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Life cycle indicators for resources, products and waste

BASKET-OF-PRODUCTS

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Life cycle indicators basket-of-products

DEVELOPMENT OF LIFE CYCLE BASED MACRO-LEVEL MONITORING INDICATORS FOR RESOURCES, PRODUCTS AND WASTE FOR THE EU-27

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AUTHORS AND ACKNOWLEDGEMENTS

This report contributes to the development of the basket-of-products life cycle indicators. These indicators are intended to be used to assess the environmental impact of the European consumption.

The work was carried out over many years and with contributions from many people:

- The authors of the original idea for life cycle indicators were Marc-Andree Wolf and David Pennington (European Commission, DG Joint Research Centre).
- Project leaders were Ugo Pretato (2009) and Małgorzata Góralczyk (2010-2011).
- The report was written by a team of consultants: Sven Lundie, Alexander Stoffregen, Neil D´Souza, Jeff Vickers (PE International), Helmut Schütz, Mathieu Saurat (Wuppertal Institute for Climate, Environment, Energy).
- The weighting scheme was developed by Gjalt Huppes and Lauran van Oers (Institute of Environmental Sciences (CML) of Leiden University).
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- Comments and scientific advice were provided by Stephan Moll and Julio Cabeca (European Commission, DG Eurostat).
- The leading editor of this report was Małgorzata Góralczyk (European Commission, DG Joint Research Centre).

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DISCLAIMER

EXECUTIVE SUMMARY

OVERVIEW

Sustainable development is an underlying objective of the European Union treaties. An important part of sustainable development is its environmental aspect, as reflected in the Europe 2020 strategy (EC, 2010a) and its Resource-efficient Europe flagship initiative (EC, 2011a). For analysing and monitoring our progress towards sustainability in terms of the environmental performance, indicators are needed. These indicators need to provide an integrated view on the links between consumption, production, resource depletion, resource use, resource recycling, environmental impacts and waste generation. One of the approaches that facilitate such integrated view is life cycle thinking (LCT).

This integrative approach underlies the development of life cycle indicators for analysing and monitoring progress towards the sustainable development of the European Union. These indicators will serve the purpose of further development and monitoring of modern, life-cycle based, environmental policies, like the Sustainable Consumption and Production Action Plan (EC, 2008a) or Europe 2020 strategy (EC, 2010a). In particular, sustainable consumption is closely linked to the Resource-efficient Europe flagship initiative (EC, 2011a) where increasing resource-efficiency *[...]is necessary to develop new products and services and find new ways to reduce inputs, minimise waste, improve management of resource stocks, change consumption patterns, optimise production processes, management and business methods, and improve logistics. [...]*.

The development of basket of products indicators responds to these needs of analysing and monitoring of the consumption patterns and their gobal influence in order to shift to more resource-efficient consumption. The present document describes the development and implementation of the basket-of-products indicators, one of three envisaged indicator sets (EC, 2012a). The basket-of-products indicators are complemented by the resource indicators (including the overall eco-efficiency indicator) (EC, 2012b) and waste management indicators (EC, 2012d).

METHODOLOGY

The general framework and methodology for the calculation of the resource indicators is presented in the Indicators Framework (JRC, 2012a). Here, we explain how to calculate the basket-of-products indicators and describe the underlying data.

The basket-of-products approach matches statistics on private consumption per capita with life cycle inventory (LCI)[1] for each product[2] consumed. As the products included in the basket are only a subset of total consumption, the basket-of-products indicators provide an index for monitoring and analysis, and not an absolute measure of environmental impact per person.

The statistics, which have been primarily derived from Eurostat, reflect apparent domestic consumption (i.e. domestic production + imports - exports) of private households. In order to match these statistics to detailed environmental profiles for each product, private consumption has been broken down into categories (nutrition, shelter, consumer goods, mobility and services), product groups (e.g. private transportation), products (e.g. mid class cars) and, where necessary, sub-products (e.g. Euro IV cars).

[1] Life cycle inventory includes emissions and resource use.

[2] Goods and services together are products.

Each (sub-)product is matched to one or more life cycle inventory (LCI) dataset. These datasets contain all environmentally relevant flows of resources from and emissions to the natural environmental across the entire life cycle of the product, from raw material extraction through production, distribution, use and disposal (end-of-life).

Once the macro statistics and life cycle inventories have been matched, the potential impacts on the natural environment are calculated using impact assessment methods. Included in this assessment are impact categories (e.g. climate change, eutrophication, and resource use) following the recommendation of ILCD handbook (EC, 2011c).

The statistics chosen represent domestic consumption only; the impacts of domestic production for export are excluded. The impacts of foreign production for domestic consumption are included and estimated using country-specific life cycle inventory (LCI) data for the most significant import countries for each product as identified by trade statistics.

OUTLINE

This report provides a brief summary of existing studies regarding the selection of product groups (section 1.2) and important methodological considerations (section 1.3). Further details are laid down in the life cycle indicators framework (EC, 2012a).

The focus of this document is to provide more insight on how to calculate the basket-of-products indicators. The application of the methodology to each consumption category (i.e. nutrition, shelter/housing, consumer goods and mobility) is described in Section 1.4. For each of these consumption categories, the selected products are specified using both a general and technical description as well as methodological considerations to be addressed. Data sources are listed at the end of each sub-section.

The preliminary calculations are described in chapter 2. The results for the EU-27 and a selected Member State (Germany) are presented in chapter 3. Chapter 4 presents the normalised and weighted results and the calculation of an optional single environmental score. Finally, chapter 5 provides an outlook with possible next steps.

