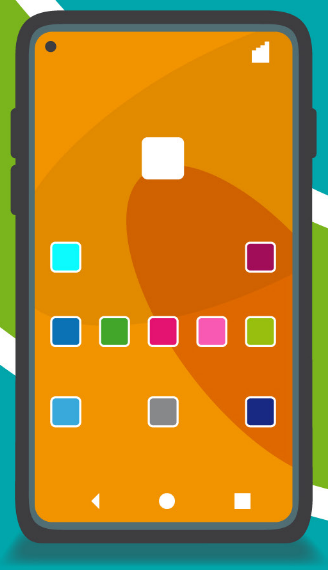
Sustainability of Consumption in Spain

Assessment of the environmental impact of consumption patterns through Life Cycle Analysis



GOBIERNO DE ESPAÑA | MINISTERIO DE CONSUMO

European Commission

Sustainability of Consumption in Spain

Assessment of the environmental impact of consumption patterns through Life Cycle Analysis

GOBIERNO DE ESPAÑA
MINISTERIO DE CONSUMO

European Commission

Acknowledgements

This report is a collaborative effort between the Ministry of Consumer Affairs and the European Commission's Joint Research Centre (EC-JRC).

The report was coordinated by the Spanish Ministry of Consumer Affairs and the EC-JRC, with strategic guidance from Serenella Sala and Esther Sanyé-Mengual, from EC-JRC. In turn, the report has benefited from the contributions of Monica Di Donato, Mateo Aguado Caso and Santiago Álvarez Cantalapiedra, members of the Ecosocial area of the FUHEM Foundation, whom we thank for their important collaboration.

The data used for this report are the result of the important research work carried out by the Life Cycle Analysis team of the Land Resources Unit of the Directorate for Sustainable Resources at the JRC (European Commission), which has supported the Ministry in the use and analysis of the data required to draft this report*. The data is publicly available on the Consumption Footprint Platform of the European Platform on Life Cycle Assessment (EPLCA). The most up-to-date consumption and household Footprint data are available on this platform, which can be accessed via the following link:

https://eplca.jrc.ec.europa.eu/ConsumptionFootprintPlatform.html

Cite as:
Spanish Ministry of Consumer Affairs/EC-JRC, Sustainability of Consumption in Spain. Assessment of the environmental impact of consumption patterns through Life Cycle Analysis, Spanish Ministry of Consumer Affairs, Madrid, 2022.

Edit and distribute:
© MINISTERIO DE CONSUMO
CENTRO DE PUBLICACIONES
Paseo del Prado, 18 - 28014 MADRID

NIPO online: 068-22-003-8

https://cpage.mpr.gob.es/

* The data used in this report is based on the data update published in February 2022.

Foreword

For a long time, economists have analysed the socio-economic reality while ignoring the context of the biophysical environment. Even today, despite decades of brilliant contributions from the fields of ecological economics and social ecology, most professionals in the field of economics fail to incorporate the ecological pressures and impacts associated with production into their work. Most conventional economic analysis starts from implicit assumptions such as the absence of limits to natural resources and/or the rejection of the most elemental laws of physics in relation to energy, such as the laws of thermodynamics. As well as a shortcoming of the science of economics, this is also a bias that is transmitted, culturally and ideologically, throughout the entire political and social sphere. Economists, ultimately, condition and influence all spaces of power with their worldview.

Breaking this dynamic is no easy task. Firstly, because university research and professional advancement in this field depend too much on established unchanging practices and academic incentives that bind researchers to conventional scientific paradigms. Secondly, because the worldview expressed in standard economic analyses is a function of the interests of important economic stakeholders who, for their own social reproduction, require the negation or underestimation of the ecological pressures and impacts associated with production activity.

However, ever since the debate regarding the limits of growth emerged in the 1970s, sounding the alarms regarding a potential or even probable ecological collapse of the industrial society, the scientific evidence has multiplied to the extent that it is now overwhelming; we're running out of time to react if we want to prevent disaster. Today, the phenomenon of climate change is familiar to us all, expressing the impacts on the planet and its ecosystems of the way we produce, distribute and consume. But environmental pressures and impacts go far beyond climate change.

The modern industrial society was made possible thanks, in no small part, to the existence of fossil fuels. This opened the door to the Industrial Revolution and, later, the Great Acceleration experienced since the middle of the 20th century. Moreover, this cheap energy was an important factor in most political-institutional designs, from urban geography to the very development of modern democracy. Our entire civil society is sustained, directly or indirectly, by a certain type of appropriation of resources and energies from nature, accumulated across the planet for millions of years. That has also permitted the multiplication of the human population, the manufacturing of products, general consumption and, ultimately, the improved life conditions of the population. But can this particular relationship between the economy and the nature last for ever?

The answer is a resounding "no". The social metabolism of our society is imbalanced. The asymmetrical use of resources and energy under this model of production and consumption is causing ecological pressures that push social metabolism out of kilter with the planet's security limits. Put another way, if we remain on this trajectory we are heading towards the disappearance of civilisation as we know it today.

That's why, in light of the triple emergency of climate change, loss of biodiversity and pollution recently signalled by the UN, or the focus on planetary boundaries postulated by the scientific community, our model of production and consumption requires a profound transformation geared towards adapting to the ecological limits of the planet.

Not exceeding the ecological ceiling involves, in some cases, reducing certain types of consumption. In other cases, they will have to be replaced. However, there will also be forms of consumption that will have to be increased, especially for the most vulnerable layers of society that haven't reached the level that could be understood as a social floor. In this sense, sustainability is not to be understood as a neutral, aseptic, or technical idea, but one that must be framed in a view of social metabolism that incorporates elements such as equality and solidarity. We cannot forget that the responsibilities for ecological pressures and impacts are no longer the same, nor does the damage caused affect all of civil society in the same way. In class-structured societies, this not only has an importance in spatial terms but also an essentially social and political one.

In effect, for the ecological transition to progress satisfactorily, the ecological phenomenon must be tackled from a comprehensive approach. In fact, on a planet with finite resources and limited capacity to assimilate waste, the production and consumption model must be revised on a global scale. Our model is not a self-contained compartment but part of a system or network of ecological interrelations on a global scale that affects many dimensions of our lives. For example, the richest countries reducing their *domestic footprints* by externalising their economic activity and thereby simply exporting aspects like environmental pollution does not resolve the eco-social challenges we face.

This report represents progress in this direction. On the one hand, the limitations of the field of economics have been let go and the case has been made for assuming the inevitable reality that the model of production and consumption generates ecological pressures and impacts. On the other hand, making use of a rigorous scientific methodology can help address how consumption influences the generation of these pressures and impacts. Consumption has also long been ignored as a driver of transformation, despite the fact that without consumption there would be no production. Both actions are, in fact, different aspects of the same phenomenon. This report helps cover this shortcoming and invites us to rethink our patterns of consumption and lifestyles to begin building habits that don't exceed the ecological limits of the planet and do not place the biological security of the rest of humanity and all living creatures at risk.

The need to reduce the dependency on fossil fuels through a renewable energy transition is evident, as is the need to foster a circular economy that also reduces the dependency on critical minerals through eco-design, reuse and repairability to tackle the issue of premature obsolescence which has prevailed in industrialised societies. The way we feed ourselves is also key, not just for our individual health but also for the health of our planet. Many daily practices can help improve it. Of course, that doesn't mean the ultimate responsibility for the response to the eco-social crisis should fall on consumers, much less those who have fewer resources. The greatest eco-social impacts are moreover, generated among the wealthier classes of modern societies. But none of this justifies failing to do what is in our own hands, and it is true that policies on the demand side can and should complement all those policies on the supply side that are aimed at reorientating production activity to uncouple it from ecological pressures and limits.

The Consumer Agenda 2021-2025, which guides the policy of the EU in this area establishes the will to have consumers play an active role in the ecological transition. I believe this is the correct approach. I am in full agreement with the words of the Commissioner for Justice and Consumer Protection, Didier Reynders, when he says, "If we don't change our behaviour, if we don't consume less, if we don't consume better, we won't reach the objective set out in the Green Deal." We should be even more ambitious and consider that, without it, we won't achieve the transformation to a fairer and sustainable reality. That's why we'll never tire of saying that our consumption is a political act.

Here at the Ministry of Consumer Affairs, we have embarked on this mission in line and in collaboration with the European Commission. This collaboration with the Joint Research Centre (JRC) is a fine example of that and will soon be followed by the development and future application of a directive to see that consumers play an active role in the ecological transition.

Contrary to positions based on ecological denial, the responsible attitude to take to the challenges we face today is to act in accordance with the scientific knowledge. This report, drafted by the professionals dedicated to scientific research, is an important contribution to the task of building a fairer world on an inhabitable planet.

Alberto Garzón,
Minister of Consumer Affairs

CONTENTS

1

Introduction

1.1. Why measure the environmental impacts of Spain's consumption?

Environmental protection is one of the core principles of the European Union (EU) and has been integrated into an increasing number of its policies. For its part, the Spanish Constitution states in Article 45: "Everyone has the right to enjoy an environment suitable for personal development, as well as the duty to preserve it", and calls on public authorities to safeguard the "rational use of all natural resources with a view to protecting and improving the quality of life and preserving and restoring the environment". In line with this and with the global and European context itself, the environmental dimension is now also shaping many of Spain's policies. A good reflection of this is the Recovery, Transformation and Resilience Plan, in which the ecological transition is the first of the axes that make up the agenda of investments and structural reforms proposed by the Spanish government to emerge from the COVID-19 crisis.

Within the economic activities that impact on the global environment, the consumption of goods and services is recognised as one of the main drivers of this impact. Addressing the environmental impacts of consumption is therefore of utmost importance in order to meet the environmental objectives and targets set by both the EU and the Spanish State.

On a global scale, the 2030 Agenda, with its 17 Sustainable Development Goals (SDGs) (UN, 2015), is the key benchmark on the road to sustainability (EC, 2016). Responsible production and consumption are at the core of SDG 12 and are also addressed in other SDGs such as SDG 11 on sustainable cities and communities and SDG 9 on industry, innovation and infrastructure. The environmental impacts generated by consumption also have an impact on a number of the SDGs, including SDG 3 on good health and well-being, SDG 6 on clean water and sanitation, SDG 13 on climate action and SDGs 14 and 15, relating to life under water and on land, respectively. Sustainability of Consumption is central to many EU environmental policies.

Within the EU context, the European Green Deal (EC, 2019) and the 8th Environment Action Programme (EC, 2020a), which will be guiding EU environmental policies up to 2030, highlight the need to live well within the ecological limits of our planet. Measuring environmental impacts over time and the extent to which the impacts of the production and consumption pattern are decoupled from economic growth are institutionally targeted as essential elements when it comes to assessing the success of the environmental policies mentioned above (European Parliament and Council, 2013). Assessing the environmental impacts over time due to production and consumption can help monitor progress towards achieving the ambitions of the European Green Deal (EC, 2019), such as those of the Farm to Fork Strategy (EC, 2020b), the Biodiversity Strategy (EC, 2020c), the New Circular Economy Action Plan (EC, 2020d), the Chemicals Strategy for Sustainability (EC, 2020e) and the Zero Pollution Action Plan (EC, 2021a).

Furthermore, the "Beyond GDP" initiative stresses the importance of developing indicators that are as clear and attractive as Gross Domestic Product (GDP), but more inclusive of environmental and social aspects of progress (EC, 2009). The Single Market for Organic Products initiative (EC, 2013) aims to remove market barriers that may limit the uptake of organic products. Furthermore, the Bioeconomy Strategy (EC, 2018) aims at a transition towards a sustainable use of biological resources to replace fossil fuels. In general, better regulation with its toolbox foresees the enhanced application of life cycle analysis to support policy impact assessments (EC, 2021b).

In the case of Spain, some of the most important milestones that have taken place recently in terms of environmental policies have been the approval of the Climate Change and Energy Transition Law (2021) which, together with the National Integrated Energy and Climate Plan (2021-2030) (MITECO, 2020), point to a significant reduction in greenhouse gas emissions through the decarbonisation of the Spanish energy system, as well as the Spanish Circular Economy Strategy (MITECO, 2020) in line with the European strategy itself and aimed at closing material cycles, as far as possible, in the different economic sectors. There are also many other legislative projects underway in different areas such as the Law on Waste and Soil Contamination, the Law on Water and the Law on Animal Welfare.

All these initiatives seek to reduce the environmental impacts linked to economic activity itself, not only those that take place in the territory itself, but also those that go beyond our own borders, but whose impacts also end up, in one way or another, having repercussions on our own well-being, with the impacts linked to climate change being the best example of this. There is also growing concern among Spanish citizens about these impacts. According to the Special Eurobarometer 513 of March-April 2021, just over eight out of ten respondents (81% compared to the EU average of 78%) indicated that climate change is a very serious problem, placing it third as the most important problem after the economic situation and poverty and hunger. In turn, 77% of people in Spain believe that their consumption habits negatively affect the environment in Europe and the rest of the world (Special Eurobarometer 501, December 2019). When it comes to opinions on the most effective ways to tackle environmental problems, the two main responses are: "changing the way we consume" and "changing the way we produce and trade".

Measuring the environmental impacts of Spain's consumption is a first step towards assessing the sustainability of our consumption insofar as our purchasing decisions and lifestyles have great potential to transform economic relations towards greater sustainability.

1.2. Why is life cycle analysis useful for assessing the environmental impacts of consumption?

The life-cycle perspective is a basic concept that refers to the need to assess the burden and benefits associated with products, sectors and projects by adopting a life-cycle perspective, from the extraction of raw materials to the end of their useful life. The life cycle perspective can be applied to the economic, social and environmental pillars. The environmental pillar of the life cycle perspective is mainly based on the Life Cycle Assessment (LCA) methodology.

Compared to other methodologies with a narrower perspective, LCA has the advantage of taking into account potential burdens shifting between life cycle stages and environmental impacts, allowing for a comprehensive assessment.

According to the International Organisation for Standardisation (ISO) (2006a, b), LCA is based on four main steps (Figure 1):

1. Definition of objective and scope. This step includes the overall design of the study, e.g. defining the specific objectives of the study, describing the assumptions of the model, identifying the target audience, etc.

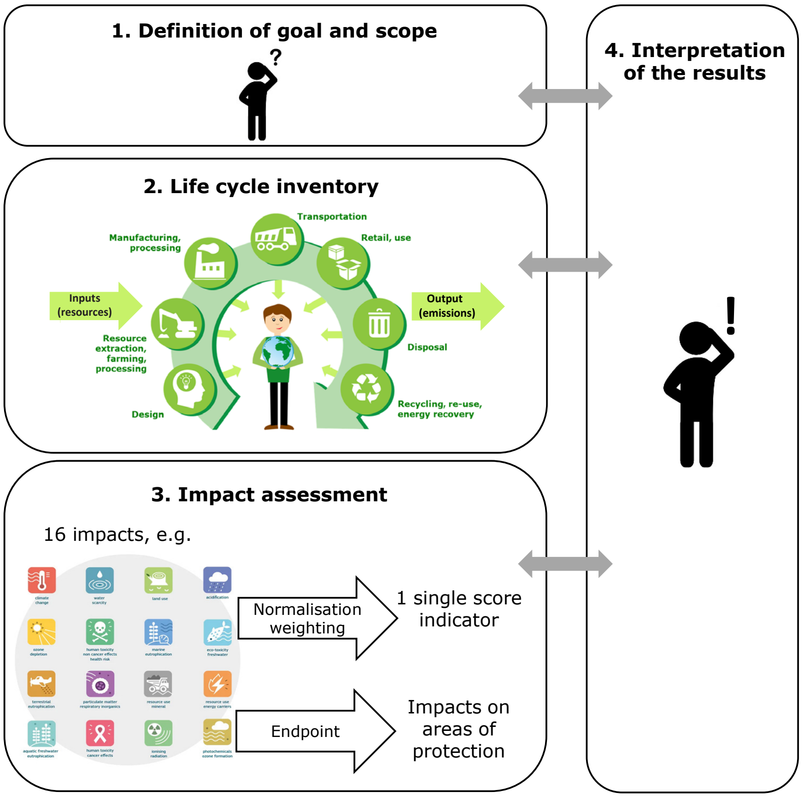
2. Definition of the life cycle inventory. In this step, data must be

collected on inputs, i.e. resources, and outputs, i.e. emissions in the different environmental compartments, entering and leaving the system under study.

3. Environmental impact assessment. In this step, the impacts of resource use and environmental emissions reported in the inventory are calculated using environmental impact assessment models. In this step, various methods and environmental impact models can be chosen. The European Commission recommends the use of the Environmental Footprint method (EC, 2021c). This environmental impact method considers 16 indicators referring to different environmental impacts, such as climate change, water eutrophication, use of fossil resources, and use of mineral resources and metals (EC, 2107). In addition, these 16 indicators can be normalised by global impacts and weighted to be summarised in a single index. Compared to the 16 indicators, the weighted index has the advantage of being more effective for communication and for supporting the selection of alternatives, but at the same time it "hides" some of the complexity of the different environmental impacts, and introduces a subjective element, i.e. weighting, which may affect the results. On the other hand, environmental impact assessment methods and models can be applied to assess environmental damage in three areas of protection, namely: human health, ecosystem health and natural resources.

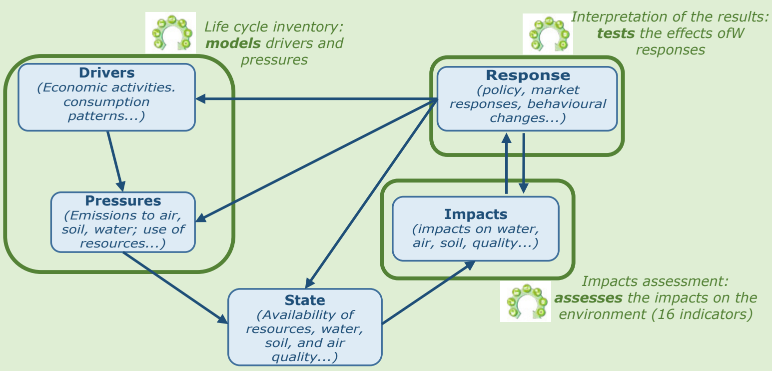
4. Interpretation of results. This step aims to fulfil the objective and scope of the study. Typical questions that can be answered at this stage are: "What are the most impactful stages of the supply chain?", "What are the environmental effects of a given policy?". LCA results are characterised by different sources of uncertainty that need to be taken into account in the interpretation of the results. The definition of the life cycle inventory is subject to the availability of information to describe the system. What's more, impact assessment models are also characterised by uncertainties, which to varying degrees influence the robustness of the results. For example, the Environmental Footprint method provides information on the level of uncertainty of the models used in the 16 indicators (details on the robustness of each indicator are provided in Annex 1).

Figure 1. Steps of Life Cycle Analysis (translated from Sala et al., 2019).



LCA and the DPSIR framework (drivers, pressure, state, impacts and responses)

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



(Figura traducida de Sala et al., 2019)

In this study, environmental impacts are analysed on the basis of the Environmental Footprint method, which includes the 16 environmental impact categories described below:

Climate change

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

Depletion of the ozone layer

The stratospheric ozone layer (O_3) protects us from dangerous ultraviolet radiation (UV-B). Depletion increases skin cancer in humans and damage to plants. The potential impacts of all ozone depletion relevant substances are converted into their equivalent kilograms of Trichlorofluoromethane (also called Freon-11 and R-11); therefore the unit of measurement is in kilograms of CFC-11 equivalent (kg CFC-11 eq.).

Human toxicity, carcinogenic effects

This indicator refers to potential impacts on human health caused by the uptake of substances through air, water and soil. Direct effects of products on humans are currently not measured. The unit of measurement is the Comparative Human Toxicity Unit (CTUh). This is based on a model called USEtox (Fantke et al., 2017).

Human toxicity, non-carcinogenic effects

This indicator refers to potential impacts on human health caused by the uptake of substances through air, water and soil. Direct effects of products on humans are currently not measured. The unit of measurement is the Comparative Human Toxicity Unit (CTUh). This is based on the USEtox model (Fantke et al., 2017).

Particulate matter

This indicator measures the adverse impacts on human health caused by emissions of particulate matter (PM) and its precursors (e.g. NOx, SO2). Generally, the smaller the particles, the more dangerous they are, as they can penetrate deeper into the lungs. The potential impact is measured as the change in mortality due to particulate emissions, expressed as the incidence of disease per kg of $PM_{2.5}$ (particulate matter below 2.5 microns) emitted.

Ionising radiation

Exposure to ionising radiation (radioactivity) can have an impact on human health. Only emissions under normal operating conditions are taken into account (accidents in nuclear power plants are not considered). The potential impact on human health of different ionising radiation is converted into kilobecquerel equivalents of uranium-235 (kBq U^{235} eq).

Photochemical ozone formation

Ozone (O_3) in the troposphere is harmful: it attacks organic compounds in animals and plants, increases the frequency of respiratory problems when photochemical smog is present in cities. The potential impact of substances contributing to photochemical ozone formation is converted into kilogram equivalents of non-methane volatile organic compounds (NMVOCs) (e.g. alcohols, aromatics, etc.; kg of NMVOC equivalent).

Acidification

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

Terrestrial eutrophication

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

Eutrophication of freshwater

Eutrophication affects ecosystems due to substances containing nitrogen (N) or phosphorus (P). If the algae grow too fast, they can leave the water without enough oxygen for fish to survive. Nitrogen emissions to the aquatic environment are mainly due to fertilisers used in agriculture but are also due to combustion processes. The most important sources of phosphorus emissions are wastewater treatment plants for urban and industrial effluents and leaching from agricultural land. The potential impact of substances contributing to freshwater eutrophication is converted into kilogrammes of phosphorus equivalent (kg P equivalent).

Marine eutrophication

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

Freshwater ecotoxicity

This indicator refers to potential toxic impacts on an ecosystem, which may harm individual species as well as the functioning of the ecosystem itself. The emission of toxic substances that are a danger to organisms such as fish, algae and other organisms living in fresh water is therefore recorded. Some of these substances have a tendency to accumulate in living organisms. The unit of measurement is the Comparative Toxic Unit (CTUe). This is based on the USEtox model (Fantke et al., 2017)

Land use

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

Water use

Water abstraction from lakes, rivers or groundwater can contribute to the "depletion" of available water. The impact category considers the availability or scarcity of water in the regions where the activity takes place if this information is known. The potential impact is expressed in cubic metres (m3) of water use related to local water scarcity.

Use of fossil resources

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

Use of mineral resources and metals

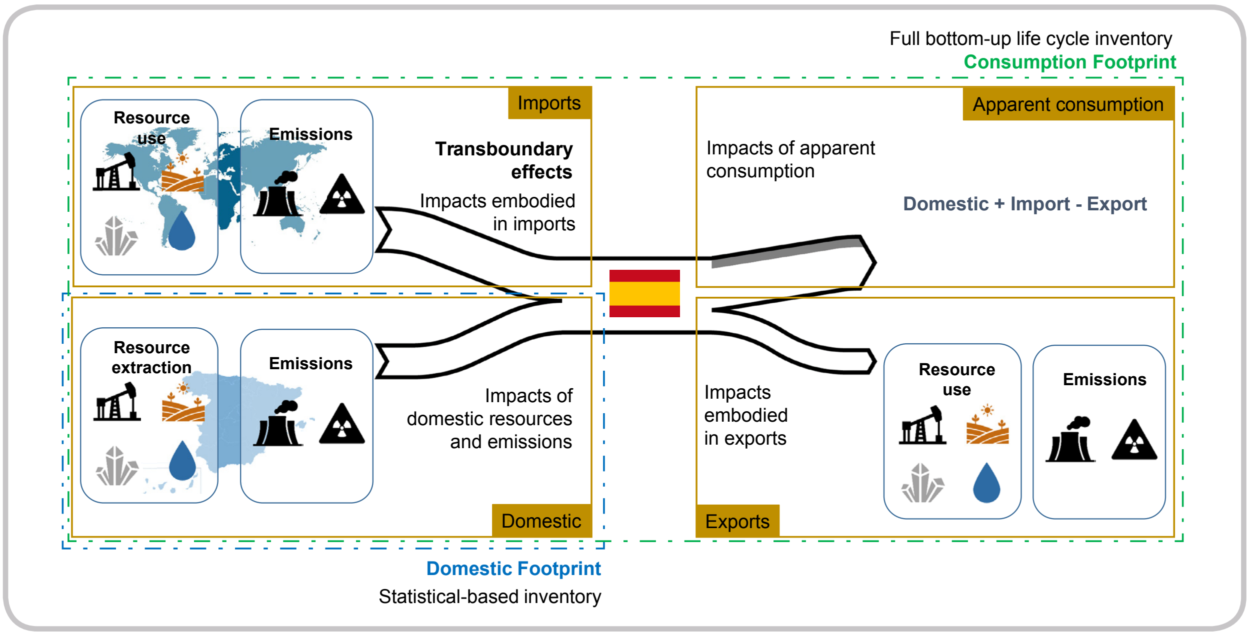
The basic idea behind this impact category is the same as that behind the resource use impact category, fossil (i.e. extracting a high concentration of resources today will force future generations to extract resources of lower concentration or lower value). The amount of materials contributing to resource depletion is converted into kilogram equivalents of antimony (kg Sb equivalent).

1.3. How to measure the environmental impacts of consumption?

The environmental impacts generated by consumption and, more generally, by people's lifestyles, is a growing topic in the scientific literature. Carbon, water, land, soil, materials and other footprints take a consumption-based approach, i.e. they consider the full life cycle of products and allocate impacts to the end consumer. They differ from the production-based approach, which instead assigns impacts to the producer of goods (Hertwich and Peters, 2009; Davis and Caldeira, 2010; Wiedmann et al., 2015).

The EU's Joint Research Centre (JRC) has developed a framework for assessing the environmental impacts of production and consumption in the EU and Member States based on the Life Cycle Assessment (LCA) method (Sala and Sanyé Mengual, 2022) (Figure 2). On the one hand, the Domestic Footprint assesses the environmental impacts that take place within the territory, resulting from the production and consumption of goods and services, including infrastructure impacts (e.g. mobility, wastewater treatment and waste management). On the other hand, the Consumption Footprint assesses the environmental impacts of the apparent consumption of goods, including impacts, taking into account both production and export/import trade.

Figure 2. Summary of the methodological framework of the Consumption Footprint and the Domestic Footprint (adapted from Sanyé-Mengual et al, 2022).



In this study, based on the same methodology used for the EU (Sala and Sanyé Mengual, 2022; Sala et al., 2019), the methodological framework for assessing the environmental impact of consumption in Spain considers a number of key principles. Firstly, the modelling approach is consumption-oriented, i.e. the assessment of the impact of final consumption. Secondly, the framework applies a systematic thinking approach, i.e. it includes different interconnected components of production and consumption to assess impacts. Finally, life cycle perspective and assessment are the basis for modelling and impact assessment.

The LCA was conducted following the recommendations of the Environmental Footprint (EF 3.0) impact assessment model (EC, 2017). Three steps have been implemented: 1) the calculation of impacts, for 16 impact categories; 2) their normalisation against a reference system (global level environmental impacts, adapted from Crenna et al., 2018); 3) their weighting, in order to derive a single weighted and aggregated score with the use of weighting factors developed in the context of the Environmental Footprint (Sala et al., 2018).

The Domestic Footprint (Figure 3) consists of a set of 16 LCA-based indicators (also available as a weighted index) that aim to quantify the environmental impacts due to domestic production and consumption, thus limiting the scope to emissions (as well as extracted resources) within the EU territory, translated into impacts through the Environmental Footprint impact models. This indicator is based on an extensive data collection of detailed information on environmental emissions and resource extraction within EU and Member State borders, resulting in a comprehensive inventory of environmental pressures due to domestic production and consumption (Sanye Mengual et al, 2022).

