	30%	71%	0%	0%	0%
Extraction of natural gas and services related to natural gas extraction, excluding surveying	0%	100%	0%	0%	0%	0%
Extraction, liquefaction, and regasification of other petroleum and gaseous materials	0%	30%	71%	0%	0%	0%
Mining of uranium and thorium ores (12)	0%	100%	0%	0%	0%	0%
Mining of iron ores	100%	0%	0%	0%	0%	0%
Mining of copper ores and concentrates	100%	0%	0%	0%	0%	0%
Mining of nickel ores and concentrates	100%	0%	0%	0%	0%	0%
Mining of aluminium ores and concentrates	100%	0%	0%	0%	0%	0%
Mining of precious metal ores and concentrates	100%	0%	0%	0%	0%	0%
Mining of lead, zinc and tin ores and concentrates	100%	0%	0%	0%	0%	0%
Mining of other non-ferrous metal ores and concentrates	100%	0%	0%	0%	0%	0%
Quarrying of stone	0%	100%	0%	0%	0%	0%
Quarrying of sand and clay	0%	100%	0%	0%	0%	0%
Mining of chemical and fertilizer minerals, production of salt, other mining and quarrying n.e.c.	0%	100%	0%	0%	0%	0%
Processing of meat cattle	100%	0%	0%	0%	0%	0%
Processing of meat pigs	100%	0%	0%	0%	0%	0%
Processing of meat poultry	100%	0%	0%	0%	0%	0%
Production of meat products n.e.c.	100%	0%	0%	0%	0%	0%
Processing vegetable oils and fats	100%	0%	0%	0%	0%	0%
Processing of dairy products	100%	0%	0%	0%	0%	0%
Processed rice	100%	0%	0%	0%	0%	0%
Sugar refining	100%	0%	0%	0%	0%	0%
Processing of Food products n.e.c.	100%	0%	0%	0%	0%	0%
Manufacture of beverages	100%	0%	0%	0%	0%	0%
Manufacture of fish products	100%	0%	0%	0%	0%	0%
Manufacture of tobacco products (16)	100%	0%	0%	0%	0%	0%
Manufacture of textiles (17)	0%	0%	0%	0%	0%	100%
Manufacture of wearing apparel; dressing and dyeing of fur (18)	0%	0%	0%	0%	0%	100%
Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear (19)	0%	0%	0%	0%	0%	100%
Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials (20)	3%	72%	0%	25%	0%	0%
Re-processing of secondary wood material into new wood material	0%	100%	0%	0%	0%	0%
Pulp	0%	0%	0%	100%	0%	0%
Re-processing of secondary paper into new pulp	0%	0%	0%	100%	0%	0%
Paper	0%	0%	0%	100%	0%	0%
Publishing, printing and reproduction of recorded media (22)	0%	0%	0%	100%	0%	0%
Manufacture of coke oven products	0%	30%	71%	0%	0%	0%
Petroleum Refinery	0%	30%	71%	0%	0%	0%
Processing of nuclear fuel	0%	100%	0%	0%	0%	0%
Plastics, basic	0%	67%	0%	21%	12%	0%
Re-processing of secondary plastic into new plastic	0%	67%	0%	21%	12%	0%
N-fertiliser	0%	0%	0%	100%	0%	0%
P- and other fertiliser	0%	0%	0%	100%	0%	0%
Chemicals n.e.c.	0%	26%	7%	54%	7%	6%
Manufacture of rubber and plastic products (25)	0%	67%	0%	21%	12%	0%

Manufacture of glass and glass products	0%	52%	0%	48%	0%	0%
Re-processing of secondary glass into new glass	0%	52%	0%	48%	0%	0%
Manufacture of ceramic goods	0%	52%	0%	48%	0%	0%
Manufacture of bricks, tiles and construction products, in baked clay	0%	100%	0%	0%	0%	0%
Manufacture of cement, lime and plaster	0%	100%	0%	0%	0%	0%
Re-processing of ash into clinker	0%	100%	0%	0%	0%	0%
Manufacture of other non-metallic mineral products n.e.c.	0%	100%	0%	0%	0%	0%