The results in chapters 3 and 4 suggest that, for the basket of products chosen in this report, Germany has a higher impact across half of the fourteen indicators calculated by the prototype compared to the EU-27. The calculation of a single environmental score for each region suggests that the impact of a German citizen (based upon the basket of products and normalisation/ weighting factors chosen in this study) may be 10% higher than that of an average citizen of the EU-27..

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LIST OF TERMS AND ABBREVIATIONS

Term	Explanation
BOM	Bill of Materials
COICOP	Classification Of Individual Consumption by Purpose
GDP	Gross Domestic Product
LCA	Life Cycle Assessment
LCI **Life Cycle Inventory**	Emissions and resource extraction profiles of goods and services, i.e. list of all physical exchanges with the environment: inputs (resources, materials, land use and energy), and outputs (emissions to air, water and soil)
LCIA	Life Cycle Impact Assessment
LCT	Life Cycle Thinking
PPS	Purchasing Power Standards
Products	Goods and services
PRODCOM	Statistics on the production of manufactured goods (Eurostat)

1 INTRODUCTION

1.1 OVERVIEW OF THE BASKET-OF-PRODUCTS APPROACH

The basket-of-products approach matches macro statistics on private consumption per capita with life cycle inventory (LCI) environmental profiles for each product[3] consumed. The preliminary calculations were done using data for EU-27 and a selected Member State (Germany).

The statistics chosen represent domestic consumption only, and the impacts of domestic production for export are excluded. The impacts of foreign production for domestic consumption are included by using country-specific LCI data for the most significant import countries for each product, as identified by trade statistics.

The application of basket-of-products indicators in the contexts of policy development, implementation and monitoring is as follows:

- Monitoring environmental impacts of relevant goods and services consumed by citizens of EU-27 and its Member States.
- Detailed consideration of products and their subsequent updates in future years will allow consumption behaviour change and the transition towards more sustainable products and consumption patterns to be monitored over time. It will also allow hotspots associated with product life cycles to be identified, making it possible to prioritise eco-innovation activities.
- Scenarios can be calculated to assess the impacts of policy measures[4] with regard to more environmentally sound goods and services and to various growth scenarios. For example, Euro-norms for emission limits on cars. The indicators provide a baseline for comparing future-orientated scenarios.

The remainder of chapter 1 reviews the products to be included in the basket and methodological considerations that must be addressed in order to include them. Further detail on these methodological considerations can be found in the indicators framework (EC, 2012a). Chapter 2 discusses the implementation of the preliminary calculations. Chapter 3 discusses the results for EU-27 and the selected Member State (Germany).

1.2 ANALYSIS OF EXISTING STUDIES TOWARDS THE SELECTION OF PRODUCT GROUPS

Studies relevant to the selection process of product groups and products have been reviewed in the indicators framework (EC, 2012a). The key considerations are briefly summarised in this section. More details can be found in the indicators framework (EC, 2012a).

Several projects have been carried in the context of quantifying the environmental impacts of production and consumption of products within the EU, both including and excluding trade. These studies have been reviewed to (1) identify relevant products with high total environmental impacts for the basket-of-products to be defined in this section, (2) understand the methodological approaches taken, including strength and weaknesses, and (3) highlight recommendations made by other researchers to overcome these obstacles.

[3] Goods and services together are products.

[4] According to the ILCD Handbook, such policy scenarios require a consequential modelling.

Five main approaches can be identified for quantifying the environmental relevance of product groups:

- Environmentally extended input-output analysis,
- Household expenditure and consumption data based on Eurostat (2008a),
- Production figures and market penetration of product groups within the EU and its Member States,
- Industry sector studies on their respective products, and
- Life cycle inventory (LCI) data for goods and services.

Goods or services need to be considered if they have (1) high impact per unit and a large number of units are sold, (2) high impact per unit but a small number of units are sold, or (3) low impact per unit but a large number of units are sold. Goods and services sold in low volumes with a low impact per unit can be ignored.

Our main observations from the studies reviewed were that:

- Meat products followed by dairy products are the key drivers within the food and beverages category,
- The greatest impact has generally been found to be caused by cars in private transport, and
- Energy usage for room and water heating has typically been identified as the single-most important factor in housing.

TABLE 1 BASKET OF PRODUCTS CHOSEN FOR THIS STUDY

Consumption category	Product group	Product
Nutrition	Meat and seafood	Beef, pork, poultry
	Dairy products and eggs	Milk, butter, cheese
	Crop-based products	Sugar, vegetable oils & fats
	Vegetables	Potatoes
	Fruits	Apples, oranges
	(Non-)alcoholic beverages	Coffee, beer
Shelter / private housing	Single-, two-family and terrace houses	Single house
	Multi-family houses	Multi-family house
	High-rise buildings	High-rise building
Consumer goods	Clothing	Shoes, cotton shirt
	White goods	Washing machine, refrigerator, dish-washer
	Consumer electronics	Laptop
Mobility	Private transport	Mid-class car
	Public transport	Travel by train, bus and plane
Services	Bars & restaurants	(Omitted from this study)
	Leisure activities	(Omitted from this study)
	Education	(Omitted from this study)
	Tourism	(Omitted from this study)

Following reviewed literature, Table 1 (see also the indicators framework (EC, 2012a)) structures goods and services for apparent consumption by consumption categories and product (sub) groups. Consumption categories encompass nutrition, shelter / private housing, consumer goods, mobility and services. Each of these categories can be further divided into product groups (e.g. private transport), products (e.g. car) and sub-products (e.g. Euro IV Car).

This list is further refined by balancing the environmental relevance of products with life cycle inventory (LCI) data availability, resulting in the product selections shown in Table 1. The service categories have been omitted from this study due to a lack of reliable statistical and LCI data.