The Consumption Footprint (Figure 3) is a set of 16 LCA-based indicators (also available as a weighted index) intended to quantify the environmental impacts of consumption at EU and Member State level. This comprehensive bottom-up approach is based on a combination of:

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

b) consumption of these products intensities;

c) the Environmental Footprint (EF) impact model, which translates emissions and resource consumption into potential environmental impacts.

Figure 3. Summary of methodological steps for calculating life-cycle based indicators in the assessment of EU and State Members consumption impacts (adapted from Sala et al., 2019).

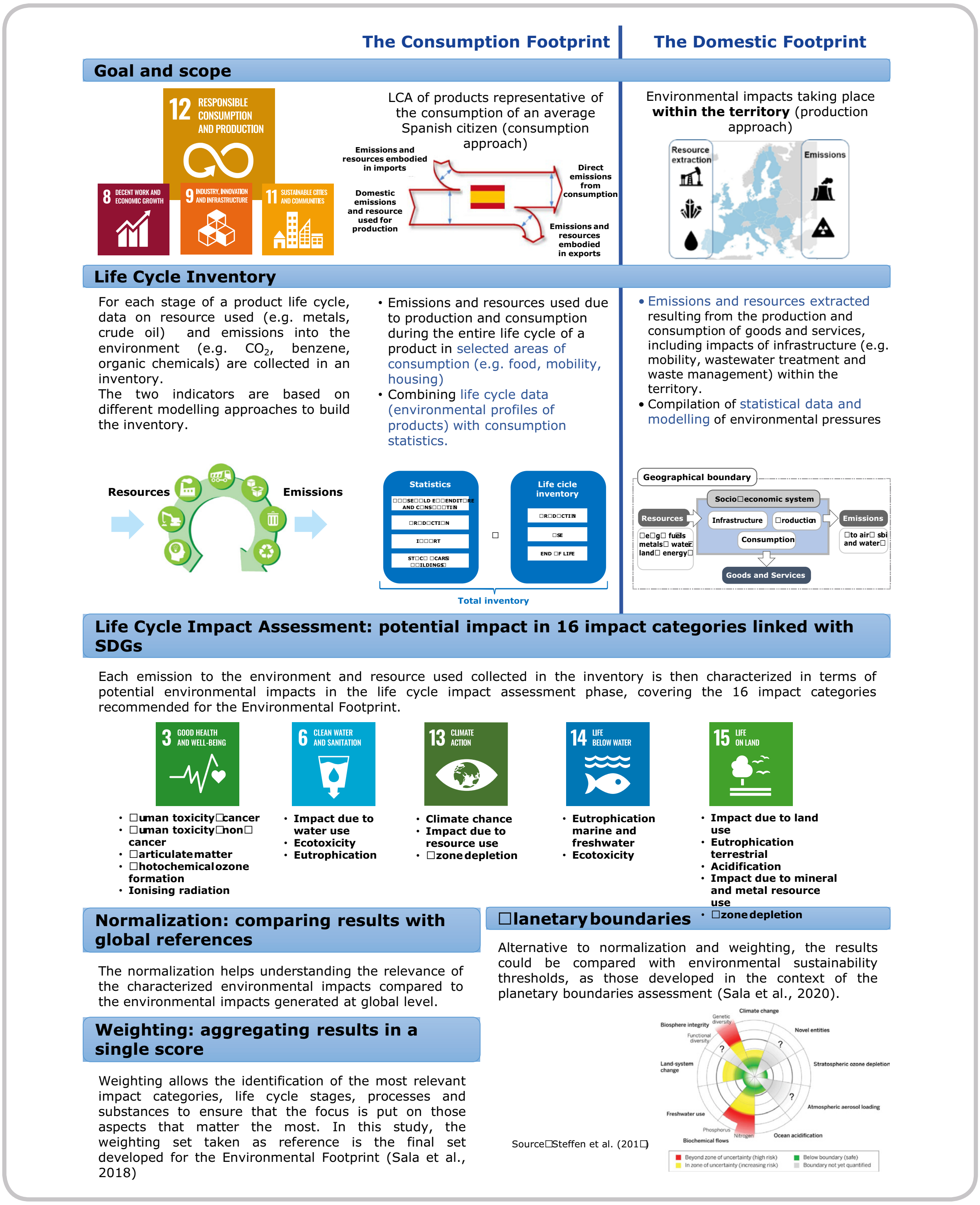
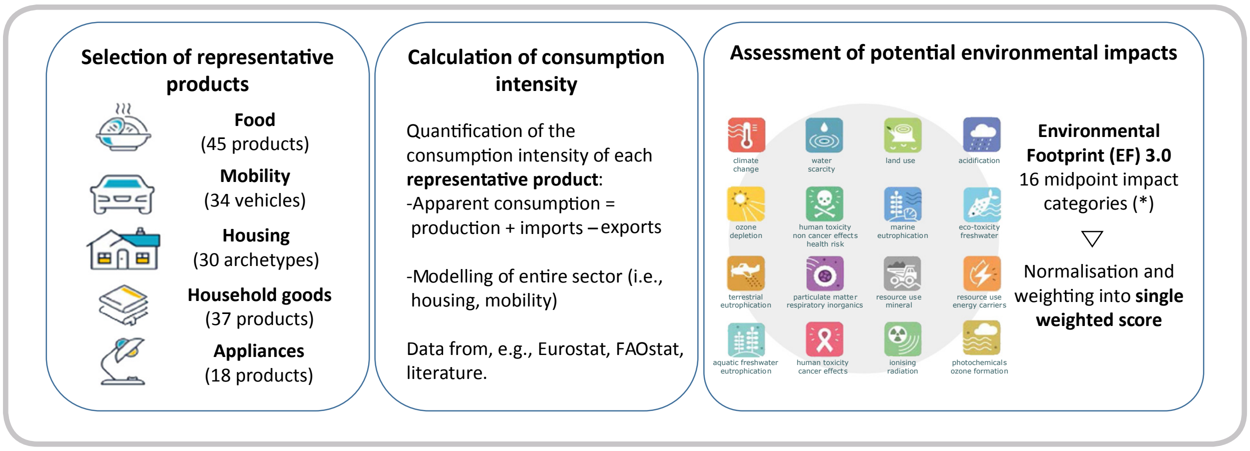


Figure 4. Summary of the Consumption Footprint methodological framework (translated from Sala & Sanyé Mengual, 2022).



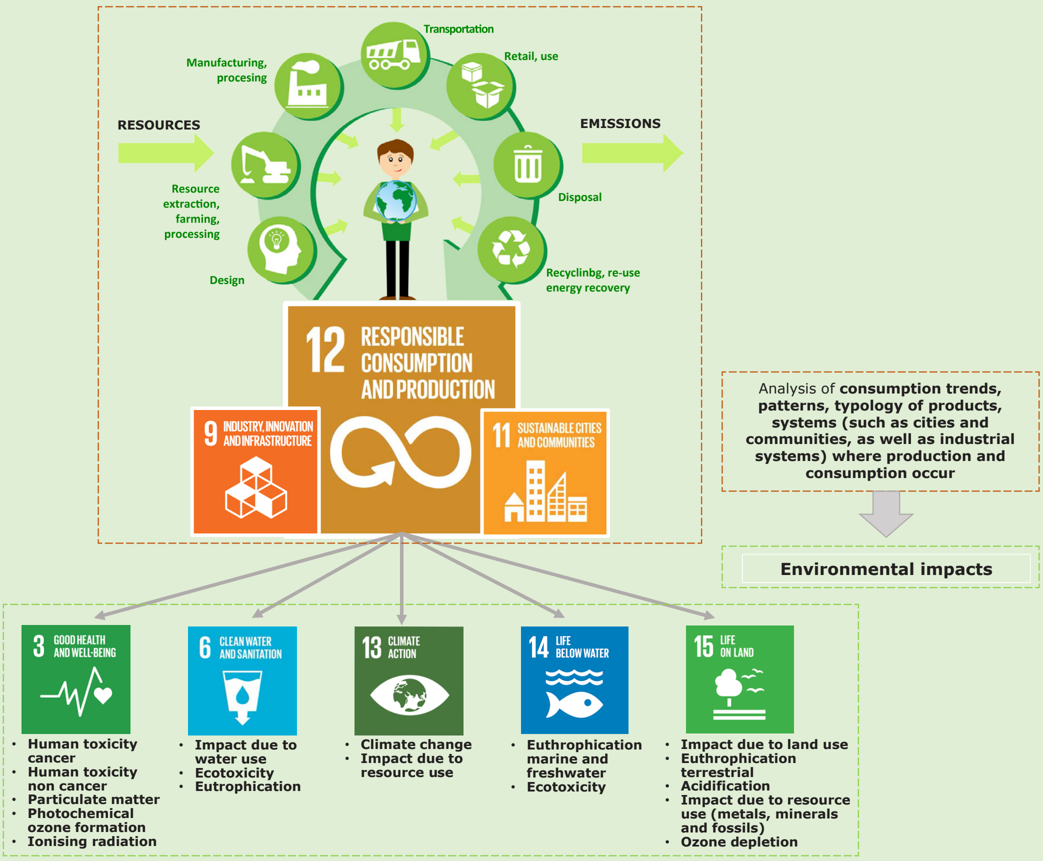
The assessment of environmental impacts can be carried out for a given year to show the status quo, or over a period of time to assess the evolution of environmental impacts. A relative approach to assessing progress towards sustainability can be made through an environmental decoupling assessment, which compares the evolution of environmental impacts and economic growth for the same period.

The environmental impact of consumption in Spain can be linked both to specific SDGs (3, 6, 13, 14 and 15) and to planetary boundaries, which represent the quantitative estimate of the Earth's carrying capacity. This link is in line with the concept of "living well within the limits of the planet" as set out in the 7th Environmental Action Programme (European Parliament and Council, 2013), and implies the quantification of the environmental performance of consumption in Spain with respect to the capacity of the Earth system as an absolute term of comparison. The connection with the SDGs and planetary boundaries helps to determine whether consumption in Spain is environmentally sustainable (Figure 5 and 6).

Consumption Footprint and SDGs

The Consumption Footprint is an LCA-based indicator to quantify the environmental impacts of consumption in the EU and its Member States. LCA is a comprehensive methodology for assessing the environmental impacts of products, sectors and projects. These two elements create several connections between the Consumption Footprint and the SDGs (Figure).

Firstly, the Consumption Footprint provides an overall picture of the environmental impacts of consumption that can support the assessment and monitoring of the decoupling of economic growth from environmental impacts, as envisaged in SDG 12 "Ensure responsible consumption and production patterns". In addition, the goals of SDG 9 "Build resilient infrastructure, promote sustainable industrialization and foster innovation" and SDG 11 "Make cities and human communities inclusive, safe, resilient and sustainable" are also partially addressed in the Consumption Footprint.



Translated from Sala et al., 2019

Figure 5. Consumption impacts in Spain: relative and absolute assessments (Sala et al., 2019).

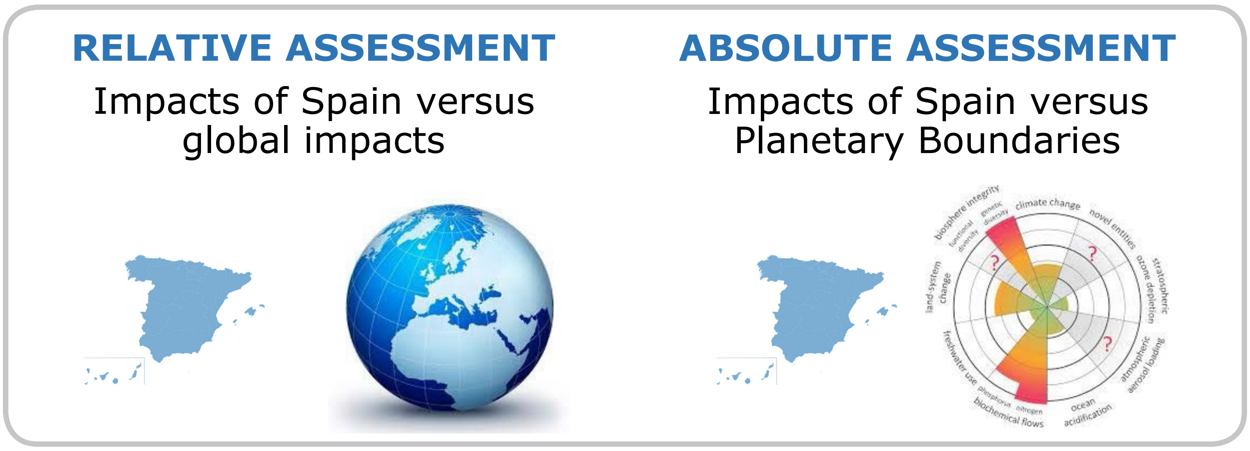


Figure 6. Overview of the link between the (intermediate) impacts adopted in the Life Cycle Impact Assessment, the Sustainable Development Goals and planetary boundaries (adapted from Sala et al., 2019).

SUSTAINABLE DEVELOPMENT GOALS		PLANETARY BOUNDARIES: Biodiversity integrity – Functional / Biodiversity integrity - Genetic	Climate change	Novel entities	Stratos-pheric ozone depletion	Atmos-pheric aerosol loading	Ocean acidifi-cation	Biogeother-mal flows - Nitrogen / Biogeother-mal flows - Phosphorus	Fresh-water use	Land-system change	Resour-cesu se
3 Good health and well-being	Human toxicity, cancer			●							
	Human toxicity, non cancer			●							
	Particulate matter					●					
	Photochemical ozone formation	○		●							
	Ionising radiation			●							
6 Clean water and sanitation	Water use (impact due to)	○							●		
	Ecotoxicity, freshwater	○		●							
13 Climate action	Climate change	○	●				○				
	Resource use, fossil (impact due to)		○								●
	Ozone depletion				●						
14 Life below water	Euthrophication, marine	○						●			
	Eutrophication, freshwater	○						●			
15 Life on land	Land use (impact due to)	○								●	
	Euthrophication, terrestrial	○						●			
	Acidification	○						●			
	Resource use, minerals and metals (impact due to)		○								●

● Link with Environmental Footprint impact category
○ Additional theoretical relation with Planetary Boundaries

2

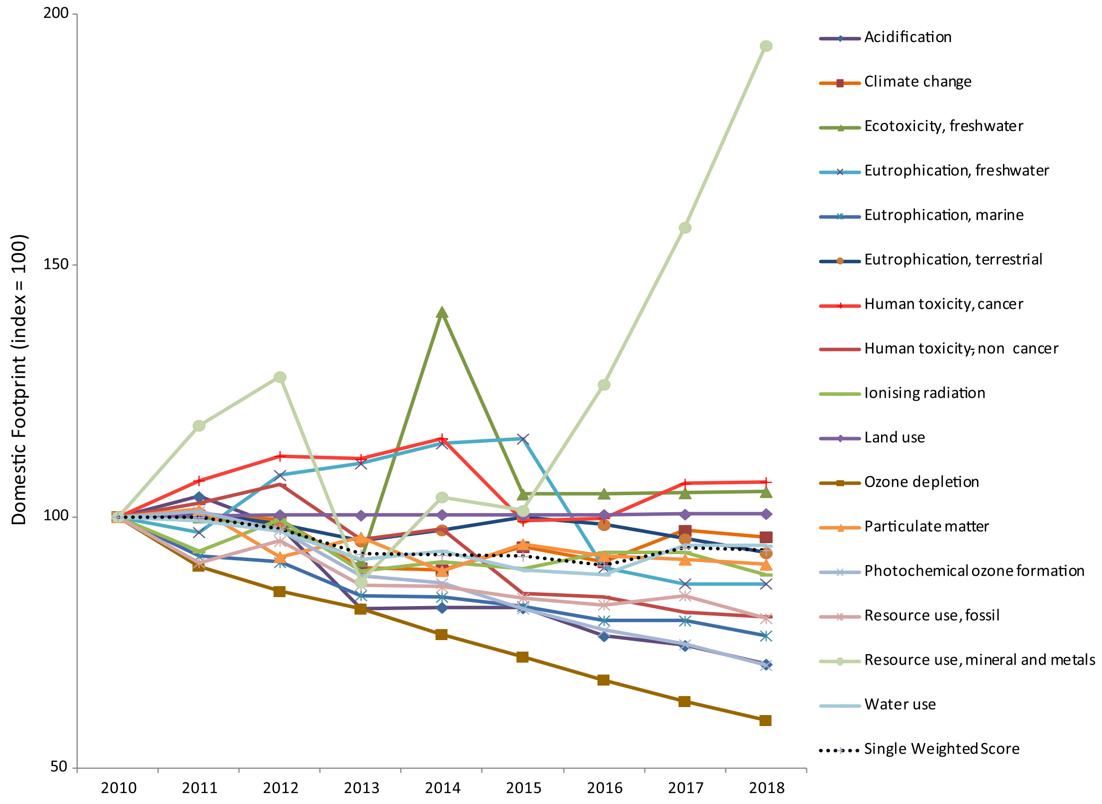
The environmental impacts of consumption in Spain: Domestic Footprint vs Consumption

2.1. The Domestic Footprint: what are the impacts generated within the territory?

The Domestic Footprint is a set of 16 indicators based on Life Cycle Assessment (LCA) (also available as a *single weighted score*) whose purpose is to quantify the environmental impact due to resource extraction and emissions that take place within the national territory (Sala & Sanyé Mengual, 2022; Sala et al., 2019). It is calculated on the basis of domestic production and consumption and therefore does not take into account environmental burdens and impacts relating to foreign trade.

Between 2010 and 2018, Spain's domestic Footprint decreased in most of the environmental impacts assessed (specifically, in 12 of the 16 impacts, as well as in the weighted index) (Figure 7). This decrease was specifically marked for ozone depletion (-40.6%), photochemical ozone formation (-29.5%), acidification (-29.4%), marine eutrophication (-23.7%), fossil resource use (-20.2%) and non-carcinogenic human toxicity (-19.8%). Overall, considering the weighted index of all environmental impacts assessed, Spain's Domestic Footprint fell by -6.7% between 2010 and 2018. It should be noted, however, that this overall downward trend did not manifest itself for four of the 16 environmental impacts assessed: land uses (which increased by +0.6%), freshwater ecotoxicity (+5.0%), human toxicity due to cancer (+6.9%), and, above all, the impact due to the use of mineral resources and metals (+93.8%), which almost doubled in just three years, between 2015 and 2018. The increase in impact due to the use of mineral resources and metals is due to an increase in the extraction of silver (+605%, +148 tonnes) and copper (+164%, +72500 tonnes) from 2015, a trend in line with national mining statistics (Ministry for Ecological Transition and the Demographic Challenge, 2020). Silver and copper mining have a medium-high impact compared to other minerals and metals, with the impact factor around the 95th and 60th percentiles, respectively.

Figure 7. Spain's Domestic Footprint for the 16 environmental impact indicators and for the weighted index (2010-2018).



Contrasting the trends shown by Spain for the 16 environmental impact indicators with the trends shown by the EU-28 (EU-27 + UK) as a whole, we can see how they all coincided; all except one: freshwater ecotoxicity, which despite falling by -9.5% in the EU-28 between 2010 and 2018, was up +5.0% in Spain for the same period. The intensive use of phytosanitary products for agricultural purposes in Spain over recent decades (Carabias-Martínez et al., 2003; Garrido et al., 2000; Hermosin et al., 2013), and the industrial pollution suffered by some rivers in the country (Gonzalo and Camargo, 2013; Suárez-Serrano et al., 2010), help to explain this fact. Throughout the period analysed, freshwater ecotoxicity shows variations (with a maximum value in 2014) associated with the consumption and use of the active ingredient *chlorpyrifos*, used in pesticides.

Another environmental impact for which values are particularly striking when comparing Spain's data with those of the EU-28 is water use, as almost 60% of all the impact associated with domestic water consumption in the EU-28 is accounted for by a single country: Spain. Figure 8 shows the weighted index of Spain's Domestic Footprint, broken down by environmental pressures. As the figure shows, freshwater consumption alone accounts for one third (34.3%) of all environmental pressures in the weighted index of Spanish domestic consumption for all the years in question. Freshwater consumption and CO_2 account for more than half (53.7%) of all environmental pressures, while freshwater consumption, CO_2 and $PM_{2.5}$ particles account for two thirds (66.4%) of all environmental pressures in Spain's Domestic Footprint. Strengthening environmental controls and policies in these three areas would allow Spain to achieve a significant reduction of its Domestic Footprint with relatively manageable and highly significant specific efforts in terms of adapting to eco-social challenges.

Figure 8. Domestic Footprint of Spain broken down by environmental pressures, weighted index (2010-2018).

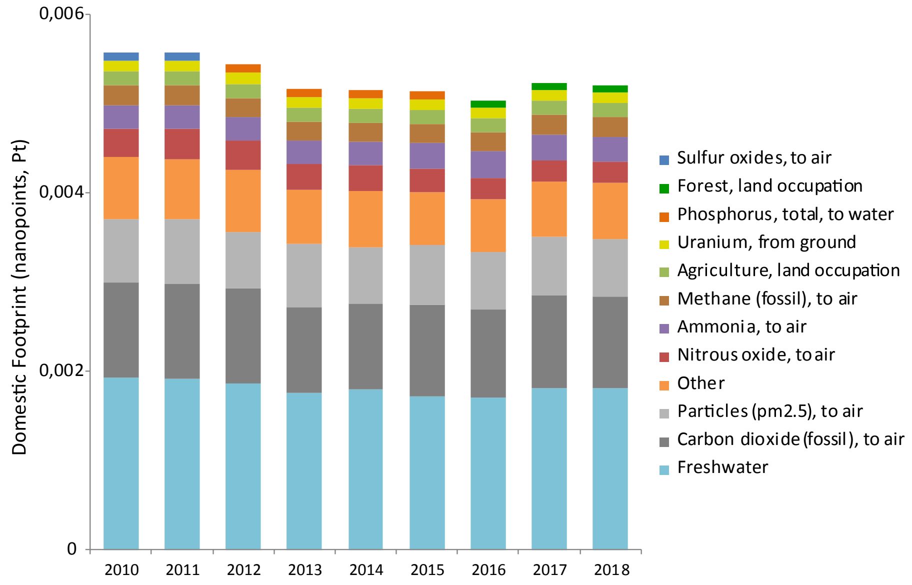


Figure 9 shows the greenhouse gases emitted in Spain that contribute most to the global problem of climate change, one of the environmental impacts of greatest scientific concern and of greatest political and media interest. As the figure shows, CO_2 emissions account for most of the environmental pressures linked to climate change, accounting for three quarters (74.8%) of the total emissions burden alone. Methane emissions (18.4%) and nitrous oxide emissions (5.4%) rank second and third respectively in terms of total national emissions linked to climate change. The emission of these three gases contributes to more than 98% of the emissions that contribute to climate change in Spain.

Looking at the values per capita of the 16 environmental impact indicators assessed for the Domestic Footprint, we see how the impacts between 2010 and 2018 worse values for Spain than for the EU-28 as a whole were: land uses (+3.0% higher in Spain for 2018), particulate matter pollution (+14.2%), freshwater eutrophication (+19.5%), human toxicity, both cancer-related (+16.1%) and non-cancer (+51.1%), freshwater ecotoxicity (+65.7%) and, above all, water use, which in 2018 was in the order of six and a half times (+546.3%) that of the EU-28 (Figure 10).

Figure 9. Contribution of the main national net greenhouse gas emissions to climate change in Spain (2010-2018).

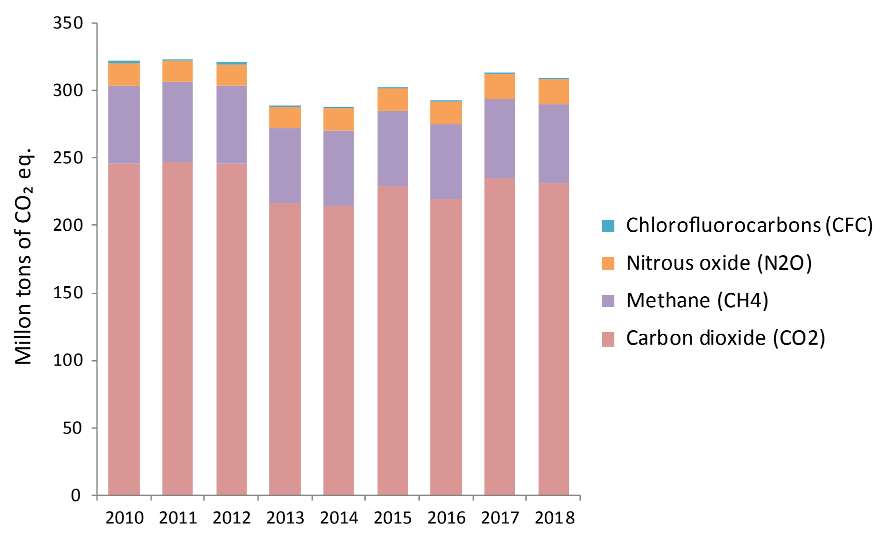
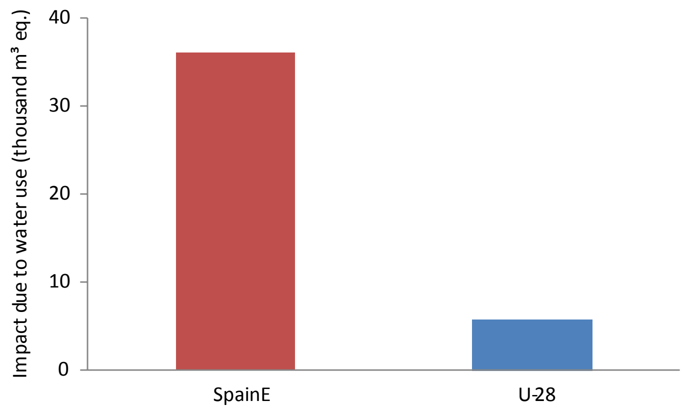


Figure 10. Environmental impact per capita related to freshwater use in Spain and the EU-28, average period 2010-2018.

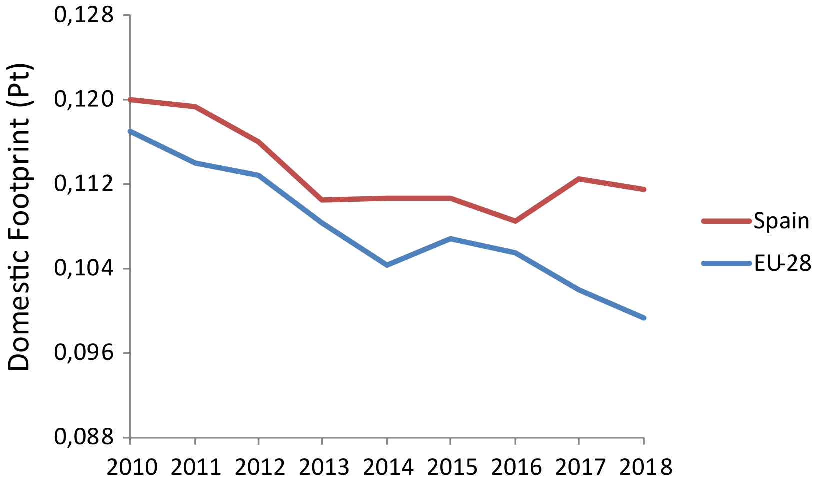


The primary cause of the enormous water consumption in Spain is the agricultural sector, which, despite representing only 3% of GDP and employing only 5% of the economically active population, accounts for about 85% of all national water consumption (Garrido et al., 2010). As suggested above, tackling this issue firmly through solid environmental legislation measures aimed at reducing the consumption of this key resource will be fundamental for Spain's sustainability in the coming years, especially if we take into account that Spain is one of the driest countries in Europe and that, according to climate predictions, by 2040 it will be one of the most water-stressed countries in the world (Luo et al., 2015). Differences in environmental impact due to water use are due not only to the intensity of consumption but also to differences in water scarcity between different geographical areas, which is considered in the environmental impact model of the Environmental Footprint. In this regard, Spain suffers from a level of water scarcity above the European average and water consumption in Spain generates a greater impact.