Manufacture of basic iron and steel and of ferro-alloys and first products thereof	0%	100%	0%	0%	0%	0%
Re-processing of secondary steel into new steel	0%	100%	0%	0%	0%	0%
Precious metals production	0%	100%	0%	0%	0%	0%
Re-processing of secondary preciuos metals into new preciuos metals	0%	100%	0%	0%	0%	0%
Aluminium production	0%	100%	0%	0%	0%	0%
Re-processing of secondary aluminium into new aluminium	0%	100%	0%	0%	0%	0%
Lead, zinc and tin production	0%	100%	0%	0%	0%	0%
Re-processing of secondary lead into new lead, zinc and tin	0%	100%	0%	0%	0%	0%
Copper production	0%	100%	0%	0%	0%	0%
Re-processing of secondary copper into new copper	0%	100%	0%	0%	0%	0%
Other non-ferrous metal production	0%	100%	0%	0%	0%	0%
Re-processing of secondary other non-ferrous metals into new other non-ferrous metals	0%	100%	0%	0%	0%	0%
Casting of metals	0%	0%	0%	100%	0%	0%
Manufacture of fabricated metal products, except machinery and equipment (28)	0%	36%	0%	64%	0%	0%
Manufacture of machinery and equipment n.e.c. (29)	0%	8%	0%	92%	0%	0%
Manufacture of office machinery and computers (30)	0%	0%	0%	100%	0%	0%
Manufacture of electrical machinery and apparatus n.e.c. (31)	0%	0%	4%	96%	0%	0%
Manufacture of radio, television and communication equipment and apparatus (32)	0%	0%	0%	100%	0%	0%
Manufacture of medical, precision and optical instruments, watches and clocks (33)	0%	0%	0%	100%	0%	0%
Manufacture of motor vehicles, trailers and semi-trailers (34)	0%	0%	100%	0%	0%	0%
Manufacture of other transport equipment (35)	0%	0%	0%	100%	0%	0%
Manufacture of furniture; manufacturing n.e.c. (36)	0%	0%	0%	100%	0%	0%
Recycling of waste and scrap	0%	100%	0%	0%	0%	0%
Recycling of bottles by direct reuse	100%	0%	0%	0%	0%	0%
Production of electricity by coal	0%	100%	0%	0%	0%	0%
Production of electricity by gas	0%	100%	0%	0%	0%	0%
Production of electricity by nuclear	0%	100%	0%	0%	0%	0%
Production of electricity by hydro	0%	100%	0%	0%	0%	0%
Production of electricity by wind	0%	100%	0%	0%	0%	0%
Production of electricity by petroleum and other oil derivatives	0%	100%	0%	0%	0%	0%
Production of electricity by biomass and waste	0%	100%	0%	0%	0%	0%
Production of electricity by solar photovoltaic	0%	100%	0%	0%	0%	0%
Production of electricity by solar thermal	0%	100%	0%	0%	0%	0%
Production of electricity by tide, wave, ocean	0%	100%	0%	0%	0%	0%
Production of electricity by Geothermal	0%	100%	0%	0%	0%	0%
Production of electricity n.e.c.	0%	100%	0%	0%	0%	0%
Transmission of electricity	0%	100%	0%	0%	0%	0%
Distribution and trade of electricity	0%	100%	0%	0%	0%	0%
Manufacture of gas; distribution of gaseous fuels through mains	0%	100%	0%	0%	0%	0%
Steam and hot water supply	0%	100%	0%	0%	0%	0%
Collection, purification and distribution of water (41)	0%	100%	0%	0%	0%	0%
Construction (45)	0%	100%	0%	0%	0%	0%
Re-processing of secondary construction material into aggregates	0%	100%	0%	0%	0%	0%
Sale, maintenance, repair of motor vehicles, motor vehicles parts, motorcycles, motorcycles parts and accessories	0%	0%	100%	0%	0%	0%