1.3 METHODOLOGICAL ASSUMPTIONS

There are several methodological aspects addressed in the indicators framework (EC, 2012a) which require attention in order to generate a consistent framework to calculate the indicators. The key considerations are listed briefly below. Further elaboration takes place in section 1.4 for each consumption category:

- Reference system relates to the consumption on a per capita basis for the region of investigation, i.e. EU-27 and its Member States (Germany in this project).
- System boundary encompasses a cradle-to-grave approach for all products within each consumption category, i.e. production, use stage and end-of-life.
- Double counting can occur within the basket-of-products for certain products, mainly due to the way that some products are aggregated in the statistics, as well as due to the choice of allocation of impacts to products. Ideally, a cradle-to-grave approach should be applied to all products within each product group and within each consumption category. The use stage would be counted twice when taking the cradle-to-grave approach for e.g.
    - shelter/private housing and consumer goods; and
    - shelter/private housing and nutrition.

The approach taken to avoid double counting is the following: for products which are listed under the consumption category consumer goods, the energy and material consumption and waste generation during their use stage are subtracted from the use stage of a house. This is possible as detailed information is available for, e.g., energy consumption of households[5] and consumer goods[6]. (However, substantiated assumptions need to be made for the use of consumer goods.) This approach ensures that all environmental impacts are covered either by detailed product-specific information or by aggregated household consumption figures.

For nutrition, the ´farm to fork´ inventory is included, as well as the waste management of human faeces by wastewater treatment plants. All energy and water consumed by white goods to store food/beverages, to assist with food preparation and to clean up after food is prepared is included in the use stage of these white goods.

Double counting is also possible between the use stage of transport (particularly private transport) and the final distribution of products (particularly nutrition and consumer goods) because one important reason to travel is to collect goods from retail stores and other people. Double counting is avoided by including only the distribution from production facility to retail store with the product itself. The final collection step is included in the use stage of transportation.

[5] Graus et al. (2009) provide a prospective breakdown for electricity use in 2050 by type of appliance based on Bertoldi and Atanasiu (2006), IEA (2006), and WBCSD (2005) assumed for all regions: standby (8%), lighting (15%), cold appliances (15%), appliances (30%), air conditioning (8%) and other (e.g. electric heating) (24%).

[6] EuP Directive 2005/32/EC – Directive for energy using products.

Allocation of environmental impacts from the production and end-of-life stages of long-living products: This imposes challenges for a consistent macro indicator which shall monitor the changes on an annual basis. The methodological conventions developed shall reflect the impacts within the reference year and region. This applies to products with a lifetime longer than one year, particularly the consumption categories shelter/private housing, consumer goods and mobility. Micro and macro data are required in order to quantify the total environmental impacts of long-living products in a given year within the reference region.

In the preliminary calculations, the impacts of the production stage are annualised over the lifetime of the product by summing the past impacts due to production of all products still in use in the reference year and then dividing them by the product's lifetime[7]. The annualised impacts of production are then divided by population in order to derive total annualised impacts of the production stage per capita. This approach will, for example, allow close monitoring of energy consumption and its associated environmental impacts.

As all products currently in use will also have to be disposed of at the end of their useful lives, the same approach is used to allocate the impacts from disposal (due to landfill, incineration and recycling). Just as the impacts of past production are equally distributed over the entire useful life, the impacts of future disposal are distributed over the entire useful life in the same way.

Implementation of the basket-of-products approach requires a range of life cycle inventory (LCI) datasets which are scaled by macro consumption statistics. Documentation for the production, use and end-of-life stages of each dataset can be found in the next section. In these calculations, unless stated otherwise, all upstream data for raw materials, energy, transport, etc. come from the GaBi Professional Life Cycle Assessment Database (PE International, 2007). However, for future calculations the life cycle data will be obtained from wider sources[8] and with increasing reliance on data from the International Reference Life Cycle Data Network.

The final distribution stage (i.e. distribution from production facility to customer) is documented here because the same set of assumptions is applied to most of the datasets. These assumptions are as follows:

- Distribution between manufacturing facility and major port: 100 km by truck.
- Distribution between ports: Calculated as a weighted sum of rail and sea freight based upon the import mix from Eurostat. Rather than calculate the import distances for all trading partners, a threshold has been set at 80% of total production. That is, import countries are added to domestic production until at least 80% of apparent consumption is accounted for. The distribution required from these countries is then assumed to represent the remaining 20% of the import mix. (If the product is imported in small quantities from many countries then the number of import countries is limited at 9.) Distances were calculated from a major city within each export country to Frankfurt, Germany. Frankfurt was chosen for EU-27 and Germany because it is relatively central geographically, both within Germany and within EU-27 as a whole. All sea freight is assumed to arrive in Hamburg, Germany's largest port, and then be forwarded 493 km by rail to Frankfurt. Due to the items in the basket of products, it is assumed that no air freight is required.[9] Once goods have arrived in Frankfurt, it is

[7] One average lifetime per product is assumed rather than varying lifetimes depending on the year of manufacture; the latter would be to difficult especially for buildings. For average lifetimes of consumer goods see Swedish Environmental Protection Agency (1999).

[8] The detailed listing of data sources and providers is available in the LCA Resources Directory (http://lct.jrc.ec.europa.eu/assessment/directories).

[9] This assumption is justified as all items in the basket are sold in high volumes and most are either low value (e.g. cotton shirt) or bulky (e.g. washing machine), making them good candidates for freight by sea and rail. As nutritional products are perishable, some are distributed by air freight. However, a study of food miles in the UK in 2006 found that air freight accounted for less than 1% of food transport overall (Holding et al. 2009, p. 53) and

assumed that a further 300 km transport by truck is required. This is designed to account for warehousing and distribution to retail outlets.

- Collection of products from retail outlets is not included in the distribution stage; rather it is considered to be part of the use stage of transportation.