Eight environmental impacts showed better values for Spain than for the EU-28 as a whole over the time series analysed (2010-2018). Particularly noteworthy is the case of acidification, whose values per capita were around 16 times lower in Spain than in the EU-28 as a whole. The cause of these differences is probably related to the use of nitrogen fertilisers such as ammonium nitrate and urea, which have traditionally been used more intensively in Central Europe and the British Isles (Goulding, 2016). The impact per capita from ionising radiation was, in turn, almost 10 times lower in Spain than in the EU-28 as a whole, while impacts caused by terrestrial eutrophication and the use of fossil resources were around three times lower for the average Spanish citizen than for the average EU-28 citizen.

The weighted index of environmental impacts per capita of domestic consumption in Spain for between 2010 and 2018 showed a downward trend quite similar to that of the EU-28, however it recorded somewhat higher values throughout the time series (Figure 11). It should be noted, however, that from 2016 onwards these trends seem to start to diverge, with the gap between them gradually widening in 2017 and 2018. This is mainly due to the stagnation in the downward trend for Spanish domestic consumption, which hardly changed between 2013 and 2018, while for the EU-28 it continued to decline during these years at a remarkably similar pace to that experienced in the rest of the time series.

Figure 11. Domestic Footprint per capita for Spain and the EU-28, weighted index (2010-2018).



2.2. The Consumption Footprint: global environmental impacts linked to Spanish consumption

Studying the patterns and trends showed by the Domestic Footprint in Spain helps us understand the environmental impacts caused by domestic production and consumption, and which are therefore due to the extractions and emissions that occur in the country. This approach, however, leaves out of the equation a whole series of environmental pressures which, the ultimate responsibility of Spanish consumption patterns, exert their impact outside Spanish borders through the importation of products and consumer goods that were produced, processed and manufactured in other parts of the world. What's more, the Domestic Footprint does not consider that part of the production, and its associated environmental pressures, takes place in Spain, is exported and therefore caused by consumption patterns in other regions of the world.

The so-called Consumption Footprint bridges these gaps by incorporating the environmental impacts of foreign trade (i.e. both imports and exports of products) into domestic consumption.

The Consumption Footprint is a set of 16 LCA-based environmental impact indicators (also available as a weighted index) that aims to quantify the environmental impacts of consumption exerted by a country's economy as a whole, including all its economic activities and considering both the burdens associated with activities occurring within the national territory and those related to foreign trade (Sala and Sanyé Mengual, 2022; Sala et al., 2019). In this way, and unlike the Domestic Footprint, the Consumption Footprint takes into account the environmental impacts associated with the product stages of supply chains that occur outside Spanish borders.

The Consumption Footprint considers the consumption intensity of representative products of the most relevant consumption areas (food, housing, mobility, appliances and household goods). The Consumption Footprint is quantified as the sum of the environmental impact of the consumption of each representative product, based the intensity of consumption, while also considering foreign trade and its unit environmental impact:

$$\textit{Huella de Consumo} = \sum_{i=0}^{n} \textit{Intensidad de consumo} * \textit{Impacto ambiental unitario} =$$

where:

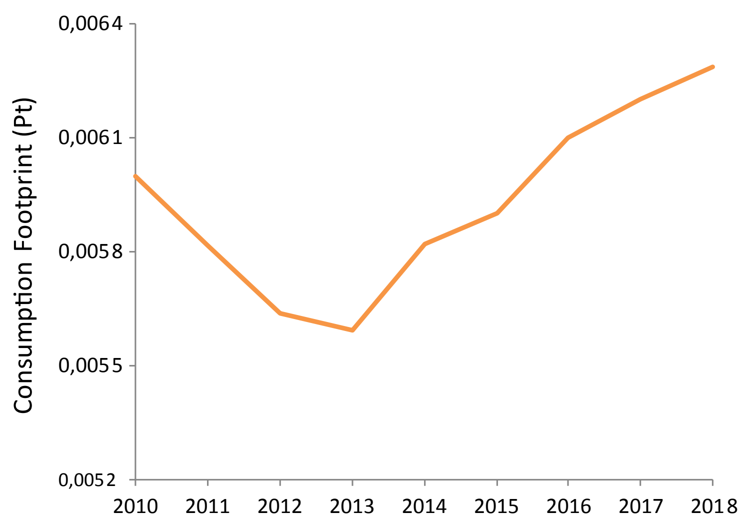
$$\textit{Intensidad de consumo} = \textit{Producción doméstica} + \textit{Importaciones} - \textit{Exportaciones}$$

Between 2010 and 2018, Spain's consumption Footprint showed a remarkably similar trend for most of the environmental impact indicators analysed. As Figure 12 shows us for the weighted index, in general terms this trend was growing (+5.0%), but with a notable change in the trend in 2013. Until 2013, the trend was decreasing, and it was that year the trajectory changed, and for most of the environmental impacts the falls recorded during the first three years of the time series were reversed.

This abrupt change in the trend recorded by the Spanish Consumption Footprint is likely related to the exit from the economic crisis of 2008, which, according to national accounting data of the National Institute of Statistics (MINECO, 2014), began to manifest itself in general terms from 2014 onwards. This would also help to interpret the interruption of the downward trend in Spanish domestic consumption detected in the previous section from 2013 onwards (see Figure 11).

However, the decreases identified in section 2.1 for most of the environmental impact indicators of the Domestic Footprint (Figure 7) go in the opposite direction to the general increase in environmental impacts detected (especially from 2013 onwards) for the Consumption Footprint (Figure 12). That means that impacts like acidification, climate change, marine and terrestrial eutrophication, human toxicity (carcinogenic and non-carcinogenic), ozone depletion, particulate matter, photochemical ozone formation, and freshwater use showed clearly increasing trends for the Consumption Footprint and decreasing trends for the Domestic Footprint. Freshwater ecotoxicity and land use showed an increasing trend in both footprints, with the increase much more marked for the Consumption Footprint.

Figure 12. Spain's Consumption Footprint, weighted index (2010-2018).

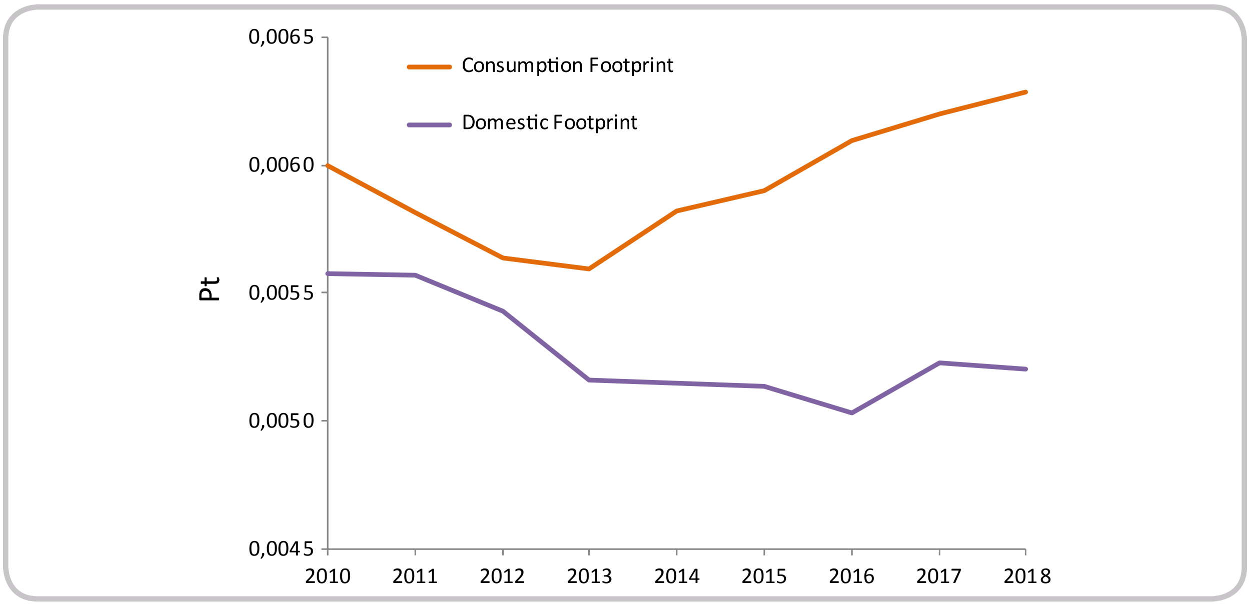


These differences between the trends in the Domestic Footprint and the Consumption Footprint highlight, after all, the Spanish economy's growing dependence on natural resources abroad; a dependence that results in the export of environmental impacts associated with the use of resources and environmental emissions that take place far from our territory. The weighted indices of the Spanish Consumption Footprint and the Spanish Domestic Footprint (Figure 13) reflect this fact well, which has increased in the last five years.

The importance of the Spanish economy's trade balance in relation to the national values as reflected by the Domestic Footprint shows how the downward trends in most of the environmental impacts of Spanish domestic consumption (Figure 7) are in fact sustained at the cost of transferring a large part of these impacts beyond Spain's borders.

A comparison of the values and trends of the 16 environmental impacts for the Consumption Footprint and the Domestic Footprint leads to the conclusion that Spain is, in general terms, a net exporter of environmental impacts to third countries. This contrast also shows that the environmental impacts linked to Spanish foreign trade are increasing (Figure 13). These results have important interpretations related to the coupling or decoupling between Spanish economic growth and the environmental impacts of consumption that will be further analysed in section 3.1.

Figure 13. Spain's Domestic Footprint and Consumption Footprint, weighted indices (2010-2018).

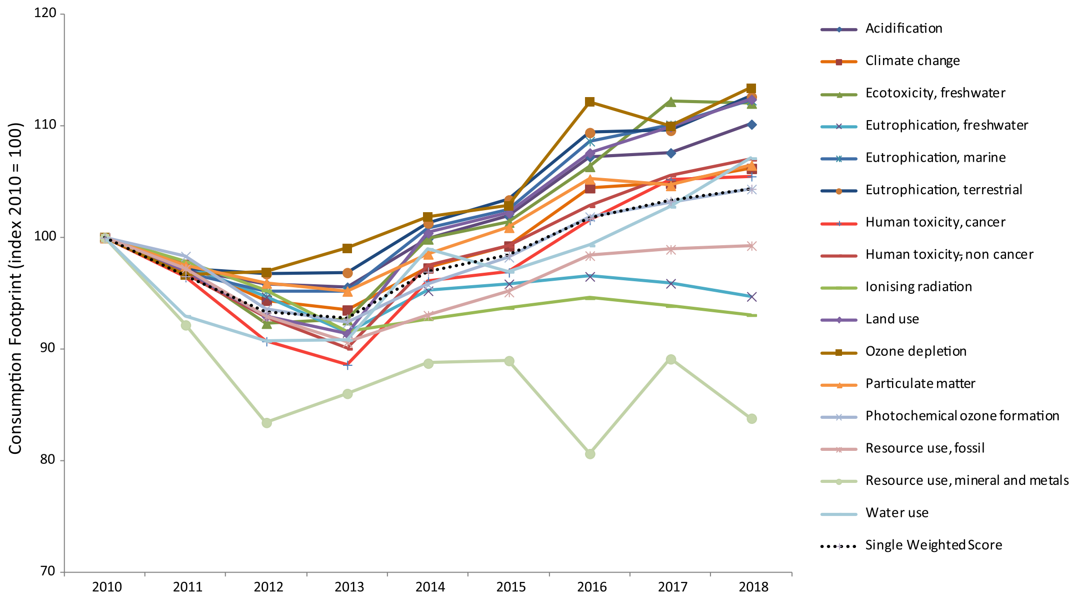


2.3. How does the Consumption Footprint per capita behave and what are its impacts and evolution over time?

Analysing the environmental impact of the average citizen through the Consumption Footprint per capita allows us to address in greater depth the key elements of production and consumption, as well as the lifestyles of consumers (Sala & Sanyé Mengual, 2022; Sala et al., 2019).

As Figure 14 shows, of the 16 environmental impacts of Spain's Consumption Footprint per capita only four showed decreasing trends between 2010 and 2018: the use of fossil resources (-0.7%), freshwater eutrophication (-5.3%), ionising radiation (-6.9%) and, above all, the use of mineral resources and metals, which experienced a fall of -16.2%, coinciding with the general fall in the consumption of minerals and metals since the bursting of the real estate bubble in 2007 and the ensuing recession. A good example of this is the data on materials consumption from the United Nations International Resource Panel, according to which, in Spain, between 2006 and 2017, the consumption of ferrous metals fell by 84%, while quarry minerals for construction fell by more than half and the consumption of other non-metallic minerals fell by a third (UN-IRP, 2018).

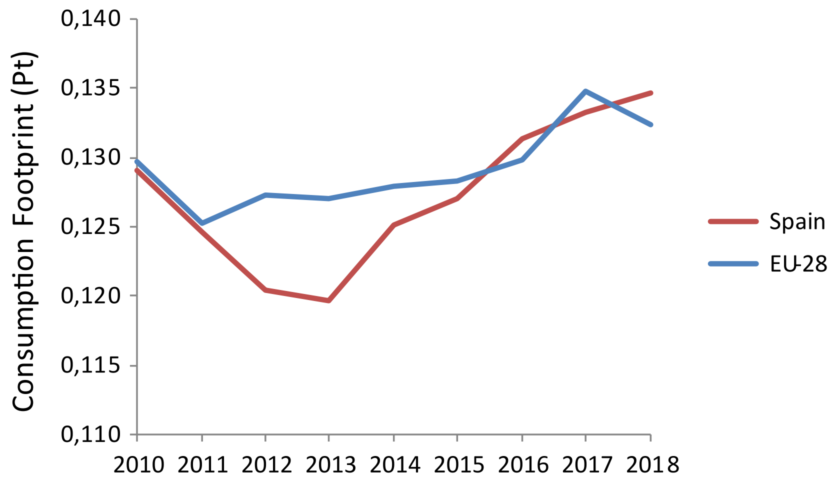
Figure 14. Spain's Consumption Footprint per capita for the 16 environmental impacts assessed and for the weighted index (2010-2018).



The environmental impacts that increased the most in Spain during the period analysed were ozone depletion (+13.4%), land use (+12.4%), terrestrial and marine eutrophication (+12.6% and +12.3% respectively), freshwater ecotoxicity (+11.4%), acidification (+10.2%) and water use (+7.1%). Overall, and considering the weighted index of all environmental impacts, Spain's Consumption Footprint per capita increased its value between 2010 and 2018 by 4.4%.

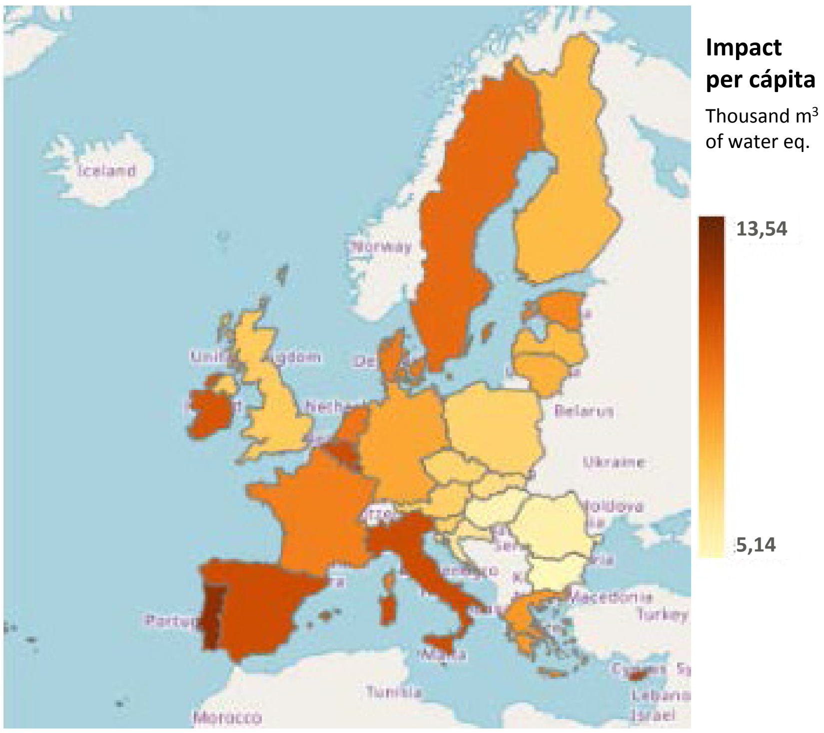
Of the 16 environmental impact indicators assessed in the Consumption Footprint per capita, seven showed better values for Spain than for the EU-28 as a whole for the average of the entire time series analysed (2010-2018). Among these seven impacts, the cases of the use of fossil resources and ionising radiation, whose values were on average respectively -14.2% and -12% lower in Spain than in the EU-28 as a whole, stand out. By contrast, seven types of impacts between 2010 and 2018 showed worse average values per capita for Spain than for the EU-28, while two of them showed a similar trend. Among the impacts that showed worse values in Spain during the period analysed, it is worth highlighting the case of water use (+29.9% higher in Spain than in the EU-28 for the 2010-2018 average), ozone depletion (+15.8%), land use (+12.9%), non-carcinogenic human toxicity (+8.5%), and terrestrial and marine eutrophication (+8% and +7.6% respectively). Figure 15 shows the time evolution between 2010 and 2018 of the weighted Consumption Footprint per capita index of Spain compared to that of the EU-28.

Figure 15. Consumption Footprint per capita for Spain and the EU-28, weighted index (2010-2018).



In relation to the rest of the EU-28 countries, Spain generally occupies an intermediate (or even low-intermediate) position in most of the environmental impacts analysed in the Consumption Footprint per capita. The only two impacts for which Spain appears in the *top 10* EU-28 countries are ozone depletion (where Spain ranks seventh) and water use (where Spain ranks sixth) (Figure 16). As indicated above, the high water consumption of the Spanish agricultural sector is probably the factor that best explains this fact.

Figure 16. Map of the EU-28 with the distribution of the Consumption Footprint per capita for the impact related to water use (2018).



2.4. Which areas and products contribute most to the Consumption Footprint?

The Spanish Consumption Footprint is calculated based on the environmental impacts associated with a total of 164 representative products, aggregated around five major consumption areas: food (broken down into 45 product groups), mobility (34 product groups), housing (30 product groups), household goods (37 product groups), and appliances (18 product groups) (Sala & Sanyé Mengual, 2022; Sala et al., 2019).

Food consumption represents by far the main driver of the environmental impacts generated by the average Spanish consumer, accounting for 52.1% of the Consumption Footprint in 2018 for the weighted index. In the same year, mobility (especially associated with private car use), with 17.1%, and housing (mainly linked to energy consumption for heating and appliances), with 16.2%, ranked second and third respectively (Figure 17). These three areas, and in that order, are, as is the case for the EU-28 as a whole, the areas with the greatest impact on average consumption, and those characterised by a higher intensity of use, representing, jointly for Spain, more than four fifths (85.3%) of the entire Consumption Footprint for 2018, which is in line with the general literature (Di Donato et al. 2015; Ivanova et al. 2016). The evolution of the data also shows that this trend is maintained over the entire time horizon analysed.

Figure 17. Spanish Consumption Footprint by consumption areas, weighted index (2018).

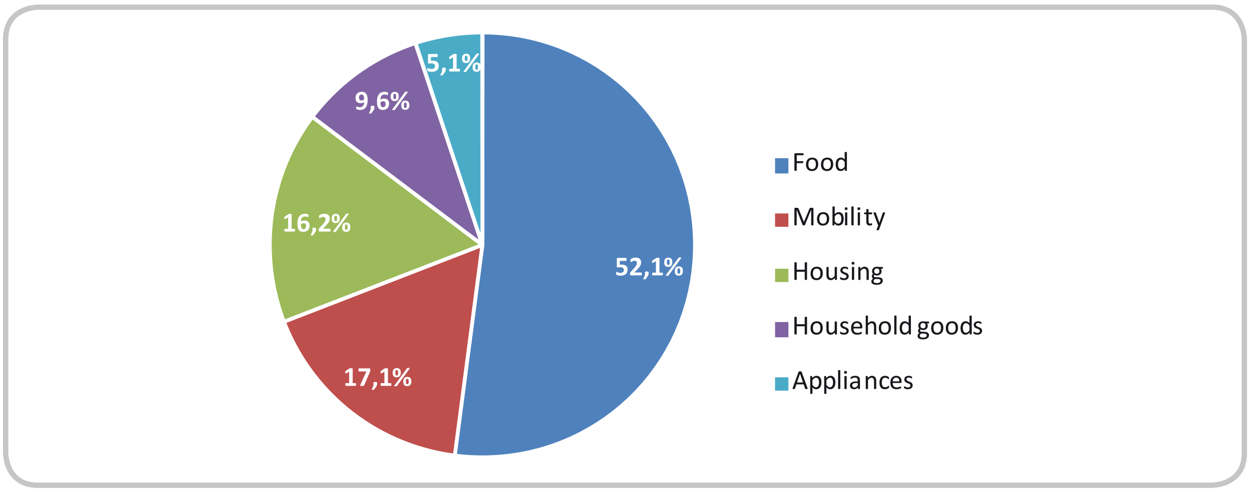


Figure 18 shows the weighted index of Spain's Consumption Footprint between 2010 and 2018 broken down by areas of consumption. As the figure shows, the weight of each area has not varied significantly over the time series analysed with food continuing to represent the area of consumption with the greatest environmental weight in the total Consumption Footprint.

However, when looking at the Consumption Footprint in terms of the 16 specific impacts associated with the LCA, the distribution by areas of consumption changes, with the exception of food which, for most of the impact categories, is still the main driver (Figure 19).

Figure 18. Spain's Consumption Footprint by areas of consumption, weighted index (2010-2018).

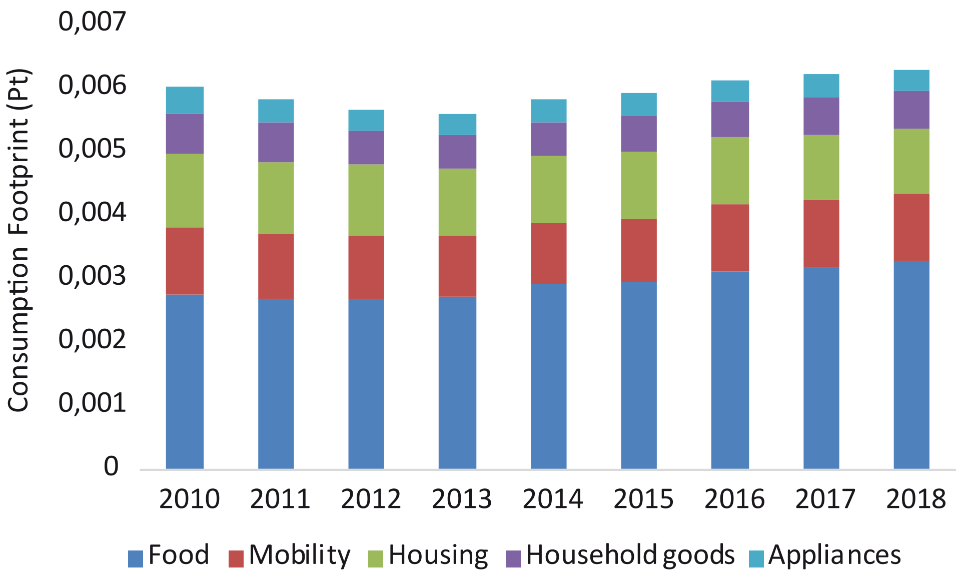
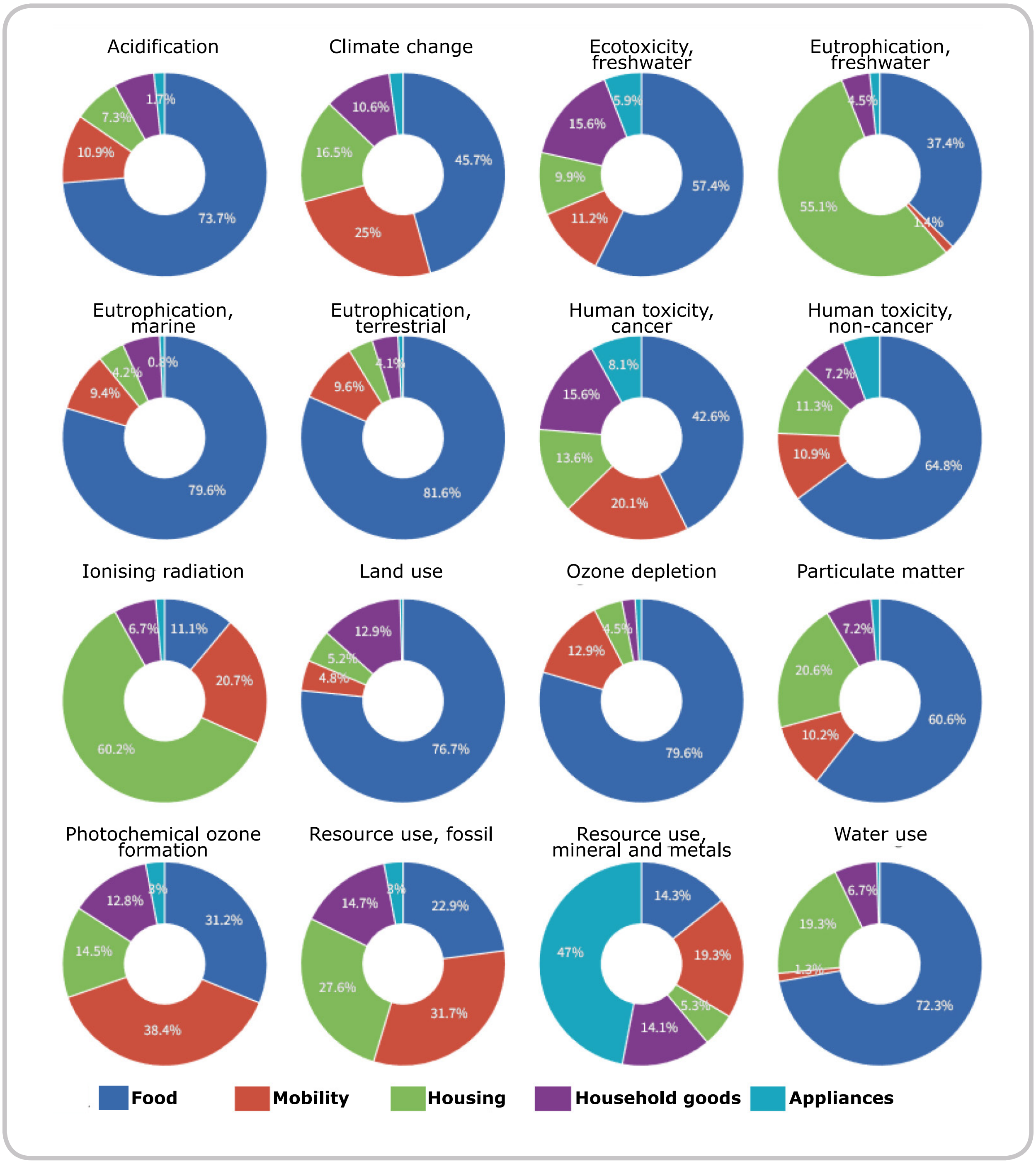


Figure 19. Spain's Consumption Footprint by areas of consumption for each of the 16 impacts analysed (2018).