Retail sale of automotive fuel	0%	0%	100%	0%	0%	0%
Wholesale trade and commission trade, except of motor vehicles and motorcycles (51)	24%	32%	12%	15%	13%	5%
Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods (52)	24%	32%	12%	15%	13%	5%
Hotels and restaurants (55)	100%	0%	0%	0%	0%	0%
Transport via railways	31%	20%	17%	19%	5%	8%
Other land transport	31%	20%	17%	19%	5%	8%
Transport via pipelines	0%	0%	100%	0%	0%	0%
Sea and coastal water transport	31%	20%	17%	19%	5%	8%
Inland water transport	31%	20%	17%	19%	5%	8%
Air transport (62)	31%	20%	17%	19%	5%	8%
Supporting and auxiliary transport activities; activities of travel agencies (63)	0%	0%	100%	0%	0%	0%
Post and telecommunications (64)	0%	0%	0%	0%	100%	0%
Financial intermediation, except insurance and pension funding (65)	0%	0%	0%	0%	100%	0%
Insurance and pension funding, except compulsory social security (66)	0%	0%	0%	0%	100%	0%
Activities auxiliary to financial intermediation (67)	0%	0%	0%	0%	100%	0%
Real estate activities (70)	0%	100%	0%	0%	0%	0%
Renting of machinery and equipment without operator and of personal and household goods (71)	0%	0%	0%	83%	17%	0%
Computer and related activities (72)	0%	0%	0%	100%	0%	0%
Research and development (73)	0%	0%	0%	0%	100%	0%

Other business activities (74)	0%	43%	0%	33%	24%	0%
Public administration and defence; compulsory social security (75)	0%	1%	0%	0%	99%	0%
Education (80)	0%	0%	0%	0%	100%	0%
Health and social work (85)	0%	0%	0%	0%	100%	0%
Incineration of waste: Food	0%	100%	0%	0%	0%	0%
Incineration of waste: Paper	0%	100%	0%	0%	0%	0%
Incineration of waste: Plastic	0%	100%	0%	0%	0%	0%
Incineration of waste: Metals and Inert materials	0%	100%	0%	0%	0%	0%
Incineration of waste: Textiles	0%	100%	0%	0%	0%	0%
Incineration of waste: Wood	0%	100%	0%	0%	0%	0%
Incineration of waste: Oil/Hazardous waste	0%	100%	0%	0%	0%	0%
Biogasification of food waste, incl. land application	0%	100%	0%	0%	0%	0%
Biogasification of paper, incl. land application	0%	100%	0%	0%	0%	0%
Biogasification of sewage slugde, incl. land application	0%	100%	0%	0%	0%	0%
Composting of food waste, incl. land application	0%	100%	0%	0%	0%	0%
Composting of paper and wood, incl. land application	0%	100%	0%	0%	0%	0%
Waste water treatment, food	0%	100%	0%	0%	0%	0%
Waste water treatment, other	0%	100%	0%	0%	0%	0%
Landfill of waste: Food	0%	100%	0%	0%	0%	0%
Landfill of waste: Paper	0%	100%	0%	0%	0%	0%
Landfill of waste: Plastic	0%	100%	0%	0%	0%	0%
Landfill of waste: Inert/metal/hazardous	0%	100%	0%	0%	0%	0%
Landfill of waste: Textiles	0%	100%	0%	0%	0%	0%
Landfill of waste: Wood	0%	100%	0%	0%	0%	0%
Activities of membership organisation n.e.c. (91)	0%	50%	0%	30%	20%	0%
Recreational, cultural and sporting activities (92)	0%	0%	0%	0%	100%	0%
Other service activities (93)	0%	0%	0%	0%	100%	0%
Private households with employed persons (95)	0%	0%	0%	0%	100%	0%
Extra-territorial organizations and bodies	0%	0%	0%	0%	100%	0%

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