In the case of Germany, products produced domestically are considered to only require the 300 km truck freight. All trade within EU-27 is grouped together and EU-27 is treated as a single region with an average freight mix. This average mix was calculated as the sum of the distance between the capital of each EU-27 Member State and Frankfurt weighted by the Member States' population. This calculation results in an average sea freight of 688 km, average rail freight of 694 km and average truck freight of 400 km (i.e. 100 km + 300 km). The details of this calculation are given in Table 14 on page 68. A complete overview of transport distances and modes is given in Table 15 on page 69 for EU-27 and Table 16 on page 70 for Germany.

Means of mobility have been assumed to have no distribution stage. In the case of buses, trains and planes, these vehicles will typically be driven/flown to their new owner. In these cases, the impact of relocation is considered by be negligible relative to the impact of their use stage. Cars may be carried in a container or on a truck; however, the impacts of this transport are negligible when compared to the impacts of driving the car regularly.

The distribution stage for buildings is also omitted. Buildings are somewhat unique in that crushed stone and gravel for concrete often makes up a large part of the total mass of the building and, due to its high mass and low value per tonne, transport of more than 50 km can double the cost of this base material (Wilson, 2007). This means that crushed stone is almost always sourced locally (<100 km radius) and, therefore, it would be necessary to separate building materials by type and apply different transportation mixes to each type to accurately reflect the distribution stage. This has not been attempted in this study.

The average calculations for distribution described above are necessary in the current implementation of the basket of products because LCI data were not available for every region where products are produced before being imported into EU-27 or Germany. There is no separate distribution calculation because each LCI dataset for the production stage is assumed to include distribution to the retailer. This allows a great deal of flexibility when choosing the most appropriate transport modes and distances for a particular product in a particular reference year. However, as the current implementation typically uses one or two production LCI datasets to represent the full production mix, it was not possible to adequately account for the distribution stage without including an average distribution figure (rather than a region-specific distribution figure).[10]

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the items in the basket were considered suitable for refrigerated distribution, which is less time critical than if the goods were shipped fresh.

[10] In principle, the choice of average distribution factors could create a problem where the distribution stage for German products would be over-estimated. This would only occur when both German and EU-27 production LCI datasets were selected together for the same product within the protytpe (i.e. production within Germany + imports from EU-27 imported into Germany). The reason for the problem is that the German LCI datasets include a weighted distribution mix which already accounts for imports from EU-27, but the weighted EU-27 mix would also be applied on top of this. One solution to this would be to have separate EU-27 LCI datasets for the EU-27 and German tools. However, this was not necessary in this case because there were no instances within the preliminary calculations where the EU-27 and German datasets varied by more than the distribution mix, meaning that the German datasets could be applied for both Germany and EU-27. As more LCI datasets are added, the choice of an average distribution mix should be revisited. It would be preferable to include a specific distribution mix from the country of production to the country of import for each production LCI dataset.

1.4 APPLICATION OF THE METHODOLOGY TO CONSUMPTION CATEGORIES

1.4.1 NUTRITION

GENERAL DESCRIPTION

Food and beverages are amongst the most important consumer goods, satisfying the basic physiological needs of hunger and thirst and forming one of the most recurrent expenditure items for the majority of EU households. There is great diversity of food and beverage products across the EU, and these often form a part of local, regional and national cultural identity. At the same time, there are examples of convergence in consumption patterns, perhaps reflecting greater consumer awareness and increasingly international distribution networks.

The proposed list of nutritional products comprises of the product groups meat and seafood, dairy products and eggs, crop-based products, vegetables, fruits and beverages.

These product groups coincide with the basket of products of the "from farm to fork" statistics of Eurostat. The basket of nutritional products is apparently representing the main categories of private consumption expenditures in EU-27 (Figure 1)[11]. The basket of nutritional products also represents the main nutrition products on a mass basis (Federal Ministry of Food, Agriculture and Consumer Protection, 2008).