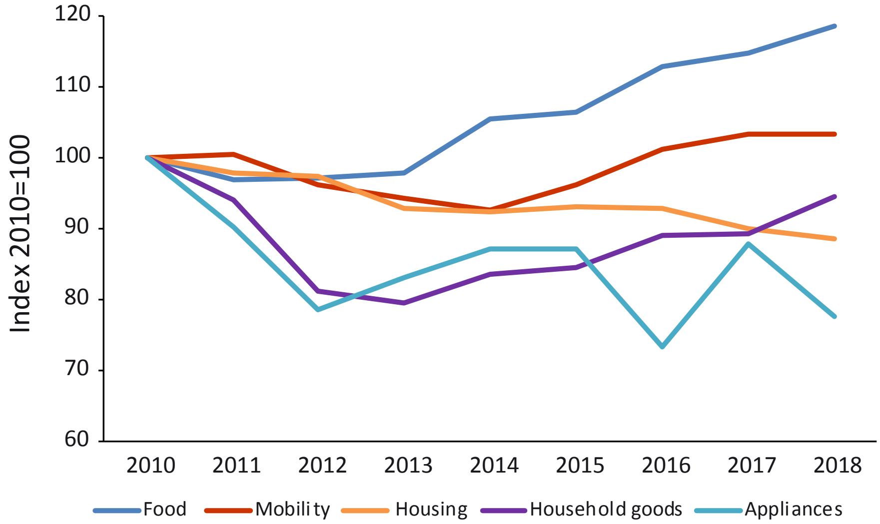


The data by impact category show a significant influence of food in terms of terrestrial (81.6%) and marine (79.6%) eutrophication, ozone depletion (79.6%), land use (76.7%), with a significant contribution also in terms of acidification (73.7%) and water use (72.3%). This is mainly due to the highly intensive and industrial nature of our agricultural and livestock farming system, which is heavily dependent on the use of fossil resources, chemical fertilisers and large quantities of water (IPCC, 2019; Aguilera et al., 2020; González de Molina et al., 2019). Another aspect to highlight is the weight of appliances in the use of mineral resources and metals (47.0%), due to the notorious demand for raw materials (including critical raw materials) in their components (WEF, 2019; Yamasue et al., 2009). Mobility has the greatest impact on ozone depletion (38.4%) and the use of fossil resources (31.7%), while housing has the greatest impact on the emission of ionising radiation (60.2%) and the eutrophication of freshwater (55.1%). Finally, household goods have a higher weight in carcinogenic human toxicity (15.6%) and freshwater ecotoxicity (15.6%).

If we focus instead on climate impact, it can be seen that three quarters of the impact is on food and mobility. Food accounts for almost half (45.7%) of the climate change impact and mobility for a quarter (25%). They are followed in this impact category by housing (16.5%), household goods (10.6%) and finally appliances, with a relatively minor impact (2.2%) in this area, but nevertheless of paramount importance as far as the use of minerals and metals is concerned.

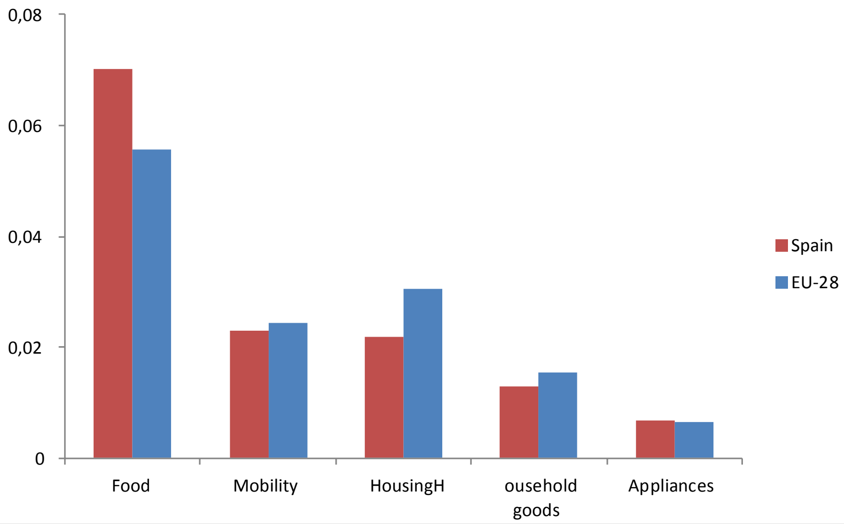
Looked at over time, Spain's Consumption Footprint showed different trends depending on the area of consumption (Figure 20). So while food and mobility showed increasing trends due, respectively, to the apparent increase in food consumption in the household shopping basket and kilometres travelled per person (up +18.6% and +3.2% respectively between 2010 and 2018), housing, household goods and appliances showed downward trends (-11.6%, -5.4% and -22.5% respectively for the same period). The case of housing seems striking, where the observed inflection may be due to an improvement in the efficiency of energy use for heating homes.

Figure 20. Consumption Footprint in Spain for the five areas of consumption, weighted index (2010-2018).



Contrasting the values per capita of the five areas of consumption of the Spanish Consumption Footprint with the values shown for the EU-28 as a whole for 2018, we see that Spain is above the European average in the Footprint related to food consumption (+26.3%) and appliances (+4.9%), and below in those related to housing (-29.0%), household goods (-15.3%) and mobility (-5.5%) (Figure 21).

Figure 21. Consumption Footprint per capita for Spain and the EU-28 for each of the five consumption areas analysed (2018).



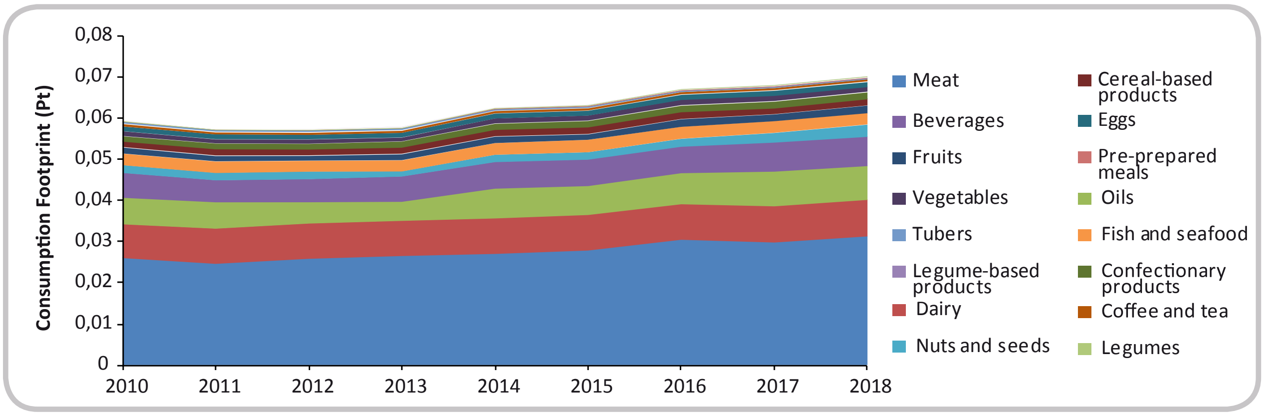
In this context, by breaking it down further, we can identify which product groups within each consumption area lead the impacts for the period analysed.

Food

As we have seen, food is the most significant consumption category in terms of weight for almost all the environmental impact categories considered in the methodological approach used. Food is represented by a basket of food products selected by importance in quantity (kg/year) and economic value, to represent the average consumption of the nutritional intake of EU-28 citizens in 2010, based on Eurostat-Prodcom data (base 2010). It also includes products that are representative of emerging trends in food and beverage consumption over recent decades (e.g. tofu, ready meals, etc.), regardless of their environmental impact and apparent extent of their consumption.

As Figure 22 shows, in Spain the main food categories that have the most impacts, according to the weighted index, are animal products (such as meat and dairy products), followed by oils and beverages, despite the fact that they are consumed in tendentially smaller quantities compared to products of plant origin. The reason for this may have something to with the different needs of conventional animal production systems, which, compared to plant production systems, require more inputs to deliver the same amount of product. In the same vein, we must remember that main life cycle impacts of meat products derived from pork, beef and poultry come mainly from emissions and land use (such as deforestation leading to biodiversity loss) due to feed production as well as direct emissions from livestock farming (methane, ammonia, etc.) (Cripa et al., 2021; Aguilera et al., 2020; Leip et al., 2015).

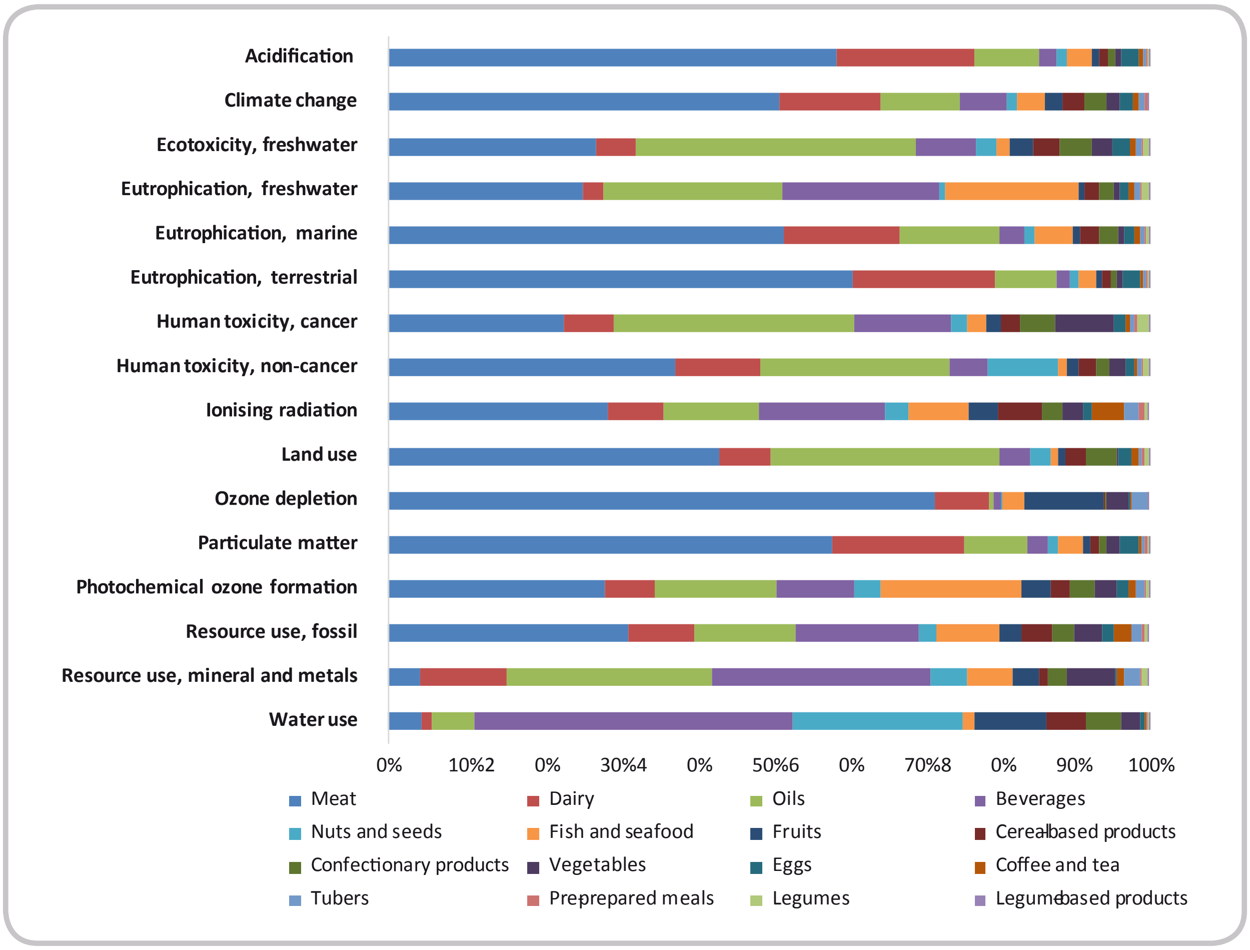
Figure 22. Consumption Footprint in Spain by type of food, weighted index (2010-2018).



Therefore, lower consumption of animal products would be beneficial in reducing the overall impacts associated with food consumption as a whole, as much of the literature has been pointing out (Di Donato, 2021). It is also important to underline that forms of production (conventional vs. agroecological; intensive vs. extensive, etc.) are fundamental in managing these impacts (Leroy et al., 2022).

For 2018, considering the weighted index, the foods with the highest consumption footprint are pork (23.0%), beef (14.4%) and chicken (7.1%). The impacts associated with wine (7.1%, mainly due to the use of water) and cheeses (7.0%) are also relevant. These contributions are also virtually unchanged from previous years.

Figure 23. Contribution of different food categories to the impact of food in Spain for the 16 impact categories assessed (2018).

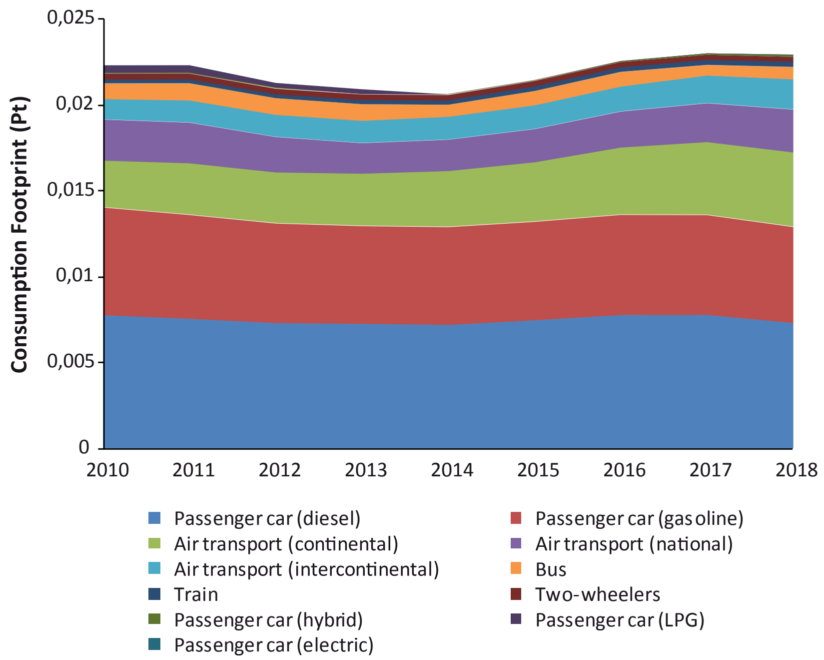


If we consider the 16 categories of specific impact (Figure 23), we also see that animal products lead the ranking. In this sense, meat and dairy have important contributions in terms of acidification, climate change, marine and terrestrial eutrophication, land use, ozone depletion and particulate matter. Oils emerge as key elements in several impact categories, such as freshwater ecotoxicity, freshwater eutrophication, human toxicity (carcinogenic and non-carcinogenic) and land use. The high impact of beverages on water resources is due to their water content and high consumption intensity per capita, followed by the nuts and seeds group represented by almonds, which require high water consumption for their cultivation (Vanham et al., 2020).

Mobility

With regard to mobility, data has been generated from the distances travelled by an average person in Spain by different means of transport (cars, bus, plane, train, etc.). The distribution of the Consumption Footprint in terms of weighted index by type of transport is as shown in Figure 24.

Figure 24. Consumption Footprint in Spain by type of transport, weighted index (2010-2018).

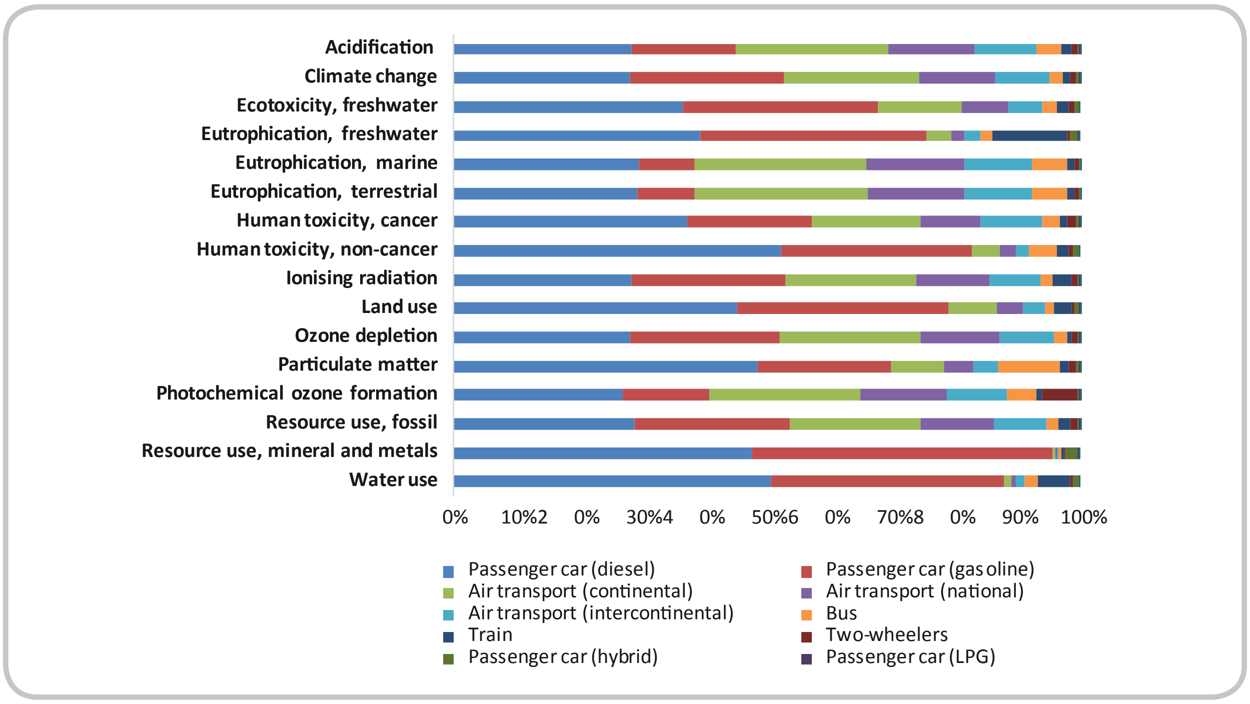


In this sense, it can be stated that, for the period analysed, the means of transport that contributed most to the Consumption Footprint (according to the weighted index) are, respectively, diesel passenger cars, petrol passenger cars and continental air transport. This result within the private transport sector is a reflection of the prevalence of diesel vehicles compared to petrol vehicles within the overall vehicle fleet in Spain for the years considered, as highlighted by the data from the Yearbook of the Directorate General of Traffic (DGT).

It should also be noted that the bulk of domestic passenger (and freight) transport in Spain is carried out by road (Pérez Martínez, 2008). In fact, according to DGT data, car transport currently accounts for more than three quarters of the total (77.4%). When analysing the international dimension, we see that in Spain, air and road transport is also predominant in terms of passenger transport.

Looking at the contribution of different modes of transport according to impact categories for 2018 (Figure 25), the weight of diesel vehicles in the bulk of per capita transport impacts (especially non-carcinogenic human toxicity, water use, particulate matter, metals and minerals use and land use) is remarkable. The contribution of petrol-powered passenger cars also accounts for a large part of the same impacts. Both types of vehicles account for 95.5% of mineral and metal use, 87.9% of water use, 82.8% of non-carcinogenic human toxicity, 79% of land use and 69.9% of particulate matter associated with mobility per person. If we add to these those associated with aviation (first continental, then national and finally intercontinental), in all types of impact we add up to more than 85% of the consumption footprint per capita attributable to transport in Spain.

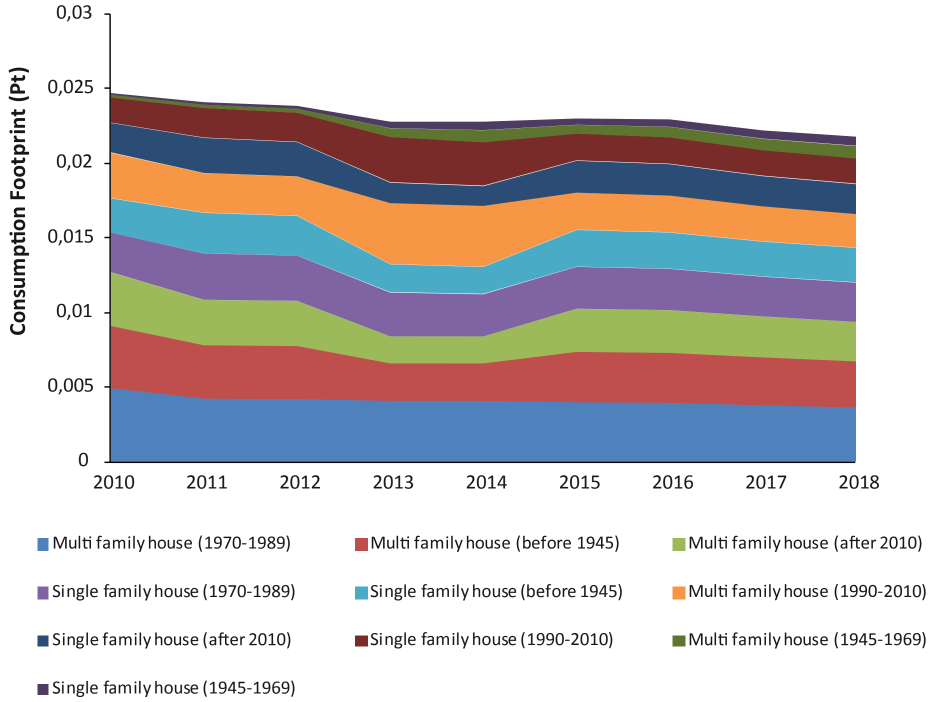
Figure 25. Contribution of types of transport to the impact of mobility in Spain for the 16 environmental impact categories analysed (2018).



Housing

Turning to the housing data, we see that the reference group at European level is composed of 30 types of dwellings representative of the housing stock of the EU-28 countries (considering the stock of permanently occupied dwellings) based on the year 2010, divided by building type (single-family or multi-family), climate zone (cold, warm or hot) and year of construction (pre-1945, between 1946 and 1969, between 1970 and 1989, between 1990 and 2010, and post-2010). Spain is one of the countries in the Mediterranean area, which belong to the warm climate zone. The calculation of the different impacts of housing types takes into account the phases of production, construction, use (average energy and water consumption of a dwelling per person per year), maintenance and lifetime of each dwelling. It is important for the analysis to consider both the unit of each type of dwelling and the number of dwellings of that type. The distribution of the Consumption Footprint in terms of broken down weighted index, for the 10 dwelling types, is displayed below in Figure 26.

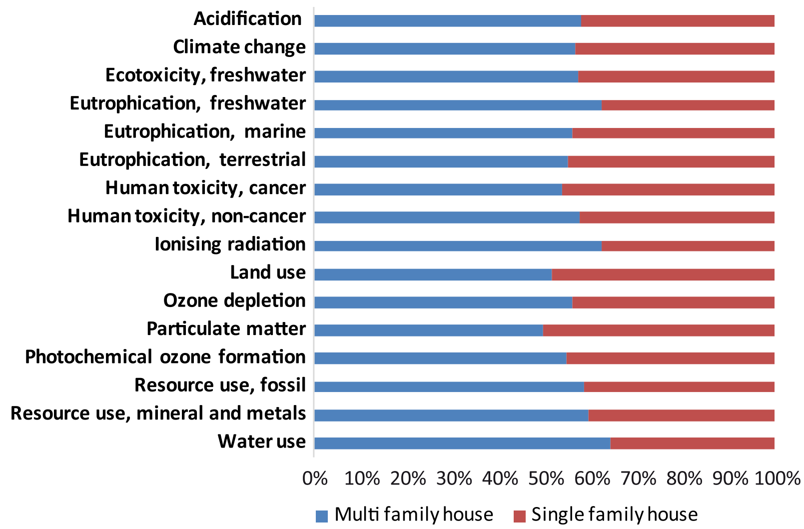
Figure 26. Consumption Footprint in Spain by type of dwelling, weighted index (2010-2018).



The three housing typologies with the highest weight on the Consumption Footprint in 2018 are multi-family dwellings built respectively between 1970-1989 (16.9%), before 1945 (14.2%) and after 2010 (12.2%), as well as single-family dwellings from the years 1970-1989 (12.1%). Single-family dwellings built before 1945 and multi-family dwellings built between 1990 and 2010 also have a significant weight in the distribution of the Consumption Footprint per capita (with 10.7% and 10.6%, respectively, for 2018). The significance of the six types of dwellings mentioned with respect to the indicator is also shown in the other years of the series analysed and may relate to the floor area and the construction materials used, the existing energy efficiency according to the type of construction, the average time of use of the dwelling itself and the number of existing buildings in each period (Baldassarri et al., 2017; Sala & Sanyé Mengual, 2022; Sala et al., 2019).

Looking at the data in terms of impact types, multi-family dwellings have a slightly higher incidence than single-family dwellings in all categories. Specifically, this higher proportion could be highlighted in terms of water use, fossil and mineral resource use, and contribution to ionising radiation and freshwater eutrophication (Figure 27).

Figure 27. Contribution of different building types to the housing impact in Spain for the 16 impact categories analysed (2018).



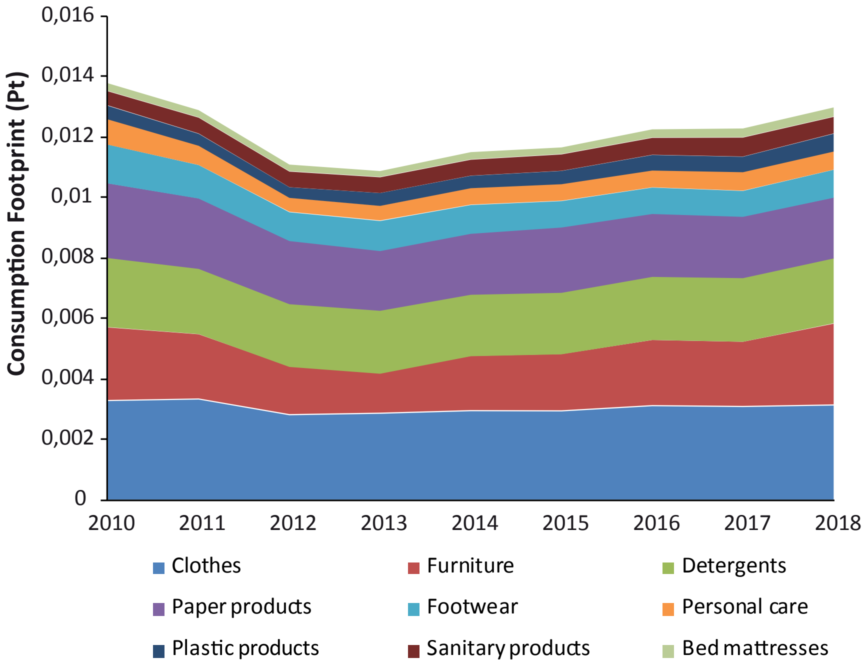
Household goods

The area of consumption referring to household goods is based on a selection of the 30 most representative products according to household consumption statistics (clothing, footwear, furniture, paper, hygiene products, detergents, etc.). The distribution of the Consumption Footprint in terms of the weighted index for the different types of household products (aggregated according to 8 relevant categories) is as shown in Figure 28 below.

Figure 28 shows us that the categories of household goods with the greatest weight on the Consumption Footprint are clothing and furniture, followed by detergents and paper products. Looking at further disaggregation, the top three household products in 2018 are T-shirts, laundry detergents and bedroom furniture. For the previous years, products such as toilet paper, newsprint and books also assume significant weight. It is worth underlining that these contributions are due, on the one hand, to the relevant quantity of products consumed, primarily paper products and clothing, and secondly, to the high impacts per product unit, especially in the case of furniture and detergents. In this sense, the reduction of the impacts of this area of consumption must include a reduction in the use of more common products, but also an improvement in production processes (Castellani et al., 2021).

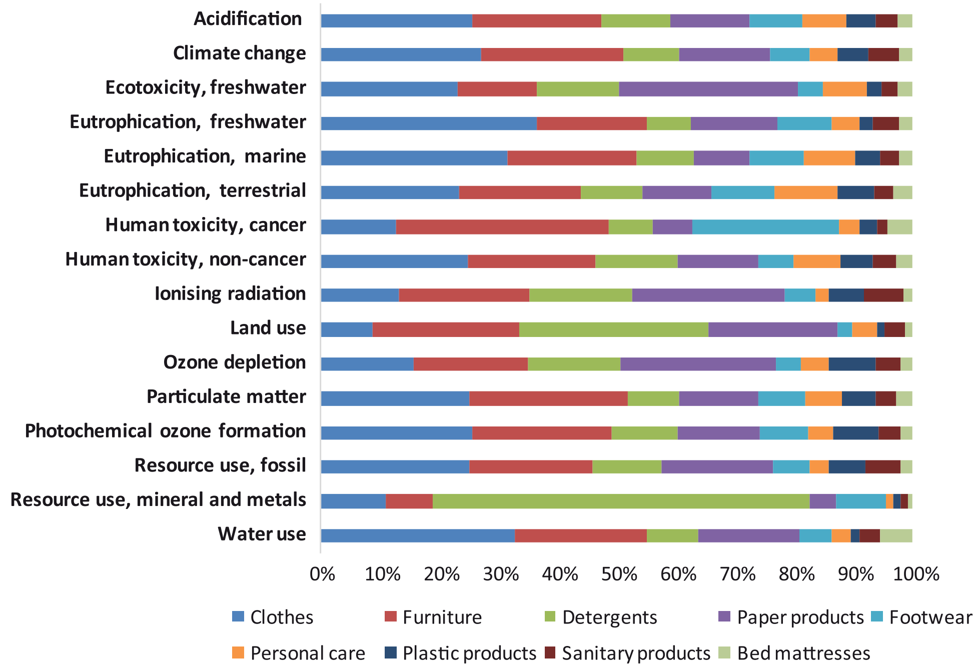
In relation to the main impacts, the contribution of clothing (especially

Figure 28. Consumption Footprint in Spain by type of household products, weighted index (2010-2018).



in the production phase, due to the transformation of raw fibres into textiles, colouring, etc.) to marine and terrestrial eutrophication, water use and climate change is of particular importance. Footwear, as well as furniture, has a relevant impact in terms of human cancer toxicity, mainly due to the leather tanning process that contributes chromium to water discharges (Castellani et al., 2019). Paper products contribute significantly to freshwater ecotoxicity, ozone depletion and ionising radiation, while detergents stand out in terms of metal and mineral use, as well as land use (Figure 29).

Figure 29. Contribution of different products to the impact of household goods in Spain for the 16 environmental impact categories analysed (2018).



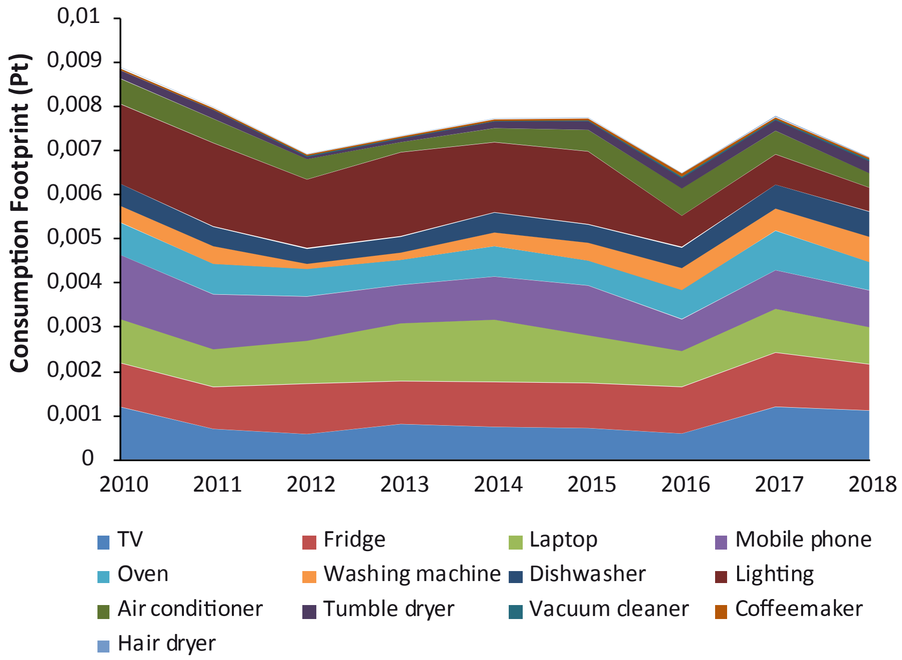
Household appliances

Finally, as far as appliances are concerned, a basket of products is considered, representing the most important appliances in terms of energy consumption and market share in the EU, which have multiple functions, from lighting to washing, storage, cooking, entertainment, etc.

An important aspect to consider in the analysis of the Consumption Footprint of the different types of appliances is that for the computation of the impacts it is also necessary to compute those that already exist in the household, given that the vast majority of the selected appliances have a useful life of more than one year and this affects the apparent annual consumption. In addition, all appliances consume energy during their lifetime. Consequently, considering only apparent consumption would not capture the real environmental impacts due to the annual purchase and use of appliances.

Figure 30 shows the composition of the Consumption Footprint (weighted index) for the period analysed (2010-2018) in terms of the different appliance groups and shows that the largest contribution is mainly made by electronic devices such as TVs, mobile phones and laptops on the one hand, and kitchen appliances such as fridges, ovens and washing machines on the other.

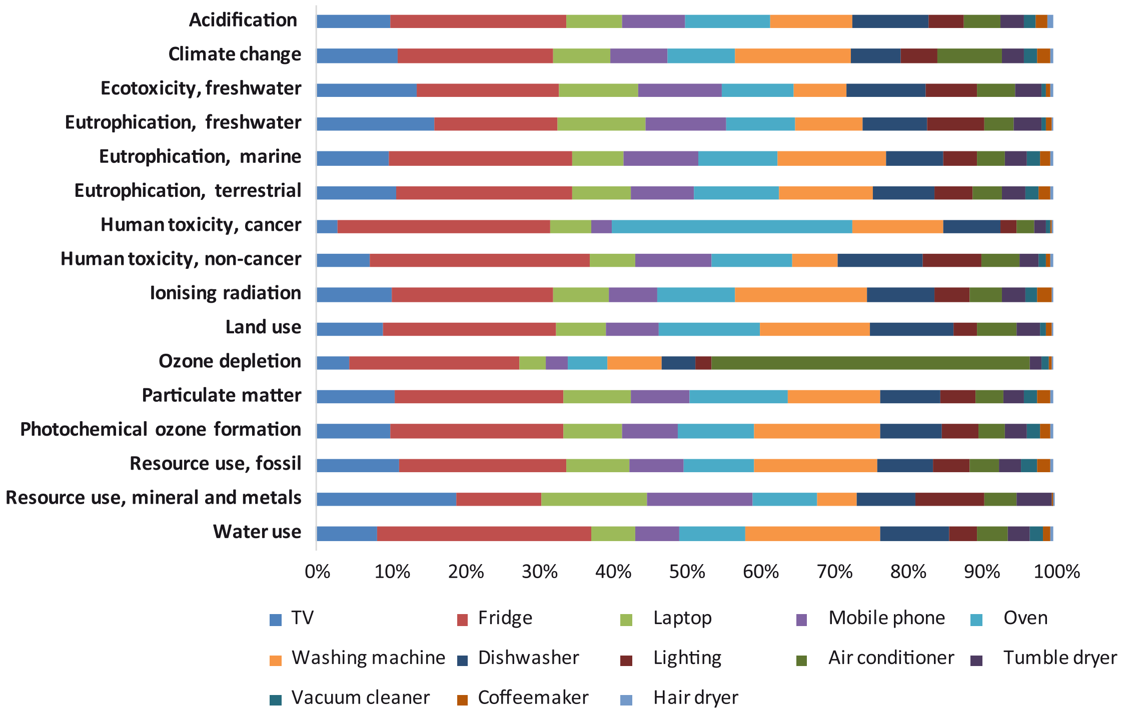
Figure 30. Consumption Footprint in Spain by type of appliances, weighted index (2010-2018).



Turning to the breakdown by product, we see that, in 2018, for the weighted index, televisions have a contribution of 16.3%, refrigerators 15.2%, laptops 12.3%, mobile phones 12.1% and ovens 9.4% of the Consumption Footprint per capita associated with appliances. The reduced impact of the lighting group is mostly due to lower consumption of fluorescent, incandescent and LED lamps. In relation to the 16 specific impact categories, each appliance group contributes differently according to the impact category (Figure 31).

The refrigerator has the largest contribution in virtually all impact categories, with the exception of the impact in terms of ozone layer depletion, where air conditioning is the main contributor, and human carcinogenic toxicity, where the oven plays a major role. Also in terms of mineral and metal use, the biggest impact comes from televisions, followed by laptops and mobile phones due to the significant requirements for metals (some considered "critical") used in their components (Arushanyan et al., 2014; WEF, 2019).

Figure 31. Contribution of the different appliance groups to the impact of the appliances consumption area in Spain for the 16 impact categories assessed (2018).



2.5. How can we reduce our Consumption Footprint? Comparison of different patterns and lifestyles in Spain

Different lifestyles in our country may differ significantly from the national average Consumption Footprint per capita, resulting in different types of environmental impacts of varying intensity. In order to better assess environmental hotspots and possible areas for improvement, it is useful to visualise different profiles with different consumption patterns and lifestyles (Sala & Sanyé Mengual, 2022; Sala et al., 2019). As well as being valuable in itself for benchmarking and comparison, this offers the country's citizens the possibility of identifying the most impactful activities in their own consumption patterns. For the latter, the Joint Research Centre has at its disposal an openly available and free online tool which enables citizens across the EU to calculate the environmental impacts linked to their own lifestyles and consumption patterns.

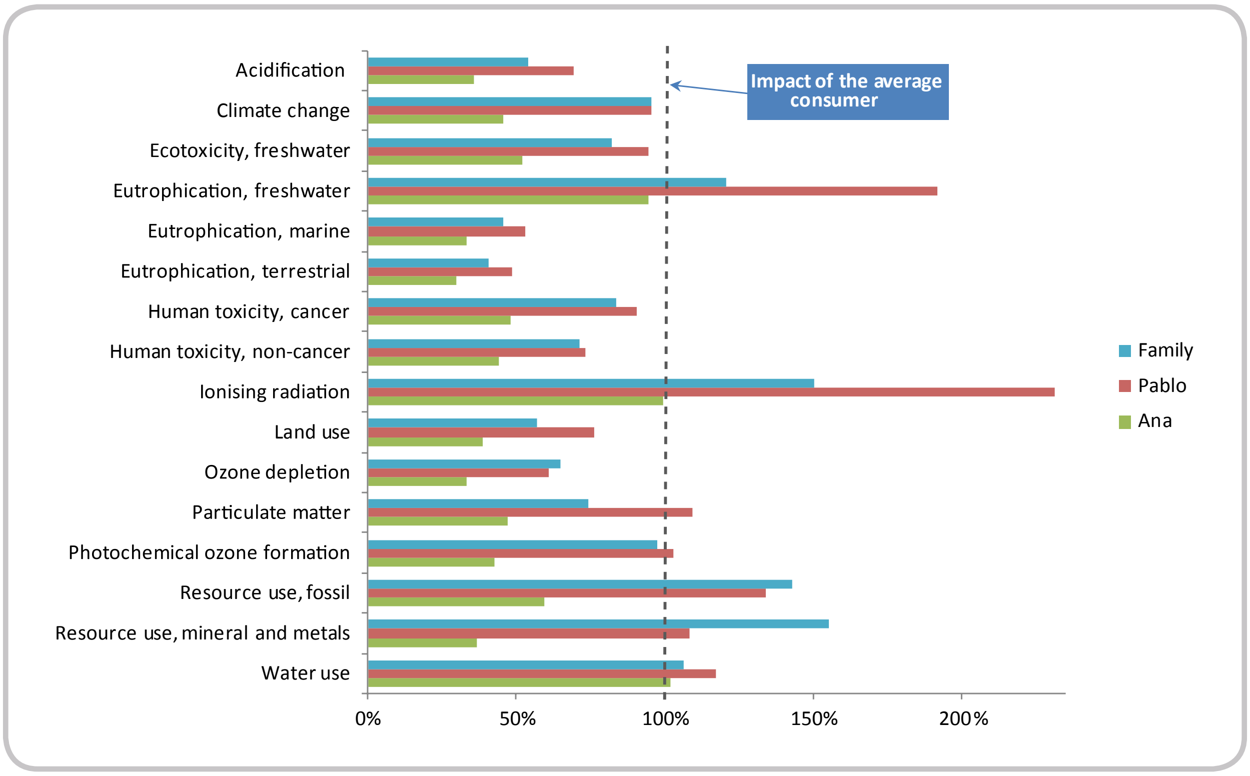
Figure 32 below shows three different consumer profiles devised from three specific lifestyles with different consumption patterns: a single woman, a single man and a family of three (Sala et al., 2019).

Figure 32. Description of three specific consumer profiles (Adapted from Sala et al., 2019).

	Ana (23 años)	Pablo (25 años)	María (32 años), Javier (35) y Alba (7)
	Vegetarian	Semi-vegetarian (non-vegetarian options only when eating outside)	Mediterranean diet
	Public transport/bike to go to the university. Trains to travel to nearby cities occasionally planes to go to other EU countries	Uses a gasoline car to go to work (15 Km). Trains to travel to nearby cities, often planes to go to distant places for vacations	María uses her diesel car to take Alba to school every day; Javier travels a lot for work in his LPG car
	Shared flat with 2 friends	Lives alone in a flat, in the city perifery	They live in an independent house with a garden in a village
	Shared dishwasher, washing machine, and dryer with 2 flat-mates	Shares the use of various appliances with six other neighbors	They have their own appliances and air conditioning

As can be seen in Figure 33, there are significant differences between the three defined consumer profiles with respect to the 16 environmental impacts assessed. Significant differences can also be observed between these three profiles and the impacts of the average consumer in Spain, corresponding to the national Consumption Footprint per capita and represented in the figure by the vertical dashed line.

Figure 33. Impacts of the three specific consumer profiles compared to the average consumer in Spain (set at 100%) (2018). "Family" results are expressed per person.



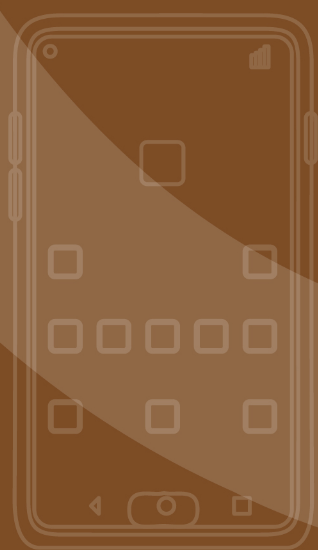
As expected, the three-person household has the highest environmental impact in absolute terms in all the impact categories assessed. However, when household impacts are calculated on a per capita basis (as shown in Figure 33), Pablo is the profile that shows the highest environmental impacts for almost all categories considered. For her part, Ana has the lowest environmental impact of the selected profiles in all the impact categories assessed, showing values below the national average in almost all of them. So it could be said that Ana adopts a series of environmentally friendly behaviours in her daily life in the different areas of consumption considered, such as using public transport and bicycles, avoiding the consumption of meat, and sharing housing and the use of appliances with her flatmates.

When assessing the environmental impacts of the different consumption patterns in Spain, it is important to bear in mind the area of consumption considered. Thus, the positive effects of adopting low-impact behaviour in a given consumption area may be offset to varying degrees by impacts associated with other consumption areas. This is the case, for example, of the impact on climate change generated by Pablo. His decision to be semi-vegetarian resulted in a reduction of the impact of Food compared to the average However, the fact that he is living alone and has to drive every weekday at least 30 km by car increases his impact in the areas of consumption Housing and Mobility, partially offsetting the positive effect of being semi-vegetarian

The analysis of consumers' profiles reveals the need to adopt a comprehensive perspective, including all the areas of consumption, when assessing the impacts of consumption patterns.

3

Sustainability of Consumption in Spain



3.1. The Sustainable Development Goals framework and its relationship with the environmental impacts of consumption

Current production and consumption patterns characteristic of developed countries demand large amounts of materials and energy from the planet's ecosystems (Wiedenhofer et al., 2020). This fact, fostered by the constant drive for economic growth, is driving unprecedented environmental degradation around the world that threatens to compromise the future prosperity of much of humanity (Moranta et al., 2021; Wiedenhofer et al. 2021).

In this context, the consumption of goods and services represents, as we have seen, one of the main causes of environmental degradation that most distances Spain from sustainability. The assessment of the environmental impacts linked to consumption is therefore a crucial step towards Spain's achievement of the Sustainable Development Goals (SDGs) defined by the United Nations in the 2030 Agenda (UN, 2015). Among the 17 major global commitments represented by the SDGs, one, SDG 12 ("Ensure sustainable consumption and production patterns"), has a particularly strong and important link to this project. Moving towards new patterns of production and consumption that are centred on healthier and more sustainable lifestyles will be crucial to reducing, over the coming years, the demands that our economic system places on the planet's ecosystems, as well as to reduce the resulting environmental degradation.

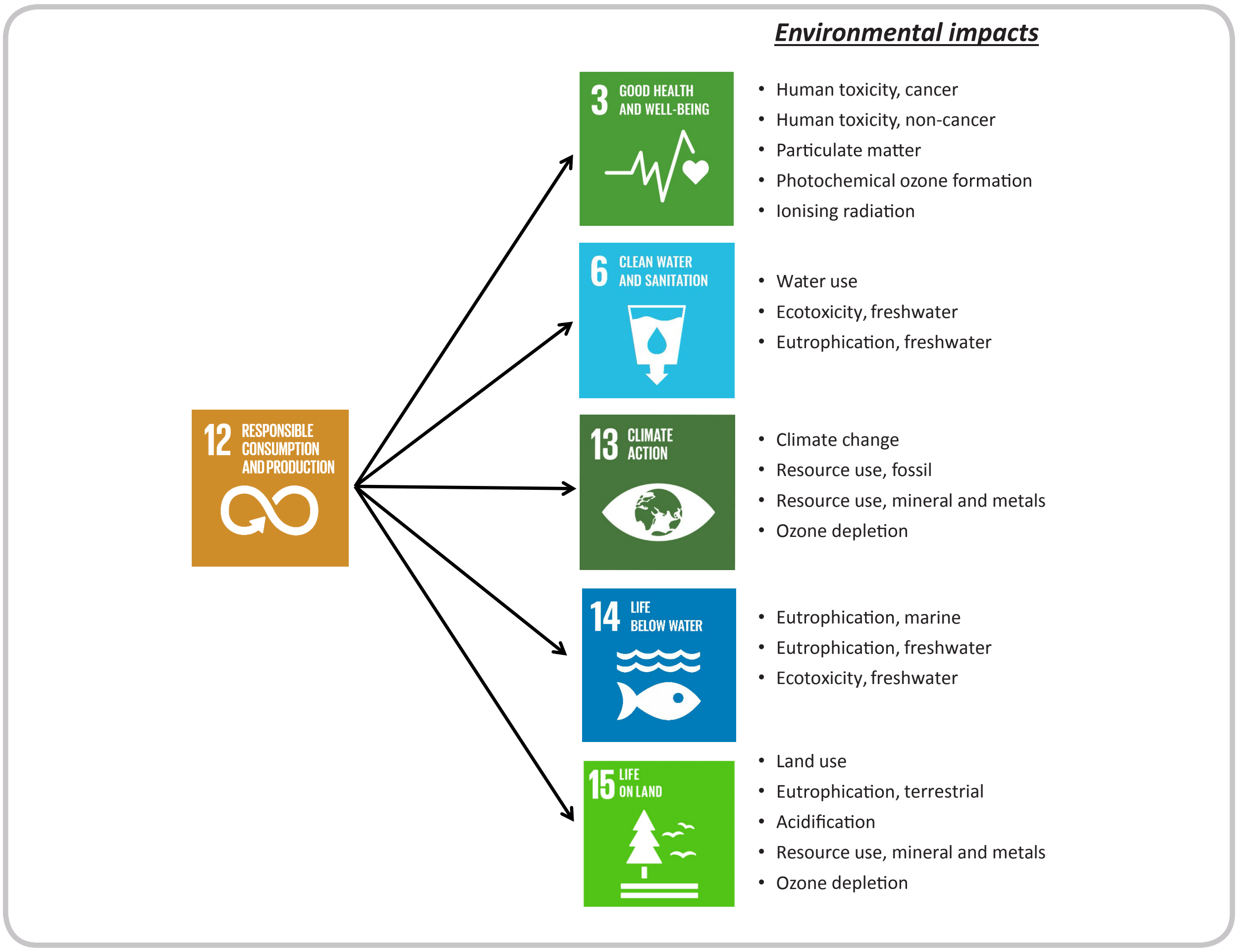
The Spanish Consumption Footprint, detailed and assessed in section 2 of this report, could therefore be used to monitor the progress or setbacks that Spain achieves with regard to the sustainable consumption in Spain and more specifically with regard to the fulfilment of SDG 12. In addition, the 16 environmental impact categories that have been assessed for the Consumption Footprint are directly linked to other SDGs whose progress will depend on the changes Spain manages to make in its production and consumption patterns. This is the case of SDG 3 ("Ensure healthy lives and promote well-being for all at all ages"), SDG 6 ("Ensure access to water and sanitation for all"), SDG 13 ("Take urgent action to combat climate change and its impacts"), SDG 14 ("Conserve and sustainably use the oceans, seas and marine resources") and SDG 15 ("Sustainably manage forests, combat desertification, halt and reverse land degradation, halt biodiversity loss") (Figure 34).

It should be noted, however, that the relationships shown in Figure 34 are only an illustrative approximation of the most obvious and important connections between SDG 12 and the other Sustainable Development Goals, and that much more could be done to explore the potential direct and indirect trade-offs and synergies between SDG 12 and the other goals and targets of the 2030 Agenda.

Based on the associations established in Figure 34 between the environmental impacts of consumption and SDGs 3, 6, 13, 14 and 15, Figure 35 shows the contribution of each of these five SDGs to SDG 12, in terms of the weighted index of Spain's Consumption Footprint.

Reducing the use of resources, environmental degradation and pollution throughout the life cycle of the goods and services consumed by Spain, while increasing the quality of life of people and improving the overall health of the planet, must undoubtedly be the horizon towards which Spain must move in the coming years in accordance with the 2030 Agenda.

Figure 34. Links between SDG 12, SDGs 3, 6, 13, 14 and 15, and the environmental impacts assessed in the Consumption Footprint. (adapted from EC-JRC (2022) *Consumption Footprint Platform*).

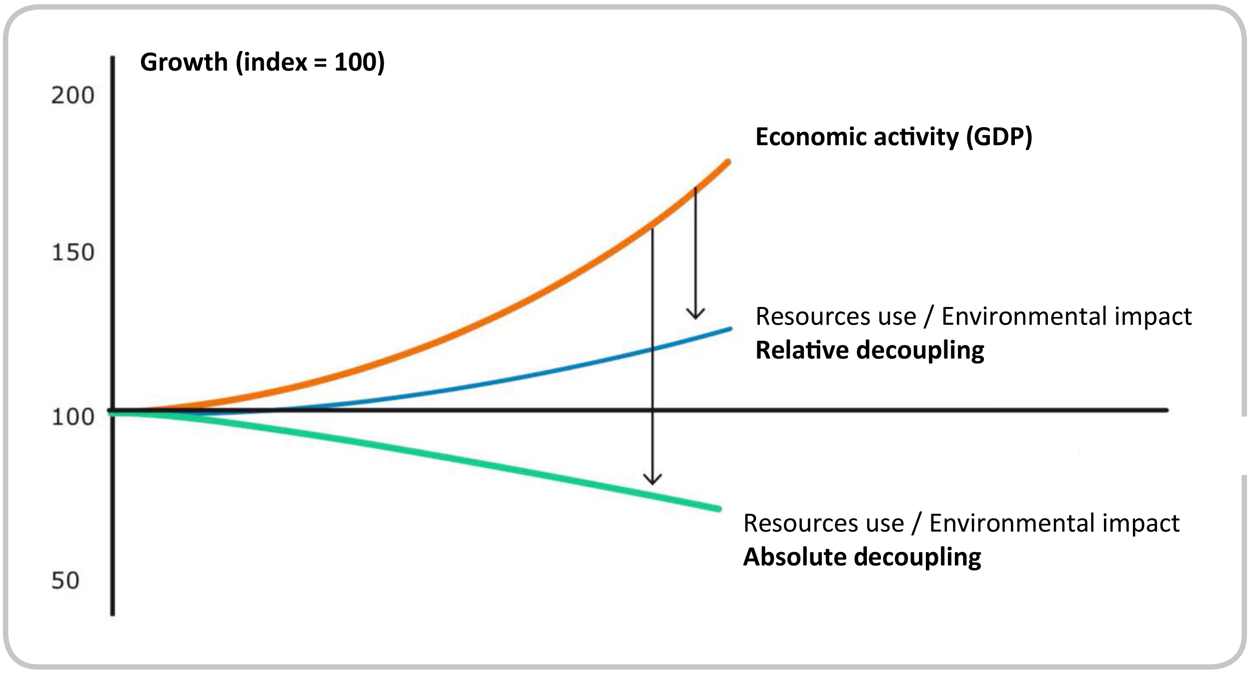


3.2. Assessment of economic-environmental decoupling in Spain: Why is a consumption based approach key?

The assessment of the environmental impacts of consumption carried out in this report provides, among other things, useful information for monitoring the State's efforts to decouple economic growth (target 8.4 of SDG 8) from the environmental impacts linked to Spain's consumption patterns (SDG 12).

Decoupling" refers to a situation in which the economic growth of any country or region is decoupled from the material and energy requirements of its economic model, as well as from the environmental impacts associated with the corresponding production and consumption patterns. The necessary condition, therefore, for an *economic-environmental decoupling* to occur in any country is that its GDP increases at the same time as the environmental impacts linked to its consumption patterns decline (absolute decoupling), or that these impacts grow but at a slower rate than the increase in GDP (relative decoupling) (Haberl et al., 2020) (Figure 35).

Figure 35. Relative and absolute decoupling of economic growth.



Through the concept of decoupling, the aim is to provide a response - especially in the context of higher income countries - to the current climate and ecological emergencies by trying to reconcile economic growth with environmental sustainability indefinitely. Through proposals like the circular economy, sustainable or green growth, and through initiatives such as the *Green New Deal* or the European Green Deal, the most powerful nations claim to be achieving the progressive dematerialisation and decarbonisation of their economies. All of these proposals and initiatives start, however, from a somewhat problematic premise insofar as they attempt to solve the climate and environmental crisis under a single package of measures (energy efficiency, renewable energies, waste reduction, recycling of materials or digitalisation) while at the same time indefinitely activating the growth of economic and financial activity, without considering the limitations implied by something as obvious as the finite nature of the planet (Dhara & Singh, 2021). As we will see below (for the specific case of Spain), considering the whole range of environmental impacts linked to consumption that operate both within and outside national borders, it is not possible to sustain the existence of an absolute economic-environmental decoupling.

Thus, what many high-consumption countries have recognised how decoupling is, in reality, a kind of "apparent decoupling" based on an externalisation of their environmental impacts towards lower-consumption countries made possible by the international market (Parrique et al., 2019). Important studies along similar lines include those developed by Wiedmann et al. (2015) argue that as a country's wealth grows, it tends to reduce its domestic extraction of materials (and associated environmental impacts), using foreign investment and international trade as levers.