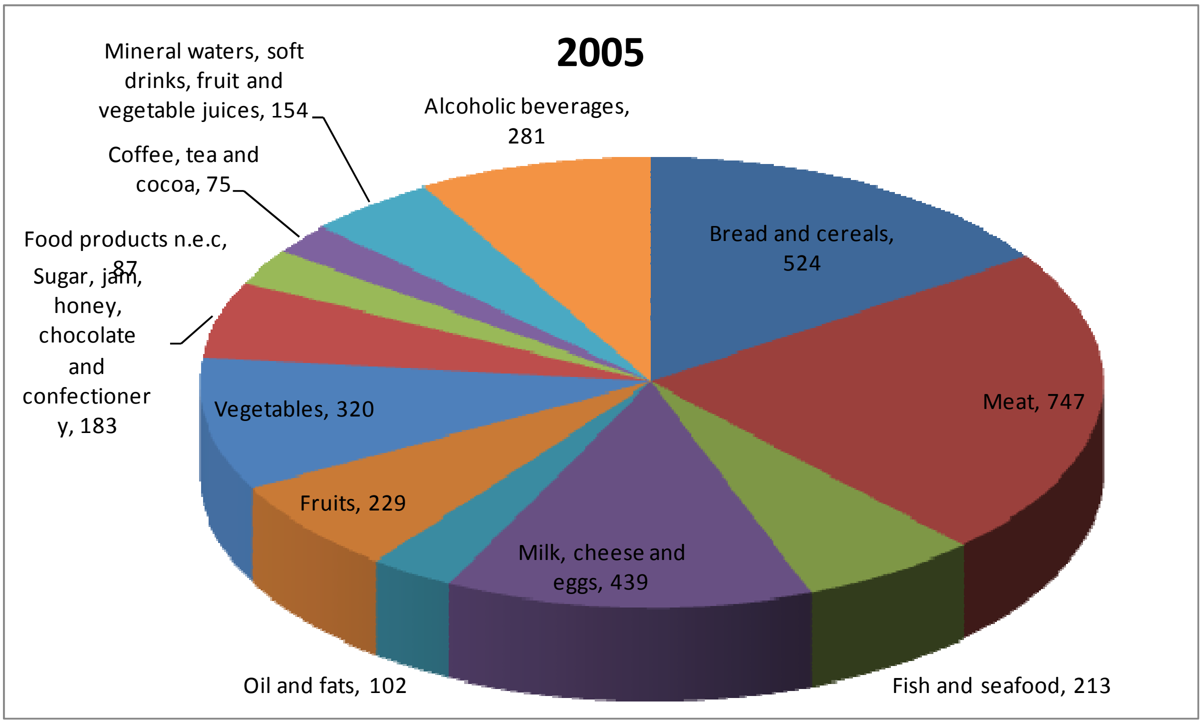

FIGURE 1 AVERAGE CONSUMPTION EXPENDITURE BY DETAILED COICOP LEVEL (IN PPS[12]), EU-27 IN 2005

[11] Note that the expenditure data for Germany are very similar.

[12] A PPS converts every national monetary unit into a common reference unit, the "Purchasing Power Standard", of which every unit can buy the same number of products across the countries in a specific year (Eurostat, 2003).

TECHNICAL DESCRIPTION OF EACH PRODUCT[13]

- Beef: Beef cattle are cattle raised for meat production (as distinguished from dairy cattle). While the principal use of beef cattle is meat production, other uses include leather and by-products used in shampoo and cosmetics. In EU-27 the volume of sold production of fresh or chilled cuts of beef and veal was 2619 thousand tonnes in 2006. There was also substantial net export (17000 tonnes) of fresh or chilled cuts of beef and veal, i.e. imports 16 000 tonnes versus exports 33000 tonnes. Fresh or chilled cuts of beef and veal imports sum up to 975 million € compared to exports of 81 million €. Consumed fresh or chilled cuts of beef and veal have a market value 12460 million € at an average price of 4.76€/kg (Eurostat, 2008a).

- Pork: In 2006 21.8 million tonnes of pork (= 161 million pigs) was produced within EU-27. The largest producers of pork were Germany, Spain, France, Poland and Denmark. These Member States reported the highest per capita apparent consumption of pork, all recording averages in excess of 50 kg, while the average EU-27 gross human apparent consumption was 41.3 kg per year (Eurostat, 2008a).

- Poultry: In 2006 8.7 million tonnes of poultry (=1.5 billion poultry birds) was produced in 24 EU Member States (Belgium, Bulgaria and Romania were not reporting). The largest producers were France, Germany, Poland, Spain and the UK. No average EU consumption figures were reported; however, the consumption ranges between 70 kg per capita per year in Austria to ~160 kg in Denmark and the Netherlands (Eurostat, 2008a).

- Milk, butter and cheese: For a little over 20 years, the volume of milk produced in the EU has been limited by production quotas. An estimated 154.1 million tonnes of milk were produced on farms across EU-27 in 2005, some 80.9 % of which came from the EU-15 Member States, with more than half (52.2 %) of the EU's total milk production being accounted for by Germany (18.5 %), France (16.6 %), the United Kingdom (9.5 %) and Italy (7.7 %). Of the 148.1 million tonnes of milk produced across EU-27 in 2006, the vast majority (89.5 %) – some 132.5 million tonnes of milk – was collected. The collected milk was used to produce 32.5 million tonnes of market milk, 2.5 million tonnes of cream for direct consumption, 0.868 million tonnes of skim milk powder, 1.758 million tonnes of butter and 8.67 million tonnes of cheese. The average per capita apparent consumption of milk, cheese and butter in the EU was just over 100 kg, of which more than 80 % was accounted for drinking milk (Eurostat, 2008a).

- Sugar: In 2006, the sold production of refined white cane or beet sugar in solid form in EU-27 was about 19.3 million tonnes at 11.4 billion €, or 0.59 €/kg on average. The quantity of sugar imports (including sugar preparations and honey) fluctuated within a relatively narrow range between 2000 and 2007. Imports of molasses fell sharply in 2005, but recovered in 2007, whereas sugar cane and beet increased over the period studied, despite falls in 2003 and 2007. By 2007, India had replaced Pakistan as the main source of EU-27 sugar imports, with the latter dropping to fourth place. In quantity terms, the EU was, in 2006, a net exporter of large quantities of refined white sugar, recording a trade surplus of 5.5 million tonnes, valued at 1.6 billion €. Among the products taken into account, apparent sugar consumption varied least between Member States, i.e. 34.8 kg per year EU-27 average in

[13] In general, data for the indicator year 2006 were collected. Due to the nature of the Eurostat from farm to fork statistics, some data are for 2005 or 2007 which is particularly marked. Seen from longer time series of consumption in German agricultural statistics this does not appear to be a major restriction for the envisaged reference period. In addition, some EU-27 data are not really sharp for a single year but use data on Member State level for adjacent year if not available for the questioned year (see e.g. sugar consumption).

2007[14] (Eurostat, 2008a).This sugar consumption comprises direct sugar as well as sugar contained in products, and no other specific data are available for EU-27. However, in the case of Germany, data on sugar by end use are available (Table 3).