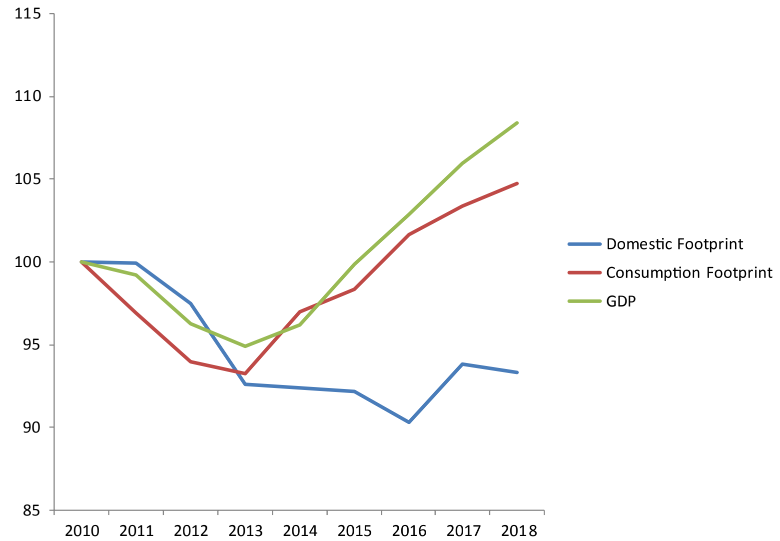
In the Spanish case, as seen in section 2.1, between 2010 and 2018 the Domestic Footprint decreased for most of the environmental impacts assessed (Figure 7). Meanwhile, during these same years, Spain's GDP grew by +8.4%, according to Eurostat data (in constant euros). These results highlight the existence of an absolute decoupling for this period between Spanish economic growth and several environmental impact indicators measured at national level. What this indicates is that most of the environmental impacts resulting from consumption in Spain (namely 12 of the 16 impacts assessed) (see Figure 7) declined within national boundaries for the impact categories assessed, while economic activity grew. However, this interpretation of decoupling is incomplete, as it leaves out of the equation the environmental burdens that, despite being linked to Spain's consumption patterns, exert their impact outside the national territory through foreign trade.

This geographical perspective is essential when assessing the decoupling of any country or region. The global expansion of production and international trade has led to a spatial dissociation between the sites of extraction, production and consumption that makes it difficult to determine who is ultimately responsible for what impacts. In this context, holistic approaches using consumption indicators that incorporate all environmental impacts associated with the goods and services consumed (production, life cycle stages, marketing, etc.) are best used, thus geographically reallocating such impacts to final consumers and thereby correctly reflecting the underlying responsibilities taking into account global value chains and international trade (Haberl et al., 2020; Parrique et al., 2019; Wiedmann et al., 2015). Tools such as the Life Cycle Analysis of products or regional *input-output* analyses thus make it possible to make the transfer of environmental impacts visible on the basis of the rules of economic power and political hierarchies at the international level (Naredo, 2006).

The Consumption Footprint indicator does, however, provide a complete overview of the environmental impacts linked to consumption with the incorporation of those impacts related to international trade, making it more appropriate as an indicator to correctly assess the possible decoupling between economic growth and environmental impacts associated with consumption patterns (Sanyé-Mengual et al., 2019).

As it can be seen in Figure 36, the temporal variation of Spanish economic growth measured through GDP fits much better with the evolution of the weighted index of the Spanish Consumption Footprint (with no absolute decoupling between both variables) than with that of the Domestic Footprint (where there is an absolute decoupling with GDP, especially visible for the last five years of the time series). The correlation between GDP and the Consumption Footprint ($R^2 = 0.92$; $p < 0.001$), as well as the absence of correlation between GDP and the Domestic Footprint (R2 = -0.225; $p > 0.05$) are good evidence of this, proving the inexistence, in general terms, of an absolute decoupling in Spain between GDP and the environmental consequences of the consumption patterns of its citizens.

Figure 36. Spain's Domestic Footprint and Consumption Footprint, weighted indices (2010-2018), compared to GDP.



The slight relative decoupling that has occurred mainly since 2016 between GDP and the Consumption Footprint (Figure 37) shows, after all, an improvement in efficiency that, in practice, translates into a decrease in the environmental impacts per unit of GDP of the Spanish economic model. It is important to note, however, that this brief, slight improvement in efficiency is far from being "sufficient", since, as we will see in the next section, environmental pressures linked to Spain's consumption are not only showing a general growth trend but are also exceeding many of the safety limits for humanity on a planetary scale.

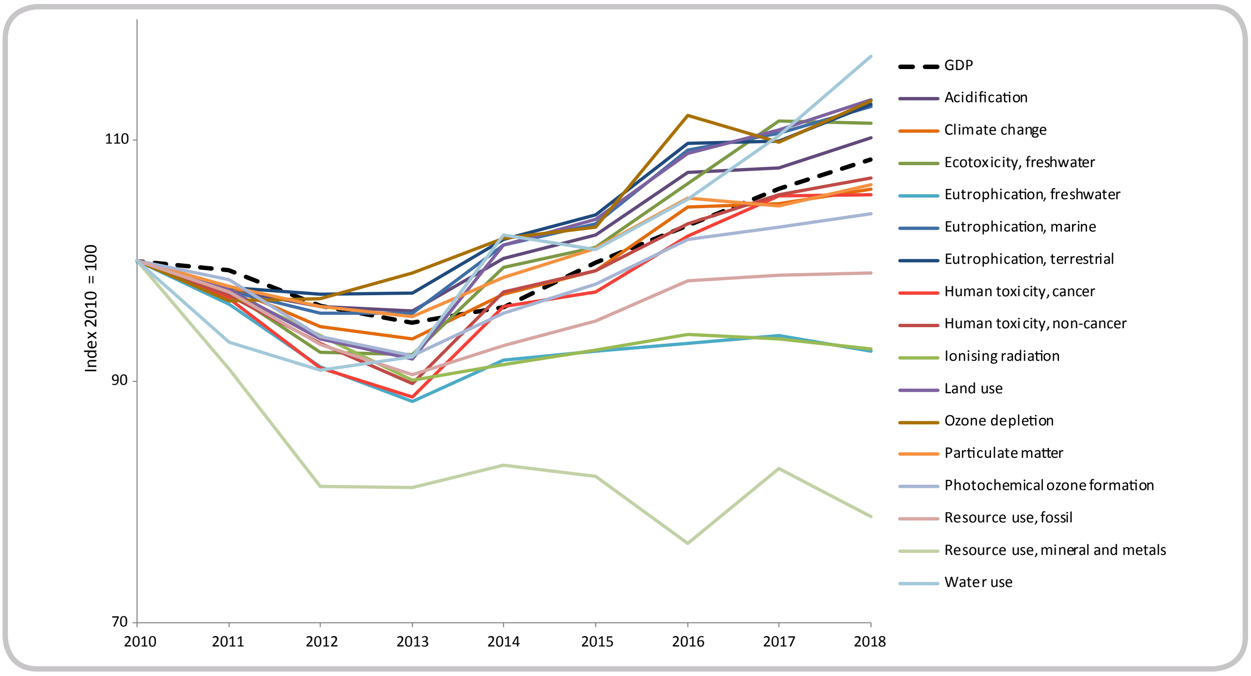
Nevertheless, it is worth noting that the overall coupling shown in Spain between GDP (+8.4%) and the Consumption Footprint (+4.8%) between 2010 and 2018 (Figure 36) is significantly higher than that showed by the EU-28 as a whole for the same period, where GDP grew by +12.9% while the Consumption Footprint only grew +3.9%.

Of the 16 environmental impacts assessed in the Consumption Footprint, 12 showed highly significant correlations with GDP, thus demonstrating the existence of a strong coupling between Spanish economic growth and such impacts resulting from the consumption patterns of Spanish society during the period 2010-2018 (Figure 37). The 12 environmental impacts that correlated significantly with national GDP were: climate change, photochemical ozone formation, human toxicity (both carcinogenic and non-carcinogenic), particulate matter, freshwater ecotoxicity, land use, acidification, marine and terrestrial eutrophication, ozone depletion and fossil resource use (see Annex 2). On the other hand, and as already noted when analysing the components of the consumption footprint (section 2.3), a divergent evolution can be observed between GDP and the footprint associated with the use of minerals and metals, which reflects a pattern of growth that is less linked to the construction sector compared to the previous cycle marked by the Spanish property bubble (Carpintero, 2018).

In short, the analysis presented in this report does not provide sufficient evidence to support the existence of a decoupling in Spain between the economic growth and the environmental impacts linked to consumption patterns (Figures 36 and 37).

These results therefore corroborate and reinforce previous reference works in our country, such as those developed by Carpintero (2015, 2018), which show that, rather than a process of decoupling, what Spain has been experiencing in recent decades has been, rather, a process of *economic re-coupling* where environmental impacts and foreign dependence have been increasing, much in the same way as high-income economies have as a whole (Hickel and Kallis, 2020).

Figure 37. Spain's Consumption Footprint for the 16 environmental impacts assessed and for national GDP (2010-2018).



The fact that certain countries such as Spain have been able to maintain high rates of economic growth without significantly increasing - or even decreasing - the pressure on their own ecosystems (Domestic Footprint) is not so much explained by a decoupling between economic growth and the environmental impacts generated, but rather by a geographical shift of resource sources and waste sinks to third countries (Gómez-Baggethun and De Groot, 2007). The consumption patterns and lifestyles of the Spanish population are therefore sustained at the cost of transferring a large part of the associated environmental impacts beyond its own borders, thereby deteriorating environmental quality, human health and the ecological integrity of other regions of the planet.

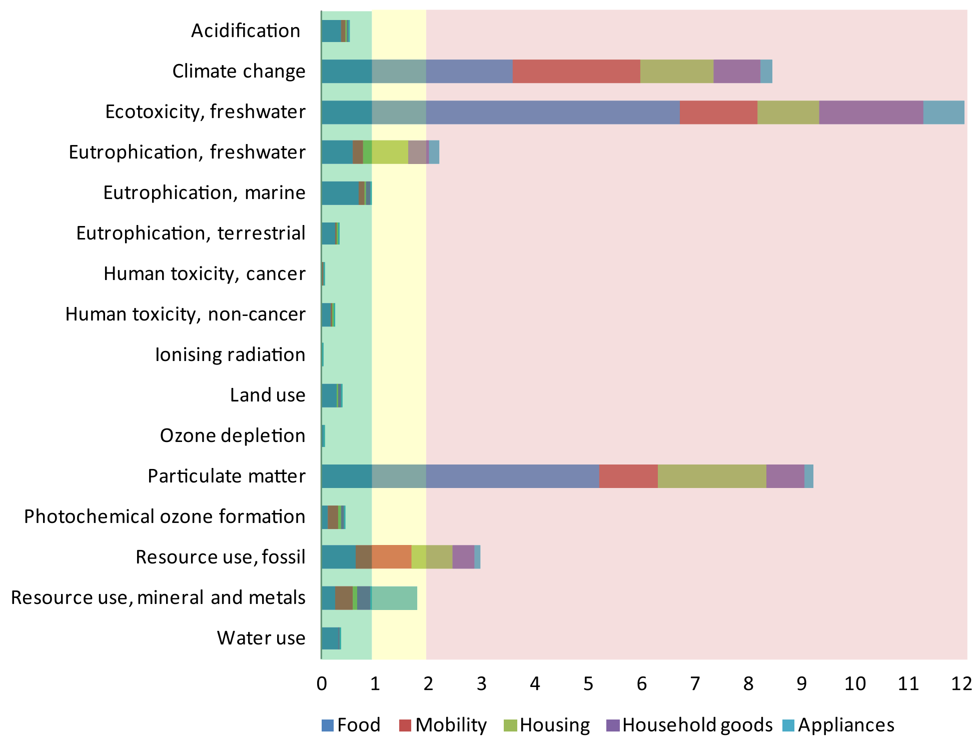
3.3. Is Spain's consumption environmentally sustainable? Is it operating within planetary boundaries?

One of the biggest challenges in assessing the sustainability of consumption is the definition of benchmarks that allow nations to quantify the environmental performance of their production and consumption systems relative to the Earth's carrying capacity in absolute terms (Sala et al., 2020). With the aim of moving towards the purpose of "living well within planetary boundaries" (EPC, 2013; O'Neill et al., 2018; Fanning et al., 2021), this section links the environmental impacts of Spain's consumption with the notion of planetary boundaries (Rockström et al., 2009; Steffen et al., 2015). Making a quantitative estimate of the environmental impacts of consumption in our country in relation to the capacity of the biosphere to sustain the main biophysical processes that support life on Earth is extremely useful in determining whether or not our consumption patterns are environmentally sustainable. This way, the conceptual framework of planetary boundaries is essential to support the formulation of public policies focused on sustainability (Sala et al., 2020).

Figure 38 shows the Consumption Footprint per capita values for Spain for the 16 environmental impacts studied, broken down into the five major consumption areas defined.

The green vertical line represents the *boundary of the safe operating space for humanity*, while the red line represents the boundary at which environmental impacts enter the *high-risk* zone (between the two lines is a *critical zone of uncertainty* , shown in yellow). As shown in the figure, of the 16 environmental impacts assessed, six have already exceeded safe planetary boundaries, with one of them in the *critical zone* (the use of mineral resources and metals), and the remaining five in the *high risk zone* (climate change, freshwater ecotoxicity, freshwater eutrophication, particulate matter, and the use of fossil resources).

Figure 38. Environmental impact of Spain's per capita consumption for the 16 impacts assessed and the five consumption areas compared to planetary boundaries (2018). The background colours reflect the status of the planetary boundary for each impact category: green = below the LP; yellow = within the uncertainty zone of the LP; red = in the high-risk zone.



If these data are compared at scale with those shown for the EU-28 as a whole (also in per capita terms), some areas of consumption and environmental impacts of Spain's Consumption Footprint can be identified that would require special policy focus in Spain in order to shift towards more sustainable horizons. This would be the case, for example, of human toxicity impacts (both carcinogenic and non-carcinogenic) linked to the consumption of appliances, which in Spain is around 30% higher than in the EU-28 as a whole. Another notable case is that of terrestrial and marine eutrophication linked to mobility, which is 17-18% higher for the average Spanish citizen than for the average European citizen. But the most striking differences are undoubtedly to be found in the impacts associated with food consumption in Spain, where three environmental impacts exceed the EU-28 average by more than 50%. These are photochemical ozone formation (+51.2%), water use (+55.1%) and freshwater eutrophication (+55.8%).

However, overall, the total environmental impacts of consumption per capita in Spain and the EU-28 for the 16 environmental impact indicators assessed against the planetary boundaries showed relatively similar situations for all impacts in 2018. Moreover, the environmental impacts that have exceeded the planetary boundaries are the same for Spain and the EU-28: the use of mineral resources and metals (in the uncertainty zone), freshwater eutrophication, the use of fossil resources, climate change, particulate matter, and freshwater ecotoxicity (in the high risk zone).

3.4. Towards more sustainable scenarios: to what extent could technological innovation and behavioural changes reduce the Consumption Footprint? The case of food and appliances.

The results of the Consumption Footprint assessment presented in the previous sections provide a picture of the impacts generated by household consumption in Spain for the available time horizon. A more detailed analysis of the hotspots, carried out at both area and product level, has identified the main impacts in relation to the five main consumption dimensions analysed (housing, mobility, food, appliances and household goods). In this sense, and based on these results, several actions could be identified to reduce the impact of household consumption, which in turn have a similar effect on the Spanish Consumption Footprint.

Designing eco-innovation scenarios and identifying more responsible and sustainable consumer behaviour with respect to the context observed in a reference year, allows us to assess the potential benefits of a transition in line with the changes proposed, as well as to identify the scale of the changes needed in the transition towards improved sustainability scenarios.

In order to select the scenarios for each area and/or type of product, it is advisable to take into account the most relevant critical points identified in the analysis of the Consumption Footprint. For example, in the case of food, the priority would be scenarios that take into account nutrient recovery, which in turn is expected to reduce impacts on eutrophication and human toxicity. In the same vein, it would also be desirable to prioritise scenarios capable of simulating the effect of EU policies (e.g. in terms of the scope of circular economy or eco-efficiency strategies), or scenarios related to innovations that are currently present in a limited way in the market but are expected to be relevant for consumer areas in the future (e.g. the increasing market presence of electric vehicles in the mobility sector).

A scenario analysis using Life Cycle Analysis can also help to identify the advantages and disadvantages associated with some technologies (e.g. reduction of direct use of fossil resources combined with additional use of mineral resources for solar and wind energy development). Thus, another important element to consider when talking about scenarios is the potential rebound effect that can occur when there is an association between certain technological improvements, such as improvements in the energy efficiency of appliances, and increases in consumption intensity (as is the case, in particular, in areas such as mobility and the use of appliances) (Hickel and Kallis, 2020; Haberl et al., 2020).

Finally, the scenarios show the environmental effects of the improvement actions analysed. Under real conditions, other aspects (especially the economic dimension) must also be considered in the decision-making process (Sala et.al., 2019).

The following paragraphs present the results of the scenario analysis for the case of food, in terms of improved impacts from behavioural changes and reduction of meat consumed in the diet, and for appliances, in terms of reduced impacts from the use of more energy-efficient services, as well as changes in user behaviour.

Dietary Modification Scenarios

In section 2.4, the analysis carried out determined that meat and dairy products are responsible for a relevant part of the environmental impacts (e.g. climate change, eutrophication, non-carcinogenic human toxicity, etc.). In this sense, the following scenario for Spain aims to assess the effect, in terms of environmental impacts, of a shift towards diets with lower meat and dairy content compared to the current one.
All stages of the life cycle of meat and dairy products and their impact on all products in the food basket are considered in the design of the scenarios.

Table 1 presents two scenarios for dietary changes and compares them with the situation in 2018 at the national scale. The scenarios are designed according to the dietary changes described in Westhoek et al. (2014), based on the IMPRO study on the environmental impacts of dietary changes (Tukker et al., 2009). These dietary changes consist of a 25% to 50% reduction in the consumption of beef, dairy, pork, poultry and poultry products, which is compensated by an increased intake of cereals, legumes and eggs. Wine and pasta were not considered in this scenario.

Table 1. Modified parameters for the dietary change scenario.

Product groups	Representative products	Scenario 1: - 25%	Scenario 2: - 50%
Meat	Beef, pork, chicken	-25%	-50%
Legume-based products	Tofu, soy beverage	+25%	+50%
Dairy products	Milk, butter, cheese	-25%	-50%
Cereal-based products	Rice, Bread, Quinoa	+25%	+50%
Meat preparations	Meat-based products	-25%	-50%
Legumes	Beans, chickpeas, lentils	+25%	+50%
Eggs	Eggs	+25%	+50%

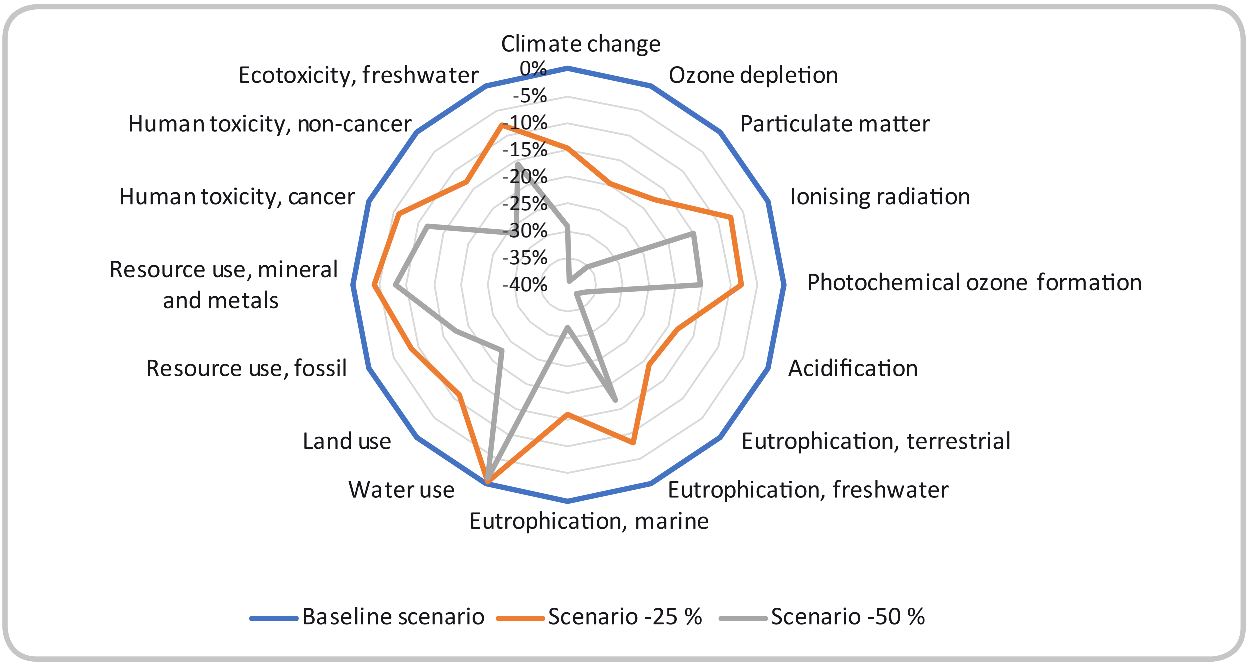
It should be noted that the scenarios designed are not intended as a suggestion for a balanced diet, but only as an example of a diet with reduced amounts of meat. In fact, the comparison of dietary scenarios is not straightforward, and must also take into account nutritional needs and a balanced composition in terms of nutrients and food types.

The results presented in Figure 39 show that partial replacement of meat and dairy with other cereal-based foods, pulses and eggs can reduce the impact generated in all impact categories, with reductions of close to 40% for ozone depletion, acidification and terrestrial eutrophication (-50% scenario). This result is not surprising, due to the assumptions made in designing the scenario.

Although the improvements in impacts are relevant, it is important to comment that further analysis of the willingness to change their diet of all consumers at country level would be necessary, especially in relation to dietary choices that can be considered valid from a nutritional content perspective. In this respect, there are several factors that may influence people's choices to change their purchasing habits in relation to food patterns such as price concerns, food purchasing habits, access to and personal benefit from certain products, the availability of clear and accessible nutritional information, etc. (Gephart et. al. Al., 2016).

At a more policy level, concerns about health issues related to nutrition, overweight and obesity, animal welfare, pollution levels, etc. should help design specific actions to ensure that all consumers have access to sufficient, healthy, nutritious and affordable food at all times, while reducing the burden of diet-related diseases, including obesity, by promoting healthier diets and providing food with a lower environmental impact (Castellani et al., 2017).

Figure 39. Implementation of dietary change scenarios. Results are expressed as % change compared to the baseline diet (for 2018, set at 0).



Eco-innovation scenarios in appliances

The scenarios considered in the field of appliances take into account the most relevant critical points identified in relation to the situation in the reference year for this area of consumption (2018), as well as scenarios related to those innovations that currently represent only a small portion in the market but are expected to be relevant for the sector in the medium to long term.

Across the entire life cycle of the products considered, two stages of appliances are considered really significant by the studies (Reale et al., 2019): the "production of materials/components" and "use" stages for all the impact categories examined, as well as "maintenance and repair" for the "ozone depletion" category.

When analysing the contribution of the different product groups, as we saw in section 2.4, the refrigerator, dishwasher, washing machine, and television are identified as more important than the others in terms of the impacts caused. Although in all these product groups the use phase dominates the life-cycle impact, they are undergoing continuous technological development - more or less rapidly - towards lower energy consumption in this phase.

In that regard, the tables below represent three different scenarios of energy efficiency improvement associated with the above-mentioned appliances. In particular:

- Scenario 1:
  dishwasher, washing machine (Table 2);
- Scenario 2:
  refrigerator (Table 3);
- Scenario 3:
  television (Table 4).

Table 2. Efficiency improvement parameters for dishwashers and washing machines.

Stage of the life cycle	Changes		
	Dishwasher Model 1	Dishwasher Model 2	Washing machine
Manufacture of components	0.4 kg of injection moulded polypropylene is added	0.5 kg of injection moulded polypropylene is added	-
Manufacture of the product	-	-	-
Packaging	-	-	-
Distribution and sales	-	-	-
Use phase	Use of 11.3 L of water and 0.66 kWh of electricity per cycle	Use of 10.2 L of water and 0.72 kWh of electricity per cycle	Use of 36.1 L of water, 0.064 L of detergent and 0.4368 kWh of electricity per cycle
Maintenance and repair	-	-	-
End of product life (EOL)	An additional amount of plastic is added to the EOL treatment: 10% incineration, 10% landfill, 80% recycling	An additional amount of plastic is added to the EOL treatment: 10% incineration, 10% landfill, 80% recycling	-

One must consider that in the case of dishwashers and washing machines, an improvement in water efficiency is also considered and, for washing machines specifically, also in the quantity of detergent needed per cycle. To achieve better efficiency, the number of components for dishwashers and refrigerators is increased. For washing machine and televisions, the components are the same as those considered for the reference year (2018, set to 0).

Table 3. Efficiency improvement parameters in refrigerator (with freezer).

Stage of the life cycle	Changes
Manufacture of components	13% of the amount is added to the following entries: - steel, low alloy, without transport and plate rolling - zinc (as a coating element) - aluminium rolling mills, primary ingots and foils - polystyrene, general purpose Add 70% of the quantity of insulation material in the form of polyurethane, rigid form.
Manufacture of the product	-
Packaging	Add 24% to all input data in this dataset (to represent the increase in packaging material required for the larger size of this device). Add additional packaging material POV treatment (same POV treatment as default amount), i.e. add 24% to all entries in the various packaging material POV datasets.
Distribution and sales	Correction of all transport loads (due to new weight of 86.03 kg for the cooling device, including packaging)
Use phase	Correction of energy consumption from 4352 to 1680 kWh (over the lifetime of the device); Transport correction from 18,626 to 21,501 t-km (taking into account the increased weight of the device)
Maintenance and repair	-
End of product life (EOL)	Adding EOL treatment of additional quantities of steel, aluminium, polystyrene and polyurethane (i.e. insulation material) while maintaining the original split between the various EOL treatment options. Correction of energy consumptions in the different EOL treatment options in relation to these modified quantities.

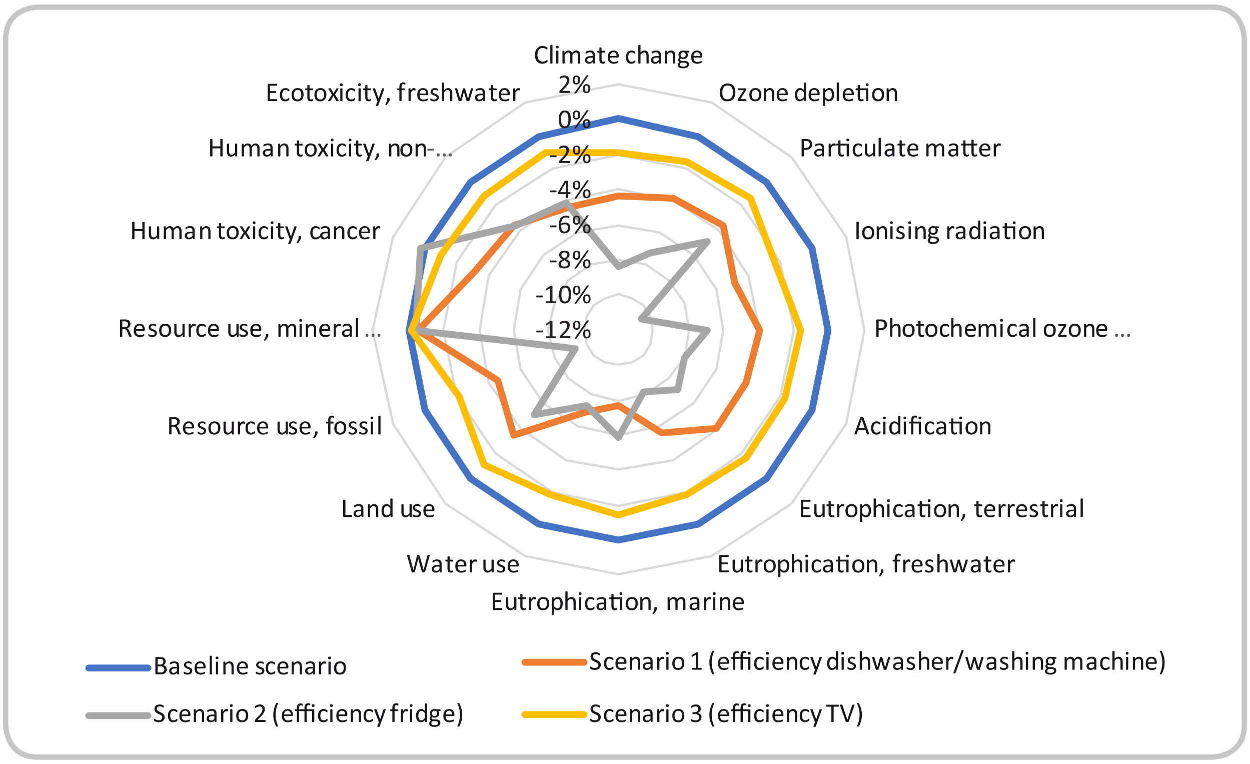
Table 4. Efficiency improvement parameters for television.