- Vegetable oils generated a turnover of 38.6 billion € in 2005 which is about 4.5% of the total turnover of food products and beverages. The principal consumers of vegetable oils and fats are Greece, Spain and Italy. The gross human apparent consumption per capita (available for human consumption) was 17.5 kg per year in 2007 in EU-27[15] with Greece on top at 48.6 kg per year (Eurostat, 2008a).
- Potatoes: Germany and Poland were the largest producers of potatoes, accounting for one third (33.5 %) of EU-27 production. In EU-27, 56.7 million tonnes of potatoes were produced in 2006. Gross human apparent consumption per capita (available for human consumption) was 74.7 kg per year on EU-27 average in 2007 while consumption of potatoes was highest in Ireland and Poland (123 and 121 kg per year respectively). The average consumption of potatoes has been stable since 1996 (Eurostat, 2008a).
- Apples: The majority (56.1 %) of the EU's apple production in 2006 came from Poland, France and Italy, i.e. total apple production within EU-27 was 11.6 million tonnes in 2006. The annual apparent consumption of oranges, apples and pears together exceeded 55 kg per capita on average. The gross human apparent consumption of apples per capita (available for human consumption) was 17.7 kg per year on EU-27 average in 2007[16] (Eurostat, 2008a).[17]
- Oranges: Orange production is concentrated in the Mediterranean Member States, particularly Spain (48%) and Italy (35%). Approximately 6.7 million tonnes of oranges were produced in EU-27 in 2006 and the annual apparent consumption (2007) was ~33 kg per capita on average. However, there is large variation in orange consumption: in France it exceeds 100 kg per capita and year, while the average consumption just above 5 kg per capita in the United Kingdom, Germany and Austria (Eurostat, 2008a). Overall fruit crop consumption is subject to large variation with a sharp increase from 2003 to 2004.
- Coffee: The volume of extra EU-27 trade in 2007 shows a significant net import (import minus export) of coffee, i.e. 2.6 million tonnes (= 4.2 billion €). In EU-27, 1.6 million tonnes of roasted, caffeinated coffee was sold in 2006 (= 8.0 billion €). There is a net export trade of roasted, caffeinated coffee outside the EU, with 51 kt exported net in 2006 (= 203 million €; Eurostat, 2008a). The average consumption of coffee per person in EU-27 is 147.5 litres per year which equals about 3 kg of roasted coffee.
- Beer: Total European beer production in 2003 was 343.750 hL according to the Deutscher Brauer-Bund (Pattinson, 2010). In 2003, average beer consumption was ~70 l per capita and year (Pattinson, 2010), ranging from 30 l in Italy to 160 l in the Czech Republic (Brauwelt Brevier, 2005, p.20). All Member States apply an excise duty on beer (15-25%). Across the EU as a whole, the share of household consumption expenditure on alcoholic beverages was fairly evenly split between spirits (0.5%), wine (0.7%) and beer (0.6%), although there were large variations in some Member States (Eurostat, 2008a).

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[14] Latest year available has been used to replace data that were not available for 2007. For EU value: Average of available countries using previous reference periods when no data were available for 2007.

[15] Latest year available has been used to replace data that were not available for 2007. For EU value: Average of available countries using previous reference periods when no data were available for 2007.

[16] Average of available countries using previous reference periods when no data were available for 2007.

[17] Please note: bananas have a total volume that exceeds the ones of apples by one order of magnitude. The apparent consumption of oranges is 33kg per annum, while apples and tomatoes are 17.7 kg per annum and 17.4 kg per annum respectively. However, there were no LCI data available for these products.

METHODOLOGICAL CONSIDERATIONS

- Reference system refers to the per capita consumption in Germany and EU-27 for the above listed products.
- System boundaries: For the production of food a cradle-to-grave approach is taken. The preparation of the food and the actual use stage, i.e. consumption of food by humans, as well as the after-use stage, i.e. the treatment of urine and faeces from humans in wastewater treatment plants, are included in the analysis.
- Lifetime of food products are considered to be less than 1 year.
- Use stage is the actual consumption of food, while the preparation of food, e.g. cooking of potatoes, is considered to be part of the production. Any associated domestic energy consumption is factored into the energy demand of white goods, i.e. is not part of the food life cycle but of the cooking devices, fridges etc. This is a solution that could be revisited towards allocating cooking/cold-storage energy to the various food and drink products.
- End-of-life covers the waste management of human faeces by wastewater treatment plants and collection of food scraps as part of the municipal solid waste stream. The carbon balance is maintained; however, other impacts due to the landfilling and/or composting of food scraps are omitted.
- Double counting is not expected as long as the effort for preparing food (electricity and / or thermal energy demand for cooking) is covered by the energy consumption of white goods in a household and is excluded from the analysis of food preparation.
- Allocation of environmental impacts during food production, e.g. sunflower oil and sunflower cereal cake, is resolved on the basis of economic allocation. Further specific allocation recommendations are being considered in e.g. the European Food SCP Round Table[18].

DATA SOURCES

Statistical data are available for EU-27 and Germany. On a European level there are two main sources to be considered, i.e. ´From farm to fork´ statistics of Eurostat (2008a and 2008b) and expenditure consumption data. For Germany there are time series and annual statistical data available from the German Federal Ministry of Food, Agriculture and Consumer Protection (2008) and expenditure data from private households from the German Federal Statistical Office (2003).

The level of detail of statistical data is presented in Figure 1. In general, the German ministerial statistics provide a high level of detail which cannot be obtained for EU-27. It was therefore anticipated to use Germany as example for the indicators derived under (relatively) good conditions.

LCI datasets for the production stage are summarised briefly in Table 2. A full list of literature sources for each dataset can be found in Table 18 on page 71. In this study, the use stage of nutritional products has been included with the energy and water consumption of white goods. Due to difficulties in modelling the end-of-life stage of food, the end-of-life datasets only includes a release of biogenic CO_2 to the environment so that a carbon balance is maintained. The calculations for these releases can be found in table 17 on page 71.

While there is good data availability to begin with, there are several assumptions that need to be made to enable this data to be used in the context of this project. This is illustrated using the example of sugar below.