Stage of the life cycle	Changes
Manufacture of components	-
Manufacture of the product	-
Packaging	-
Distribution and sales	-
Use phase	Energy consumption goes from 1,161.3 to 392 kWh (for the lifetime of such a device)
Maintenance and repair	-
End of product life (EOL)	-

Figure 40 presents the results of the three scenarios compared to the results of the reference scenario. The data show that the scenario whose impacts show the most significant reduction is scenario 2, referring to refrigerator efficiency improvements, as a large majority of the impacts examined show a reduction between 5% and 8%. There are a few exceptions, such as the use of mineral and metal resources, which shows little change (this is an indicator of mineral and metal resources that varies according to the infrastructure, i.e. the device, and not its level of electricity consumption), or carcinogenic human toxicity, which even shows a positive, albeit minimal, contribution.

A topic of interest within the analyses of changes in user behaviour concerns the area of re-use in a broad sense, i.e. in the form of actual re-use of whole devices or parts of such devices, as well as increased collection and/or recycling rates (to achieve a higher degree of "re-use", at least on a material level). These two aspects are investigated separately here, in scenarios 4a and 4b, respectively.

Figure 40. Implementation of equipment efficiency change scenarios. Results are expressed as % change compared to the baseline profile (for 2018, set to 0).



When talking about reuse (Scenario 4a), one aspect to take into account in this context is the "psychology" of the user in terms of consumption behaviour, i.e. why would a user want to replace an appliance that is in use, or, in other words, what factors might make a user use the existing appliance for a longer time (compared to the average lifetime assumed for the baseline scenario)?

In principle, there are several options and ways of modelling such "re-use" or life extension. The simplest form is chosen here, which means that the average lifetime of the various product groups for which such reuse is taken into account has simply been adjusted to investigate the potential that an extended lifetime would generate compared to the reference scenario. This does not take into account, for example, the fact that energy efficiency is becoming higher in more modern appliances, and the "re-use" of an old device is often made as opposed to the purchase of a new, more efficient device (although this involves new energy and material costs in its manufacture). Additional repair is taken into account in order to have a longer service life (Table 5).

Table 5. Improvement parameters towards greater reuse of devices/parts.

Factor	LV	LD	SC	NE	HE	Notes
1st year of life	12,5	12,5	13,0	15,0	19,0	Data according to reference scenario
2nd life devices (in%)	15%	10%	20%	10%	10%	Survey assumption (taking the number of machines in the population as an indication: the more machines, the lower the % reuse)
2nd year of life	4	4	4,5	5	6	Study assumption (taking about 1/3 of the average first lifetime of a machine)
Average life (years)	13,1	12,9	13,9	15,5	19,6	Calculated, out of the values in the above lines
Repair	x 2	x 2	x 2	x 2	x 2	Compared to the baseline scenario

LV= dishwasher; LD= washing machine; SC=dryer; NE= fridge; HE= electric oven; HE= electric oven

For Scenario 4b, the more psychological user aspects are left aside a priori, i.e. the scenario is mainly based on the end-of-life treatment of appliances, in order to achieve an increasing collection rate of these devices.

Due to the lack of reliable studies on this issue, a uniform collection rate of 90% was finally assumed for all products except lamps, which have been assumed to go 100% to household waste, both in the baseline scenario and in this one. It is assumed that this 90% would represent the upper limit of return that could be expected in an optimal situation.

Finally, Scenario 4c of improvements in component recycling rates can be envisaged, in which improved end-of-life treatment processes for appliances become more significant. According to the analysis of Seyring et al

(2015) on the recovery and reuse of metals and other materials, these elements would have a potential material recovery of up to almost 100%, while plastics, even in an optimal case, do not exceed approximately 85%.
In order to assess the potential for a more efficient recycling process, the material recovery values used in the Seyring et al. study are taken into consideration in order to establish "optimistic" recycling rates for the different fractions distinguished within the reference scenario. In more detail, the following assumptions are used in this study as a starting point for an optimal material recovery scenario (Table 6):

- for the plastics fraction, it is assumed that "high value" plastics (acrylonitrile butadiene styrene, polypropylene and polystyrene) will be recovered at a maximum level (assumed to be 5% above the highest value currently shown for plastics recycling according to Seyring et al. 2015), while for the other fraction of plastics a low recycling rate is assumed (one third compared to high-value plastics). For the remaining parts, energy recovery is assumed to be the main option, while landfilling is only of minor relevance;

- for the metal fractions, an almost complete material recovery is assumed (based on the fact that Seyring et al. 2015 assume a potential of approximately 100%);

- for all other fractions (glass, concrete, mixed materials) it is assumed that the first two will be used mainly for material recovery and the last one for energy recovery, which in all three cases reduces the amount in landfill.

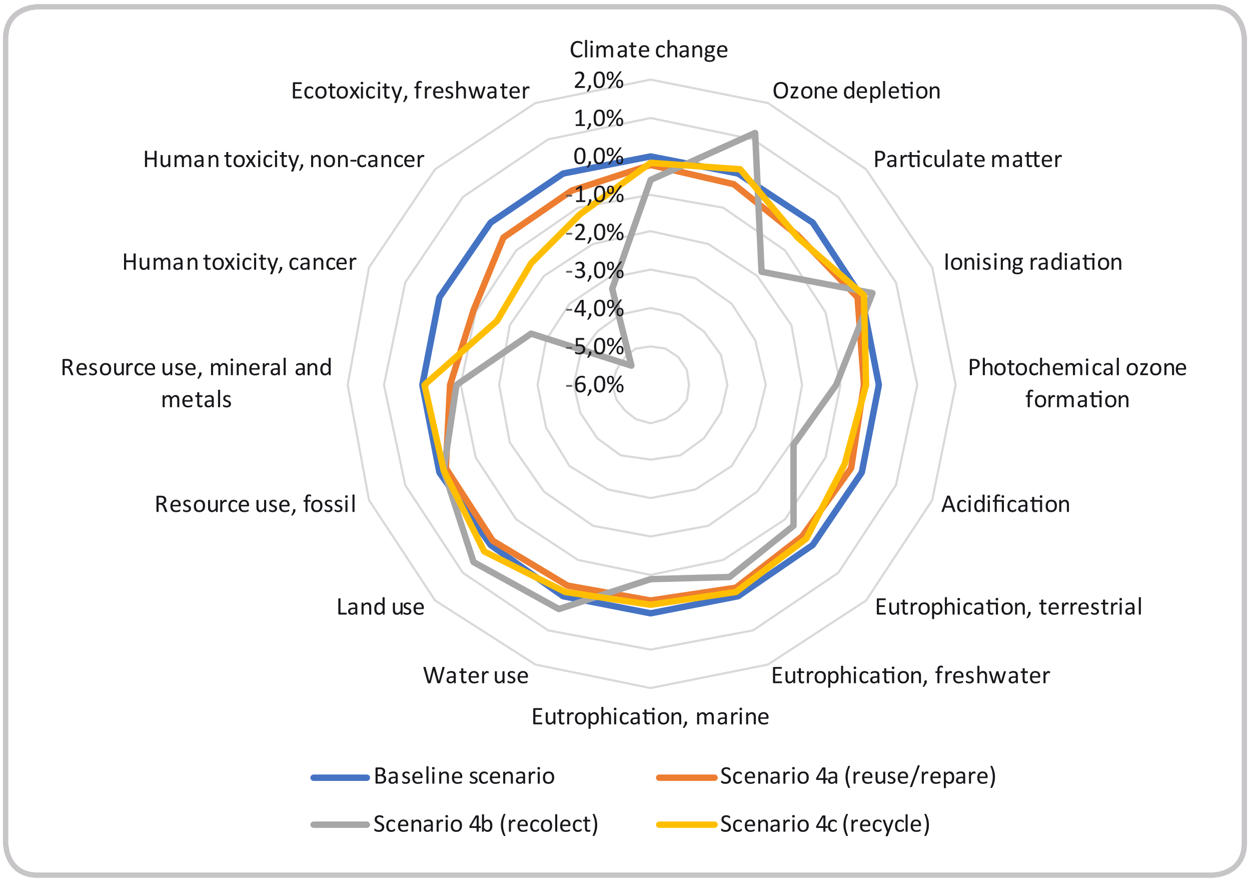
Table 6. Improvement parameters towards increased recycling rates for the various material fractions.

Fractions	Reference scenario			Scenario 4c		
	RM	RE	V	RM	RE	V
High-value plastics	80	10	10	90	10	-
Other plastics	-	50	50	30(*)	60	10
Ferrous metals	95	-	5	98	-	2
Non-ferrous metals	85	-	15	98	-	2
Glass	65	17,5	17,5	90	-	10
Concrete	65	17,5	17,5	90	-	10

RM = material recovery (recycling)/ RE = energy "recovery" / V = landfill; (*) Takes into account the individual types of plastics contained in the respective appliances of the product group.

In Figure 41, the results of the scenarios described above (4a, 4b and 4c) are compared with the results of the reference scenario. The data show that user behaviour in scenario 4a can also lead to a moderate reduction of environmental impacts related to appliances, in particular when they are used for longer periods of time.

Figure 41. Implementation of user behaviour change scenarios. Results are expressed as % change compared to the baseline scenario (set to 0).



Although the reductions in terms of impacts remain minimal for all three scenarios (the reduction of impacts is less than 1% for almost all impact categories), scenario 4b (increased collection of devices) has the most significant contribution for most of them, in particular in terms of freshwater ecotoxicity and carcinogenic and non-carcinogenic human toxicity. It shows, however, an increase in impacts on land use and water use. Finally, the third scenario (4c), assuming an increase in the recycling rates of the different metal/plastic streams during recycling treatment, shows hardly any reduction in environmental impacts.

4

Assessment of damage to ecosystem integrity and human health

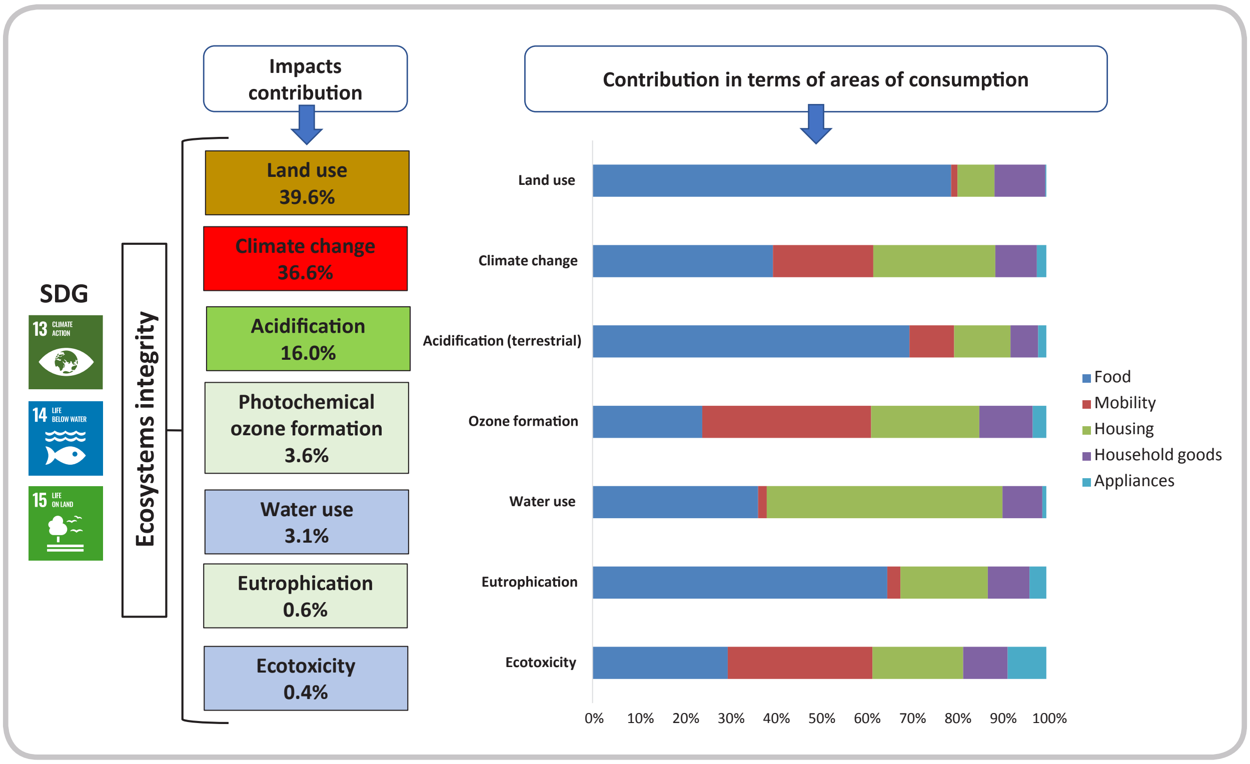
The 16 LCA-based impact indicators discussed above assess the alterations of certain parameters of the natural environment caused by environmental pressures (midpoint approach). This section adopts an approach that is geared more towards estimating the effects, in terms of damages that these pressures may be exerting on both ecosystem integrity (also addressing biodiversity loss) and human health (endpoint approach). This is an approach that is especially useful in decision making, as it focuses attention on a few areas of interest (Reimann et al., 2010; Sala et al., 2019; Kägi et al., 2016), which are amenable to intervention from a policy perspective, 2010; Sala et al., 2019; Kägi et al., 2016), which are amenable to policy intervention.

By focusing the assessment of the damage caused by certain environmental pressures on a few protection areas, this approach can facilitate and enhance the interpretation of the results of the Consumption Footprint in the context of the SDGs, as well as reveal potential connections between them.

To explore how different impact indicators ("midpoint", effect prior to harm generated) affect human health and ecosystem integrity (Sala et al., 2019), the ReCiPe 2016 method (RECIPE, 2016; Huijbregts et al., 2017) has been applied on baseline data for the year 2018, by product and by area of consumption. Specifically, following the ReCiPe 2016 method, human health damages are measured in DALYs (Disability Adjusted Life Years), which represent years of life lost due to disability, an overall measure of the burden of disease that represents both years lost due to premature death and years lived with disability. In terms of ecosystem integrity, ReCiPe 2016 expresses the measure of damage in terms of PDF (Potentially Disappeared Fraction), i.e., the fraction of species potentially missing in a given area, and over a given period of time.

As shown in Figure 42, changes in land use and global warming affecting terrestrial ecosystems are responsible for about 80% of the damage to ecosystem integrity associated with consumption patterns in Spain. These results are also consistent with the findings of the Millennium Ecosystem Assessment (MEA, 2005; WWF, 2017), which identify these two categories among the main drivers of biodiversity loss. In terms of contribution according to different areas of consumption, food is the largest contributor to the loss of ecosystem quality (and thus to biodiversity loss), especially because of environmental impacts related to the use of agricultural land for crops and pasture for food (Crenna et al. 2019).

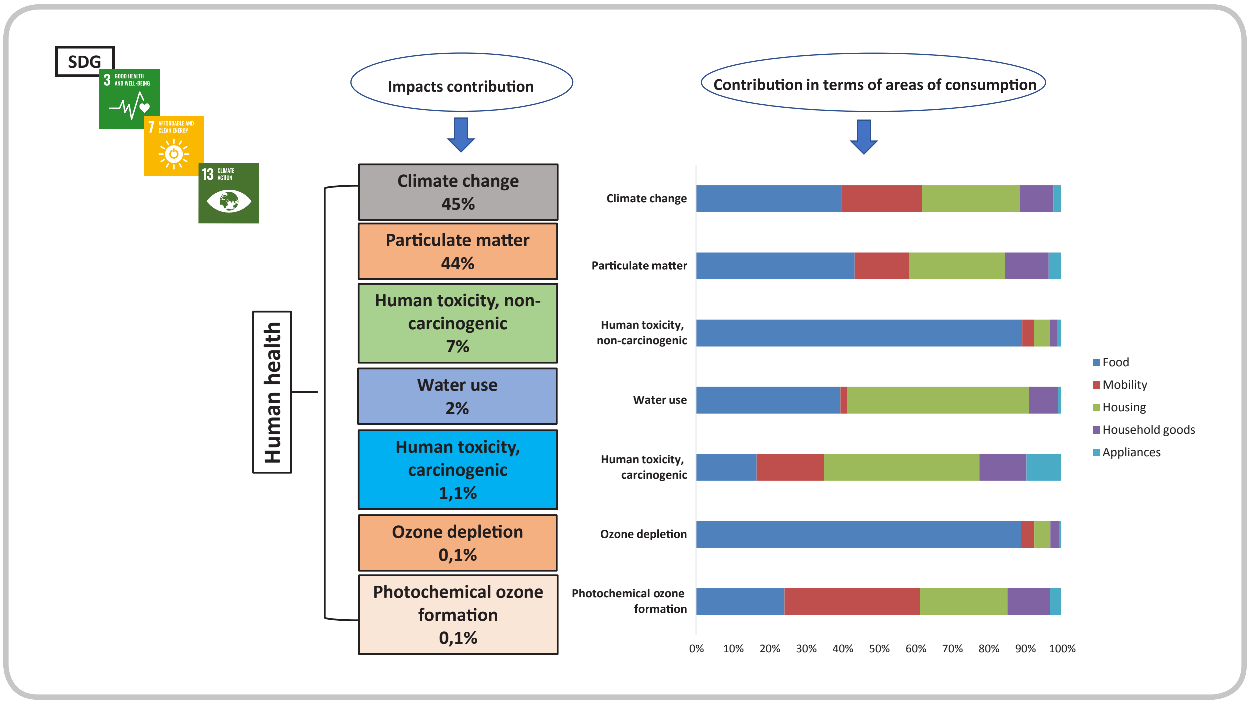
Figure 42. Damage to ecosystem integrity (Consumption Footprint, Spain, 2018).



Global warming and certain levels of particulate matter emissions into the atmosphere are the main drivers of harmful effects on human health related to consumption in Spain, which raises the need to intervene in this area to ensure better health conditions in accordance with SDG 3. This result is in line with current WHO mortality statistics, which present diseases associated with the respiratory system as one of the leading causes of death (WHO, 2018; GBD, 2019). The concentration of particulate matter in the air prevails over the global warming category by damaging human health in those areas of consumption where electricity use is high (in the whole life cycle), such as appliances and household goods, but also in food (Balasubramanian et al. 2021) (Figure 43). In terms of contribution in terms of areas of consumption, food has the greatest impact on human health, followed by housing and mobility.

In general terms, it can be said that global warming is a major contributor to damage to the health of both ecosystems and people. In fact, it is predominant in human health, while it is second only to land use in its contribution to the deterioration of ecosystem integrity. This would reflect the need for continued commitment to climate-related policies to meet SDG 13. On the other hand, land uses which are not linked to harm to human health, according to ReCiPe 2016, are the impact category with the highest score for the objective of protecting ecosystem integrity, leading to increased biodiversity loss, as has been corroborated by science since the Millennium Ecosystem Assessment (MEA, 2005).

Figure 43. Damage to human health (Consumption Footprint, Spain, 2018).



5

Conclusions

Based on data provided by the European Commission's Joint Research Centre, this paper has used the Life Cycle Assessment methodology to estimate the environmental pressures and impacts behind the consumption patterns of Spanish citizens. This is the first study carried out in our country aimed at exploring the environmental impact of consumption in a systemic and integrated way to assess its degree of decoupling with economic growth, comparing its results with the patterns showed by the EU-28 as a whole and showing them in reference to the SDGs and planetary boundaries.

Between 2010 and 2018, Spain's Domestic Footprint decreased for most of the environmental impacts assessed (as well as in the weighted index). Only four of the 16 impacts showed growth trends. The use of mineral resources and metals is worthy of special mention here, an environmental impact that almost doubled during the period analysed due not only to an increase in the silver and copper mining in Spain since 2015 but also the impact associated with the extraction of these resources and their global availability. For its part, freshwater consumption, despite showing a decreasing trend in the time series, emerged as one of Spain's main environmental problems, accounting for 34% of the contribution of environmental pressures linked to Spain's Domestic Footprint. Spain is currently responsible for almost 60% of the environmental impact due to water consumption in the EU-28.

Looking at the full range of environmental impacts associated with Spaniards' consumption patterns (regardless of where these impacts take place), we see that 13 of the 16 environmental impacts assessed in Spain's Consumption Footprint per capita (as well as the weighted index) showed upward trends between 2010 and 2018. These growth trends were mainly due to the increase in Spanish imports and the increase in the intensity of consumption of most products.

In recent years, Spain has managed to reduce the environmental impacts linked to its domestic consumption while at the same time keeping its economy growing thanks to a process of externalisation of its global consumption patterns that has transferred a large part of these impacts abroad through international trade. Our country is, in general terms, a net exporter of environmental impacts to third countries; countries that have acted as a source of resources and a waste sink for Spain.

The use of consumption-based indicators, such as Spain's own Consumption Footprint, has proved essential to be able to perceive the full range of environmental impacts linked to the consumption patterns of its inhabitants and who, in a highly globalised economy, operate within and beyond national borders.

Food consumption emerged as the main driver of environmental impacts generated by Spanish household consumption, followed by mobility and housing. These three areas together accounted for 85.3% of the entire Spanish Consumption Footprint in 2018. A Consumption Footprint that, in per capita terms, has moved above the EU average in 2016 and 2018.

Food and mobility were also the two areas of consumption whose footprints increased the most between 2010 and 2018. The only environmental impacts that did not have food as a main driver were eutrophication of freshwater and ionising radiation (housing), photochemical ozone formation and use of fossil resources (mobility) and use of mineral resources and metals (appliances).

At the product level, the foodstuffs with the highest impact were meat and dairy products, while the means of transport that contributed most to Spain's Footprint were diesel cars, petrol cars and continental air transport. On the other hand, the housing typologies that had the greatest weight on the Consumption Footprint were multi-family dwellings (both those built between 1970-1989 and those built before 1945). Finally, the household goods that contributed the most in terms of Consumption Footprint were clothing, furniture and paper products, and in the case of appliances the biggest impact came from the refrigerator, TV, oven and laptop.

The weighted index of Spain's Consumption Footprint, as well as 12 of the 16 environmental impacts assessed, showed a strong absolute and significant coupling with national GDP. The study carried out here does not, therefore, allow us to argue that there is a decoupling between the growth of the Spanish economy and the environmental impacts linked to consumption.

The results obtained in this report showed that Spain's consumption patterns are generating impacts outside the safe operating space for humanity at several planetary boundaries, namely: climate change, resource use (both fossil and mineral and metal), ecotoxicity, freshwater eutrophication and particulate matter. Thus, six of the 16 environmental impacts assessed in Spain exceed the safety thresholds for the proper functioning of the Earth System. An overreach that ultimately has a negative impact on people's health and the planet.

The results of the scenario analyses for the two areas addressed highlighted how life cycle analysis can help identify trade-offs associated with policy, technological and behavioural change options.

The analysis showed that sometimes the intensity of consumption can be more relevant than possible technical improvements. In the case of appliances, for example, the crossover effect of technological improvements and increased consumption intensity (more devices per household) generates diverging trends between impact categories (e.g. reduction of climate change at the same time as increased depletion of mineral resources). Future research could, for example, include potential rebound effects in scenario modelling. Scenarios in the area of transition to dietary change have shown that combining several actions could be a good way to cover a wider range of impacts, and to maximise the potential reduction, both at consumer level and at national level.

The results of this study constitute, in short, a scientific basis on which to define objectives for future policies and initiatives at different scales, as well as to promote changes in habits towards healthier and more sustainable consumption patterns.

6

Bibliography

Aguilera, E., P. Piñero, J. Infante Amate, M. González de Molina, L. Lassaletta, A. Sanz Cobeña. (2020). Emisiones de gases de efecto invernadero en el sistema agroalimentario y huella de carbono de la alimentación en España. Real Academia de Ingeniería, Madrid, Spain.

Arushanyan, Y., Ekener-Petersen, E., Finnveden, G. (2014). Lessons learned–Review of LCAs for ICT products and services. Computers in industry, 65(2), 211-234.

Balasubramanian, S., Domingo, N.G.G., Hunt, N.D., Gittlin, M., Colgan, K.K., Marshall, J.D., Robinson, A.L., Azevedo, I.M., Thakrar, S.K., Clark, M.A., Tessum, C.W., Adams, P.J., Pandis, S.N., Hill, J.D. (2021). The food we eat, the air we breathe: a review of the fine particulate matter-induced air quality health impacts of the global food system. Environmental Research Letters, 16 (10), 103004.

Baldassarri, C., Allacker, K., Reale, F., Castellani, V., Sala S. (2017). Consumption Footprint. Basket of Products indicator on Housing. European Commission, Joint Research Centre, Publication Office of the European Union, Luxembourg.

Boulay, A.M., Bare, J., Benini, L., Berger, M., Lathuillière, M.J., Manzardo, A., Margni, M., Motoshita, M., Núñez, M., Pastor, A.V., Ridoutt, B., Oki, T., Worbe, S., & Pfister, S. (2018). The WULCA consensus characterization model for water scarcity footprints: assessing impacts of water consumption based on available water remaining (AWARE). The International Journal of Life Cycle Assessment, 23(2), 368-378.

Carabias-Martínez, R., Rodríguez-Gonzalo, E., Fernández-Laespada, M. E., Calvo-Seronero, L., Sánchez-San Román, F. J. (2003). Evolution over time of the agricultural pollution of waters in an area of Salamanca and Zamora (Spain). Water Research, 37(4), 928-938.

Carpintero, O. (2015). El metabolismo económico regional español. Madrid: FUHEM Ecosocial, 1127.

Carpintero, O. (2018). Crecimiento económico y deterioro ecológico de la economía española: una visión a largo plazo. Ambienta 124, 40-57.

Castellani, V., Fusi, A. and Sala, S., Consumption Footprint. Basket of Products indicator on Food, EUR 28764 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-73194-5, doi:10.2760/668763, JRC 107959.

Castellani, V., Beylot, A., Sala, S. (2019). Environmental impacts of household consumption in Europe: Comparing process-based LCA and environmentally extended input-output analysis. Journal of Cleaner Production 240: 117966.

Castellani, V., Sanye Mengual, E., Sala, S. (2021) Environmental impacts of household goods in Europe: a process-based life cycle assessment model to assess consumption footprint, International Journal of Life Cycle Assessment, 26 (10), 2040–2055.

Crenna, E., Secchi, M., Benini, L., & Sala, S. (2018). Global environmental impacts: data sources and methodological choices for calculating normalisation factors for LCA. Submitted to The international Journal of Life Cycle Assessment.

Crenna, E., Sinkko, T., Sala, S., (2019). Biodiversity impacts due to food consumption in Europe. Journal of Cleaner Production, 227: 378-391.

Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F. N., & Leip, A. J. N. F. (2021). Food systems are responsible for a third of global anthropogenic GHG emissions. Nature Food, 2(3), 198-209.