[18] http://www.food-scp.eu/

TABLE 2 OVERVIEW OF LCI DATASETS FOR NUTRITION

Product	Production Stage
Coffee	Industry data for the production of coffee in Costa Rica in the 2009 reference year. The dataset includes growing, harvesting and roasting of coffee beans.
Beer	Production of 1 litre of Italian lager beer from Cordella et al. (2008) assuming local EU-27 / German electricity, water and barley. Barley grain datasets were derived from Ecoinvent (2010). All other upstream data was from the GaBi (2006) database. Packaging (bottle, keg, can) was excluded due to high rates of reuse and recycling in Europe. Spent grain assumed to go to landfill with energy recovery.
Beef	Production of a 1 kg boneless cut of beef in Germany in the 2010 reference year. Data were derived from literature and interviews.
Pork	Production of a 1 kg boneless cut of pork. The dataset was based on literature for US production in the 2010 reference year, but the electricity grid mix has been adapted to better reflect EU-27 and German production.
Poultry	Production of a 1 kg boneless cut of chicken. The dataset is based on US production (based on sources from literature) and a US electricity grid mix in the 2010 reference year.
Milk	Production of 1 kg of milk from dairy cows in Germany in the 2009 reference year. Based on data from industry supplemented with published literature.
Butter	Production of 1 kg of butter from dairy cows in the USA in the 2009 reference year based on a US electricity grid mix. Based on industry and literature sources.
Cheese	Production of 1 kg of soft cheese (bresso) from cow's milk in Germany in the 2009 reference year. The "Milk" dataset above was used as upstream data for cheese production. Data for cheese production was derived primarily from industry data.
Sugar	Production of 1 kg of sugar from sugar beets. Data is for Europe in the 2008 reference year and is based primarily on literature sources.
Sunflower Oil	Production of 1 kg of sunflower oil from sunflower seeds containing 20% water weight/weight. Data for both growing/harvesting the seeds and for production of the oil is for France in the 2007 reference year and is derived from literature.
Potatoes	Production of 1 kg of potatoes in Germany in the 2010 reference year. Primary data were derived from industry.
Apples	Production of 1 kg of apples in China in the 2009 reference year. The dataset reflects a Chinese electricity grid mix and was based primarily on industry data.
Oranges	Production of 1 kg of oranges in the USA in the 2010 reference year. The dataset reflects a US electricity grid and it was based primarily on data from literature.

EXAMPLE: SUGAR

Raw and derived data for the consumption of sugar in Germany for nutrition are presented in Table 3. The supply and use data from the German Federal Ministry of Food, Agriculture and Consumer Protection (2008) show that, e.g., in 2006/07 32.1 kg sugar were consumed by each German citizen on average as direct sugar and sugar contained in products. The ministerial statistics do not explicitly state the share of direct sugar. The latter statistic was estimated from the Ministry's data on sales of sugar factories and trade companies and arrived at ca. 6 kg per person and year (the cells highlighted in green in Table 3).

The issue of direct and indirect use for nutrition applies for other products as well, e.g. potatoes. Comparing German statistics with data from Eurostat's farm to fork statistics, it was found that the latter report direct and indirect use as data a combined statistic. This means that data for direct consumption in EU-27 also needs to be derived from estimates.

Another question that emerges from this example is which level of detail for the product needs to be addressed for the inventory. The two most important kinds of sugar are beet sugar and cane sugar. The table below highlights that the entire domestic German production of white sugar is practically beet sugar. Cane sugar may be imported directly as the import statistics classification shows, i.e.

- Raw cane sugar, for refining (excluding added flavouring or colouring),
- Raw cane sugar (excluding refining and added flavouring or colouring),
- Raw beet sugar, for refining (excluding added flavouring or colouring),
- Raw beet sugar (excluding refining and added flavouring or colouring),

- Refined cane or beet sugar, containing adds flavouring or colouring, in solid form,
- White sugar, containing in dry state ≥99.5% sucrose (excluding flavoured or coloured), and
- Cane or beet sugar and chemically pure sucrose, in solid form (excluding cane and beet sugar containing added flavouring or colouring, raw sugar and white sugar).

However, in Germany most of the imported (and exported) sugar is white sugar (93% for both in 2004), for which the share of cane sugar may only be estimated based on the country of origin of imports and their specific sugar feedstocks for domestic production. The issue of more specific data requirements than the statistics provide may be relevant also for other nutritional products. For instance, vegetable oils and fats produced in Germany from imported feedstocks (e.g. rapeseed, soy and sunflower seed) may have very different environmental impacts and may therefore deserve specific consideration.

TABLE 3 MACRO DATA FOR SUGAR CONSUMPTION PER CAPITA AND YEAR IN GERMANY

Item (1000 t)	2004/2005	2005/06	2006/07	Remarks
Production	4334	4052	3288	
of which: from domestic harvest of sugar beets	4296	4049	3289	
of which: from other sources	38	3	-1	Negligible
Initial stock	1196	1382	954	
Closing stock	1382	954	1113	
Import				
as sugar	550	638	553	Virtually all white sugar
as sugar-containing products	1027	1088	1122	
Export				
as sugar	1365	1909	749	Virtually all white sugar
as sugar-containing products	1243	1310	1376	
Domestic use	**3117**	**2987**	**2679**	
Feed	2	2	2	
Industrial use	27	25	38	
Nutritional consumption (total)	**3088**	**2960**	**2639**	Includes direct sugar and sugar in products
Nutritional consumption (kg/capita)	**37.4**	**35.9**	**32.1**	
Self-supply ratio (%)	139	136	123	
Sugar sales of sugar factories and trade companies	3202	3150	2855	
of which: sugar for households	518.3	498.4	448.7	
of which: sugar for processing	2683.7	2651.6	2406.4	
Sugar for households, processing, export, and stock	4753	4631	3763.1	
of which: from domestic production	4334	4052	3288	Assuming total domestic production
of which: from imports	419	579	475.1	From difference only
Import direct sugar not allocated	131	59	77.9	From difference only
Direct consumption (total)	649	557	527	Assuming sugar for households + unallocated imports of direct sugar
Direct consumption (kg/person)	7.9	6.8	6.4	

1.4.2 SHELTER/HOUSING

GENERAL DESCRIPTION

For the consumption category “shelter”, the basket of products consists of three product groups that correspond to the groups defined in the IMPRO-Building study (Nemry et al., 2008). For each group, one dwelling in a representative building of the group is chosen as the representative “product” for the group, i.e. a dwelling in a single house, multi-family house or high-rise building.