Davis, S.J., & Caldeira, K. (2010). Consumption-based accounting of CO2 emissions. Proceedings of the National Academy of Sciences, 107(12), 5687-5692

De Laurentiis V, Secchi M, Bos U, Horn R, Laurent A, Sala S (2019). Soil quality index: exploring options for a comprehensive assessment of land use impacts in LCA. Journal of Cleaner Production, 215, 63-74

Di Donato, M., Ó. Carpenter. (2021). Household Food Metabolism: Losses, Waste and Environmental Pressures of Food Consumption at the Regional Level in Spain Foods 2021, 10(6), 1166

Di Donato, M., P. L. Lomas, O. Carpintero. (2015). Metabolism and Environmental Impacts of Household Consumption: A Review on the Assessment, Methodology, and Drivers. Journal of Industrial Ecology 19(5): 904-916.

EC-JRC (2022) Consumption Footprint Platform, accessible via: https://eplca.jrc.ec.europa.eu/ConsumptionFootprintPlatform.html

European Commission (EC) (2009). Communication from the Commission GDP and beyond: measuring progress in a changing world COM(2009)0433 final.

European Commission (EC) (2013). Communication from the Commission to the European Parliament and the Council - Building the Single Market for Green Products - Facilitating better information on the environmental performance of products and organisations. COM(2013)196.

European Commission (EC) (2016). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Next steps for a sustainable European future European action for sustainability. COM(2016)0739 final.

European Commission (EC) (2018). A sustainable bioeconomy for Europe: strengthening the connection between economy, society and the environment. Updated Bioeconomy Strategy, based on Communication (2018) 673/2 and SWD (2018)431/2.

European Commission (EC) (2019). Communication from the Commission to the European Parliament and the Council. The European Green Deal. COM(2019) 640 final.

European Commission (EC) (2020a). Proposal for a Decision of the European Parliament and of the Council on a General Union Environment Action Programme to 2030. COM(2020) 652 final

European Commission (EC) (2020b). Communication from the Commission to the European Parliament and the Council. A Farm to Fork Strategy for a fair, healthy and environmentally-friendly food system. COM/2020/381 final.

European Commission (EC) (2020c). Communication from the Commission to the European Parliament and the Council. Biodiversity Strategy for 2030: Bringing nature back into our lives. COM/2020/380 final.

European Commission (EC) (2020d). Communication from the Commission to the European Parliament and the Council. A new Circular Economy Action Plan: For a cleaner and more competitive Europe. COM/2020/98 final.

European Commission (EC) (2020e). Communication from the Commission to the European Parliament and the Council. Chemicals Strategy for Sustainability: Towards a Toxic-Free Environment. COM(2020) 667 final.

European Commission (EC) (2021a). Communication from the Commission to the European Parliament, the Council, the European and Social Committee and the Committee of the Regions. Pathway to a Healthy Planet for All EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil'. COM (2021) 400 final.

European Commission (EC) (2021b). Communication from the Commission to the European Parliament, the Council, the European and Social Committee and the Committee of the Regions. Better Regulation: Joining forces to make better laws. COM/2021/219 final.

European Commission (EC) (2021c). Commission Recommendation on the use of the Environmental Footprint methods to measure and communicate the life cycle environmental performance of products and organisations. C(2021) 9332 final.

European Parliament and Council. (2013). Decision No 1386/2013/EU of the European Parliament and of the Council of 20 November 2013 on a General Union Environment Action Programme to 2020 'Living well, within the limits of our planet'.

Fanning, A. L., O'Neill, D. W., Hickel, J., & Roux, N. (2021). The social shortfall and ecological overshoot of nations. Nature Sustainability, 1-11.

Fantke P, Bijster M,Guignard C, Hauschild M, Huijbregts M, Jolliet O, Kounina A, Magaud V, Margni M, McKone TE, Posthuma L, Rosenbaum RK, van de Meent D, van Zelm R, (2017). USEtox 2.0 Documentation (Version 1 and related updates of version 2.1), http://usetox.org.

Fantke, P., Evans, J., Hodas, N., Apte, J., Jantunen, M., Jolliet, O., & McKone, T.E. (2016). Health impacts of fine particulate matter. In: Frischknecht, R., Jolliet, O. (Eds.), Global Guidance for Life Cycle Impact Assessment Indicators: Volume 1. UNEP/SETAC Life Cycle Initiative, Paris, pp. 76-99. Available at www.lifecycleinitiative.org/applying-lca/lcia-cf/ (Accessed January 2018).

Frischknecht, R., Braunschweig, A., Hofstetter, P., & Suter, P. (2000). Modelling human health effects of radioactive releases in Life Cycle Impact Assessment. Environmental Impact Assessment Review, 20 (2), 159-189.

Garrido, A., Llamas, M. R., Varela-Ortega, C., Novo, P., Rodríguez-Casado, R., Aldaya, M. M. (2010). Water footprint and virtual water trade in Spain: Policy implications. In Natural resource management and policy series: Springer-Fundación Marcelino Botín.

Garrido, T., Fraile, J., Niñerola, J. M., Figueras, M., Ginebreda, A., Olivella, L. (2000). Survey of ground water pesticide pollution on rural areas of Catalonia (Spain). International Journal of Environmental Analytical Chemistry, 78(1), 51-65.

Gephart, J. A., Davis, K. F., Emery, K. A., Leach, A. M., Galloway, J. N., & Pace, M. L. (2016). The environmental cost of subsistence: optimising diets to minimise footprints. Science of the Total Environment, 553, 120-127.

Giljum, S., Bruckner, M., Martinez, A. (2015). Material footprint assessment in a global input-output framework. Journal of Industrial Ecology, 19(5), 792-804.

GBD (2019). Global Burden of Disease Study 2019. Data Resources. Institute for Health Metrics and Evaluation. Disponible en: http://ghdx.healthdata.org/gbd-2019.Gobierno de España. 2021. Plan de Recuperación, Transformación y Resiliencia. Available at: https://planderecuperacion.gob.es/

Gómez-Baggethun, E., De Groot R. (2007). Natural capital and ecosystem functions: exploring the ecological basis of the economy. Ecosystems, 16 (3): 4-13.

González de Molina, M., Soto Fernández, D., Guzmán Casado, G., Infante Amate, J., Aguilera Fernández, E., Vila Traver, J., García Ruíz, R. (2019). Historia de la Agricultura española desde una perspectiva biofísica, 1900-2010. Ministerio de Agricultura y Pesca, Alimentación y Medio Ambiente, Secretaría General Técnica, Madrid, Spain.

Gonzalo, C., Camargo, J. A. (2013). The impact of an industrial effluent on the water quality, submersed macrophytes and benthic macroinvertebrates in a dammed river of Central Spain. Chemosphere, 93(6), 1117-1124.

Goulding, K. W. T. (2016). Soil acidification and the importance of liming agricultural soils with particular reference to the United Kingdom. Soil use and management, 32(3), 390-399.

Haberl, H., Wiedenhofer, D., Virág, D., Kalt, G., Plank, B., Brockway, P., ... Creutzig, F. (2020). A systematic review of the evidence on decoupling of GDP, resource use and GHG emissions, part II: synthesizing the insights. Environmental Research Letters, 15(6), 065003.

Hermosin, M. C., Calderon, M. J., Real, M., Cornejo, J. (2013). Impact of herbicides used in olive groves on waters of the Guadalquivir River basin (Southern Spain). Agriculture, Ecosystems & Environment, 164, 229-243.

Hertwich, E.G., & Peters, G. P. (2009). Carbon footprint of nations: A global, trade-linked analysis. Environmental Science & Technology, 43(16), 6414-6420.

Hickel, J., Kallis, G. (2020). Is green growth possible? New political economy, 25(4), 469-486.

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

Huijbregts, M.A., Steinmann, Z.J., Elshout, P.M., Stam, G., Verones, F., Vieira, M., Zijp, M., Hollander, A. & van Zelm, R. (2017). ReCiPe2016: a harmonised life cycle impact assessment method at midpoint and endpoint level. The International Journal of Life Cycle Assessment, 22(2), 138-147.

IPCC (Intergovernmental Panel on Climate Change) (2013). IPCC Climate Change Fifth Assessment Report: Climate Change 2013. Available at http://www.ipcc.ch/ipccreports/assessments-reports.htm.

IPCC. (2019): Summary for Policymakers In: Climate change and land: An IPCC Special Report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems

ISO (International Organization for Standardization) (2006a) ISO 14040. Environmental management - Life cycle assessment - Principles and framework. Geneva, Switzerland.

ISO (International Organization for Standardization) (2006b) ISO 14044. Environmental management - Life cycle assessment - Requirements and guidelines. Geneva, Switzerland.

Ivanova, D., K. Stadler, K. Steen-Olsen, R. Wood, G. Vita, A. Tukker, E.G. Hertwich. (2016). Environmental Impact Assessment of Household Consumption. Journal of Industrial Ecology 20(3): 526-536.

Kägi, T., Dinkel, F., Frischknecht, R., Humbert, S., Lindberg, J., De Mester, S., Ponsioen, T., Sala, S., & Schenker, U.W. (2016). Session "Midpoint, endpoint or single score for decision-making?"-SETAC Europe 25th Annual Meeting, May 5th, 2015. The International Journal of Life Cycle Assessment, 21(1), 129-132.

Leip, A., Billen, G., Garnier, J., Grizzetti, B., Lassaletta, L., Reis, S., Simpson, D., Sutton, M.A., De Vries, W., Weiss, F. and Westhoek, H. (2015). Impacts of European livestock production: nitrogen, sulphur, phosphorus and greenhouse gas emissions, land-use, water eutrophication and biodiversity. Environmental Research Letters, 10(11), 115004.

Leroy, F., Abraini, F., Beal, T., Dominguez-Salas, P., Gregorini, P., Manzano, P., Rowntree, J., van Vliet, S. (2022). Animal board invited review: Animal source foods in healthy, sustainable, and ethical diets - An argument against drastic limitation of livestock in the food system. Animal, 16 (3), 100457,

Ley 7/2021, de 20 de mayo, de cambio climático y transición energética. Boletín Oficial del Estado, no. 121, of 21 May 2021, pp 62009 to 62052 (44 pages.) https://www.boe.es/diario_boe/txt.php?id=BOE-A-2021-8447

Luo, T., Young, R., Reig, P. (2015). Aqueduct projected water stress country rankings. Washington, D.C.: World Resources Institute. Technical Note, 16.

MEA (Millennium Ecosystem Assessment), (2005). Ecosystems and Human Well-being: Biodiversity Synthesis. World Resources Institute, Washington, USA.

MINECO (Ministerio de Economía y Competitividad). (27 February 2014). La economía española cierra 2013 con un crecimiento del 0,2%, una décima superior al trimestre previo [Press release].

MITECO (Ministerio de Transición Ecológica y Reto Demográfico). Plan nacional integrado de energía y clima (2021-2030). 2020. Available at: https://www.miteco.gob.es/es/prensa/pniec.aspx

MITECO. España Circular 2030. Estrategia Española De Economía Circular. 2020. Available at: https://www.miteco.gob.es/es/calidad-y-evaluacion-ambiental/temas/economia-circular/estrategia/

MITECO. 2020. Estadística minera de España 2019. Available at: https://energia.gob.es/mineria/Estadistica/DatosBibliotecaConsumer/2019/estadistica-minera-anual-2019.pdf

Moranta, J., Torres, C., Murray, I., Hidalgo, M., Hinz, H., & Gouraguine, A. (2021). Transcending capitalism growth strategies for biodiversity conservation. Conservation Biology.

Naredo, J.M. (2006). Raíces económicas del deterioro ecológico y social más allá de los dogmas. Madrid, Siglo XXI.

O'Neill, D. W., Fanning, A. L., Lamb, W. F., Steinberger, J. K. (2018). A good life for all within planetary boundaries. Nature sustainability, 1(2), 88-95.

Parrique, T., Barth, J., Briens, F., Kerschner, C., Kraus-Polk, A., Kuokkanen, A., Spangenberg, J. H. (2019). Decoupling debunked. Evidence and arguments against green growth as a sole strategy for sustainability. A study edited by the European Environment Bureau EEB.

Pérez Martínez, P.J., A. Monzón de Cáceres. (2008). Consumo de energía por el transporte en España y tendencias de emisión. Observatorio Medioambiental 11: 127-147.

Posch, M., Seppälä, J., Hettelingh, J.P., Johansson, M., Margni, M., & Jolliet, O. (2008). The role of atmospheric dispersion models and ecosystem sensitivity in the determination of characterisation factors for acidifying and eutrophying emissions in LCIA. The International Journal of Life Cycle Assessment, 13, 477-486.

Reale, F, Castellani, V, Hischier, R, Corrado, S, Sala, S, Consumption Footprint - Basket of Products indicator on Household appliances, EUR 29758 EN, Publications Office of the European Union, Luxembourg, 2019, ISBN 978-92-76-05003-2, doi:10.2760/964701, JRC116704.

RECIPE. (2016). RECIPE model website: https://www.rivm.nl/en/life-cycle-assessment-lca/downloads.

Reimann K, Finkbeiner M, Horvath A, Matsuno Y, authors Pretato U, Pennington D, Pant R. (2010). Evaluation of Environmental Life Cycle Approaches for Policy and Decision Making Support in Micro and Macro Level Applications. Luxembourg: Publications Office of the European Union. JRC60640

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin III, F. S., Lambin, E., ... Foley, J. (2009). Planetary boundaries: exploring the safe operating space for humanity. Ecology and society, 14(2).

Sala S., Benini L., Beylot A., Castellani V., Cerutti A., Corrado S., Crenna E., Diaconu E., Sanyé-Mengual E, Secchi M., Sinkko T., Pant R. (2019) Consumption and Consumption Footprint: methodology and results. Indicators and Assessment of the environmental impact of EU consumption. Luxembourg: Publications Office of the European Union, ISBN 978-92-79-97255-3, doi 10.2760/15899, JRC 113607.

Sala, S., Cerutti, A.K., & Pant, R. (2018). Development of a weighting approach for Environmental Footprint. European Commission, Joint Research Centre, Publication Office of the European Union, Luxembourg. ISBN 978-92-79-68041-0.

Sala, S., Crenna, E., Secchi, M., & Sanyé-Mengual, E. (2020). Environmental sustainability of European production and consumption assessed against planetary boundaries. Journal of environmental management, 269, 110686.

Sala, S., Sanyé-Mengual, E. (2022). Consumption Footprint: assessing the environmental impacts of EU consumption, European Commission.

Sanyé-Mengual, E., Sala, S. (2021). Assessing the transboundary effects of EU consumption: Applying a life cycle perspective to SDG 12, in OECD-JRC, Understanding the Spillovers and Transboundary Impacts of Public Policies. Implementing the 2030 Agenda for More Resilient Societies (pp.155-166), Paris: OECD Publishing.

Sanyé Mengual, E; Tosches, D; Sala, S. (2022) Domestic Footprint of the EU and Member States: methodology and results (2010-2018), EUR 30796, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-40828-4, doi:10.2760/441655, JRC125941

Sanyé-Mengual, E., Secchi, M., Corrado, S., Beylot, A., Sala, S. (2019). Assessing the decoupling of economic growth from environmental impacts in the European Union: A consumption-based approach. Journal of cleaner production, 236, 117535.

Saouter, E., Biganzoli, F., Ceriani, L., Versteeg, D., Crenna, E., Zampori, L., Sala, S, Pant, R. (2018). Environmental Footprint: Update of Life Cycle Impact Assessment Methods - Ecotoxicity freshwater, human toxicity cancer, and non-cancer. EUR 29495 EN, Publications Office of the European Union, Luxembourg, ISBN 978-92-79-98182-1
Smeets E., Weterings R. (1999). Environmental indicators: Typology and overview. EEA Technical report No 25.

Seyring, N., Kling, M., Weissenbacher, J., Hestin, M., Lecerf, L., Magalini, F., Khetriwal, D. S. & Kuehr, R. (2015). Study on WEEE recovery targets, preparation for re-use targets and on the method for calculation of the recovery targets - Final Report. European Commission, Luxembourg: Publications Office of the European Union.

Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E.M., Biggs, R., Carpenter, S.R., de Vries, W., de Wit, C.A., Folke, C., Gerten, D., Heinke, J., Mace, G.M., Persson, L. M., Ramanathan, V., Reyers, B., & Sörlin, S. (2015). Planetary boundaries: Guiding human development on a changing planet. Science, 347(6223), 1259855.

Struijs, J., Beusen, A., van Jaarsveld, H., & Huijbregts, M.A.J. (2009). Aquatic Eutrophication. Chapter 6 in: Goedkoop, M., Heijungs, R., Huijbregts, M.A.J., De Schryver, A., Struijs, J., & Van Zelm, R. (2009). ReCiPe 2008 A life cycle impact assessment method which comprises harmonised category indicators at the midpoint and the endpoint level. Report I: Characterisation factors, first edition.

Suárez-Serrano, A., Alcaraz, C., Ibanez, C., Trobajo, R., Barata, C. (2010). Procambarus clarkii as a bioindicator of heavy metal pollution sources in the lower Ebro River and Delta. Ecotoxicology and environmental safety, 73(3), 280-286.

Tukker U., Bausch-Goldbohm S., Verheijden M., de Koning A., Kleijn R., Wolf O. & Pérez Dominguez I. (2009). Environmental impacts of diet changes in the EU. Luxembourg: Office for official publications of the European Communities.

UN (United Nations) (2015). Sustainable Development Goals. Available at: https://sdgs.un.org/ (Accessed November 2021).

UNEP (United Nations Environment Programme) (2011). Decoupling Natural Resource use and Environmental impact from economic growth. International Resources Panel.

UNEP (United Nations Environment Programme) (2016). Global guidance for life cycle impact assessment indicators. Volume 1. ISBN: 978-92-807-3630-4. Available at: http://www.lifecycleinitiative.org/life-cycle-impact-assessment-indicators-and-characterization-factors/.

UN-IRP. (2018). Global Material Flows Database, from UN International Resources Panel. Available at: http://www.resourcepanel.org/global-material-flows-database.

Yamasue, E., Minamino, R., Daigo, I., Okumura, H., Ishihara, K.N. (2009). Evaluation of Total Materials Requirement for the Recycling of Elements and Materials (Urban Ore TMR) from End-of-Life Electric Home Appliances. Materials Transactions. Vol. 50, No. 9, pp. 2165-2172.

Vanham, D., Mekonnen, M. M., & Hoekstra, A. Y. (2020). Treenuts and groundnuts in the EAT-Lancet reference diet: concerns regarding sustainable water use. Global food security, 24, 100357.

van Oers, L., de Koning, A., Guinee, J.B., & Huppes, G. (2002). Abiotic Resource Depletion in LCA. Road and Hydraulic Engineering Institute, Ministry of Transport and Water, Amsterdam, The Netherlands.

Van Zelm, R., Huijbregts, M.A.J., Den Hollander, H.A., Van Jaarsveld, H.A., Sauter, F.J., Struijs, J., Van Wijnen, H.J., & Van de Meent, D. (2008). European characterization factors for human health damage of PM10 and ozone in life cycle impact assessment. Atmospheric Environment, 42, 441-453.

Ward, J. D., Sutton, P. C., Werner, A. D., Costanza, R., Mohr, S. H., Simmons, C. T. (2016). Is decoupling GDP growth from environmental impact possible? PloS one, 11(10), e0164733.

Westhoek H., Lesschen J.P., Rood T., Wagner S., De Marco A., Murphy-Bokern D., Leip A., van Grinsven H., Sutton M.A. & Oenema O., (2014). Food choices, health and environment: Effects of cutting Europe's meat and dairy intake. Global Environmental Change 26, 196-205.

Wiedmann, T. O., Schandl, H., Lenzen, M., Moran, D., Suh, S., West, J., Kanemoto, K. (2015). The material footprint of nations. Proceedings of the national academy of sciences, 112(20), 6271-6276

Wiedenhofer, D., Virág, D., Kalt, G., Plank, B., Streeck, J., Pichler, M., Mayer, A., Krausmann, F., Brockway, P., Schaffartzik, A. and Fishman, T., (2020). A systematic review of the evidence on decoupling of GDP, resource use and GHG emissions, part I: bibliometric and conceptual mapping. Environmental research letters, 15(6), 063002.

Wiedenhofer, D., Fishman, T., Plank, B., Miatto, A., Lauk, C., Haas, W., Haberl, H. & Krausmann, F. (2021). Prospects for a saturation of humanity's resource use? An analysis of material stocks and flows in nine world regions from 1900 to 2035. Global Environmental Change, 71, 102410.

World Economic Forum (WEF) (2019). A New Circular Vision for Electronics. Time for a Global Reboot, World Economic Forum. Available at: http://www3.weforum.org/docs/WEF_A_New_Circular_Vision_for_Electronics.pdf.

WHO (World Health Organization) (2018) Global Health Observatory (GHO) data - Top 10 causes of death. Available at: http://www.who.int/gho/mortality_burden_disease/causes_death/top_10/en/

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

WWF (World Wide Fund for Nature) (2017). The threats and problems affecting species and their survival. Available at: http://wwf.panda.org/our_work/wildlife/problems/.

7

List of definitions

Concepts	Definitions
Life Cycle Assessment (LCA)	LCA is a methodology for the systematic assessment of the environmental aspects of a product or service system at all stages of its life cycle.
Carrying capacity	The carrying capacity of a biological species in a given environment is the maximum population size of the species that the environment can sustain indefinitely, given the food, habitat, water and other needs available in the environment. In population biology, carrying capacity is defined as the maximum load of the environment, which is different from the concept of population equilibrium (Hui, 2006; Sayre, 2008).
Apparent consumption	It is the mathematical sum of domestic production plus imports less exports (APPARENT CONSUMPTION = IMPORTS + DOMESTIC - EXPORTS). It differs from "real" consumption because it does not take into account changes in stocks.
Absolute decoupling	Environmental impacts are falling as economic activity continues to grow.
Relative decoupling	The increase in environmental impacts is smaller than the growth in economic activity.

Footprint	A "footprint" is a quantitative measure that describes humans' appropriation of natural resources. A footprint describes how human activities can impose different types of burdens and impacts on global sustainability (Čuček et al., 2012).
Environmental Footprint	Life cycle based methodology for the assessment of the environmental profile of products (PEF) or organisations (OEF).
Consumption Footprint	The Consumption Footprint is a set of 16 indicators based on the LCA method, which can be summarised in a single weighted index, aimed at quantifying the environmental impacts of apparent consumption in the EU and Member States.
Domestic Footprint	Overall environmental impact of the European Union (EU-28) and ultimately of each Member State with a production-based approach.
Environmental Impact	A consequence of an intervention in the environmental system (Guinée et al 2002). Potential impact on ecosystems, human health or natural resource depletion caused by interventions between the technosphere and the ecosphere covered by the LCA (e.g. emissions, resource extraction, land use).
Planetary boundaries	A framework concept developed by Rockström et al (2009) to define a desired operating range for essential Earth system features and processes. The transgression of a terrestrial planetary boundary implies the risk of a catastrophic or damaging loss of existing ecosystem functions or services throughout the terrestrial biosphere.

Standardisation	According to ISO 14044, standardisation is an optional interpretation step in a full LCA study. Standardisation allows the practitioner to express the results after characterisation, using a common reference impact. Using standardisation references in combination with weighting factors, the relative magnitude of an impact can be related to other impacts in the life cycle with a common unit.
Life cycle perspective	The life cycle approach seeks to go beyond the traditional focus on the production site and manufacturing processes to include the environmental, social and economic impacts of a product throughout its life cycle, regardless of the territory in which they occur.
Weighting	According to ISO 14044, weighting is an optional interpretation step of a full LCA study. Weighting allows the results to be expressed as a single final score, resulting from assigning a weighting to each impact category based on the relative importance of one impact compared to another.

8

List of Figures

9

List of Tables

10

Annexes

Annex 1. Impact categories, supporting models and robustness of impact assessment models.

Impact category	Unit	Model adopted as in studio Environmental Footprint (Robustness of the model[a])	Global standardisation factors[b]	Planetary boundaries	Weighting factors[c] (%)
Climate change	kg CO_2 eq	IPCC, 2013 (I)	5.58E+13	6.81E+12	21.06
Depletion of the ozone layer	kg CFC-11 eq	World Metereological Organisation (WMO), 2014 (I)	3.70E+08	5.39E+08	6.31
Particles in suspension	Disease incidence	Fantke et al., 2016 (I)	4.11E+06	5.16E+05	8.96
Ionising radiation	kBq U-235 eq.	Frischknecht et al., 2000 (II)	2.91E+13	5.27E+14	5.01
Ozone formation photochemical	kg COVNM eq.	Van Zelm et al., 2008, as applied in ReCiPe 2008 (II)	2.82E+11	4.07E+11	4.78
Acidification	mol H+ eq	Posch et al., 2008 (II)	3.83E+11	1.00E+12	6.2
Eutrophication, terrestrial	mol N eq		1.22E+12	6.13E+12	3.71
Eutrophication, freshwater	kg P eq	Struijs et al., 2009 (II)	1.11E+10	5.81E+09	2.8
Eutrophication, marine	kg N eq		1.35E+11	2.01E+11	2.96
Ecotoxicity, freshwater	CTUe	based on USEtox2.1 model (Fantke et al. 2017), adapted as in Saouter et al., 2018	8.51E+14	1.31E+14	1.92
Human toxicity, non-carcinogenic effects	CTUh		1.74E+07	4.10E+06	2.13
Human toxicity, carcinogenic effects	CTUh		1.91E+05	9.62E+05	1.84
Land use	Pt	Soil quality index based on an updated LANCA model (De Laurentiis et al. 2019) and on the LANCA CF version 2.5 (Horn and Meier, 2018)	5.65E+15	3.98E+15	7.94
Water use	m^3 water eq	AWARE 100 (based on) (UNEP 2016; Boulay et al. 2018) (III)	7.91E+13	1.82E+14	8.51
Use of fossil resources	MJ	ADP fossils (van Oers et al., 2002) (III)	4.48E+14	2.24E+14	8.32
Use of mineral resources and metals	kg Sb eq	ADP ultimate reserve (van Oers et al., 2002) (III)	4.39E+08	2.19E+08	7.55

[a] EC, (2017). PEFCR Guidance document - Guidance for the development of Product Environmental Footprint Category Rules (PEFCRs), version 6.3, December 2017.

[b] Crenna E., Secchi, M., Benini, L., & Sala, S. (2018). Global environmental impacts: data sources and methodological choices for calculating normalisation factors for LCA. Submitted to The international Journal of Life Cycle Assessment.

[c] Sala S., Cerutti, A.K., & Pant, R. (2018). Development of a weighting approach for Environmental Footprint. European Commission, Joint Research Centre, Publication Office of the European Union, Luxembourg. ISBN 978-92-79-68041-0.t al., 2018.

Annex 2. Results of Pearson's correlation tests between Spanish GDP and the 16 environmental impact indicators of the Spanish Consumption Footprint (as well as the weighted index) between 2010 and 2018.

Environmental Impacts of the Consumption Footprint	R^2	p-value	Significance
Acidification	**0,8832**	**0,0002**	**
Climate change	**0,9414**	**0,0000**	***
Freshwater ecotoxicity	**0,9026**	**0,0001**	**
Eutrophication of freshwater	0,0508	0,5599	
Marine eutrophication	**0,8718**	**0,0002**	**
Terrestrial eutrophication	**0,8390**	**0,0005**	**
Human cancer toxicity	**0,8922**	**0,0001**	**
Non-carcinogenic human toxicity	**0,9149**	**0,0001**	**
Ionising radiation	0,0011	0,9333	
Land use	**0,8901**	**0,0001**	**
Ozone depletion	**0,7427**	**0,0028**	**
Particulate matter	**0,9040**	**0,0001**	**
Photochemical ozone formation	**0,9404**	**0,0000**	***
Use of fossil resources	**0,6781**	**0,0064**	**
Use of mineral resources and metals	0,0239	0,6913	
Water use	0,7527	0,0024	**
Consumption Footprint (weighted index)	**0,9219**	**0,0000**	***

Independent variable: GDP at constant prices.
Significance: * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$.

Sustainability of Consumption in Spain

Assessment of the environmental impact of consumption patterns through Life Cycle Analysis

GOBIERNO DE ESPAÑA
MINISTERIO DE CONSUMO

European Commission