Calculations of environmental impacts relate to the number of dwellings in each building type “consumed” privately per person and per year in the region of investigation (EU-27 and Germany). Impacts of the production stage are annualised over the lifetime of the building by summing the past impacts resulting from production of all products still in use in the reference year and then dividing them by the product’s lifetime.[19] The annualised impacts of production are then divided by population in order to derive total annualised impacts of the production stage per capita. Accordingly, the lifecycle-wide environmental impacts of a representative dwelling need to be expressed on an annual basis.

TECHNICAL DESCRIPTION

For each of the three building types (defined in the IMPRO study) in which dwellings are located, a reference building is chosen. The chosen reference building is always the most widely-used building type of the three building groups, i.e. single house, multi-family house and high-rise building.

LCI datasets for the production and end-of-life stages have been taken directly from the IMPRO study (Nemry et al., 2008). The single-family house was modelled with IMPRO building number Z2_SI_005, the multi-family house with IMPRO building number Z2_MF_003 and the high-rise with Z2_HR_001. As floor area used per person can change over time (which will have a significant influence on the overall environmental impacts), new LCI datasets must be added over time in order to account for these changes.

Rather than calculate energy consumption of the dwelling from its type, which could lead to multiplication of small errors, the average energy consumption (fuels for space heating, electricity etc.) are taken from EU or national energy statistics.

TABLE 4 SELECTION OF REFERENCE BUILDINGS

Building group	Single house	Multi-family house	High-rise building
IMPRO number	Z2_SI_005	Z1_MF_003	Z1_HR_001_ex
Construction year	1945-1980	1945-1990	Since 1975
Dimension	10m*9m	32m*12m	30m*15m
Storey	1-2	4	10
Floor to floor height	3 m	3 m	3 m
Roof	Pitched roof, brick	Pitched roof, brick	Flat roof, bitumen layer
Exterior wall	Brick masonry 35 cm	Brick masonry 35 cm	Brick masonry 35 cm
Interior load-bearing wall	Brick masonry 20 cm	Reinforced concrete 20cm	Reinforced concrete 20cm
Interior wall	Plasterboard 10 cm	Plasterboard 10 cm	Plasterboard 10 cm
Floor	Reinforced concrete	Reinforced concrete 20 cm	Reinforced concrete
Basement wall	Reinforced concrete	Reinforced concrete 20 cm	Reinforced concrete
Basement ceiling	Reinforced concrete	Reinforced concrete	Reinforced concrete
Foundation	Concrete	Reinforced concrete	Reinforced concrete
Window	Plastic frame, double-glazing	Wooden frame, double-glazing	Plastic frame, double-glazing
Size	119.75 m2	72.07 m2	72.07 m2

[19] One average lifetime per product is assumed rather than varying lifetimes depending on year of manufacture. See note 7.

METHODOLOGICAL CONSIDERATIONS

- Reference system refers to the living space per capita in Germany and EU-27 for the considered reference buildings.
- System boundaries: The “shelter / private housing” consumption category is addressed with a cradle-to-grave approach.
- Lifetime: In contrast to cars or white goods for which disposal or recycling can be assumed after a certain lifetime, houses are sometimes completely renovated resulting in a very long lifetime. Calculating an average lifetime for a house/dwelling in Europe is therefore extremely difficult, a fact which is further complicated because part of the stock was built before consistent statistics were established. In addition, the German statistics on housing (Federal Statistical Office, 2010b) reports a negative outflow for single-family houses for the last 10 years which would not result in a meaningful lifetime. The IMPRO study (Nemry et al., 2008) uses a maximum lifetime of 40 years, which is, for part of the dwelling stock in Europe, certainly too short. However, 40 years could be seen as a reasonable renovation cycle, i.e. whether the building is demolished after 40 years or completely renovated. 40 years is therefore also assumed for all building types in this report.
- Use stage: The following are considered: combustion of natural gas, consumption of electricity, consumption of water, treatment of waste water and collection of municipal solid waste. Combustion of fuel oil, wood and other fuels for home heating are not included as insufficient data were available. Treatment of solid waste (landfill, incineration, recycling, etc.) is associated with the product to which it applies. The influence of changes in technology on the energy consumption of households, e.g. better insulation measures, is reflected in the overall fuel and electricity consumption per household. Renovation of buildings is considered, but on-going maintenance is not.
- End-of-life: A generic approach for the end-of-life of buildings is chosen. Inert materials like bricks and plaster are landfilled, high calorific materials like wood and plastic are incinerated with energy recovery, and metal scrap is recycled.
- Double counting: Double counting can be an issue when the use stage of the representative dwelling includes the use stages of appliances, such as white goods and consumer electronics. A pragmatic modelling approach to overcome this issue consists of subtracting from the use stage impacts of a representative dwelling the energy and material consumption and waste generation from the use stage of other products (e.g. white goods) included elsewhere in the basket of products.

DATA SOURCES

Every three or so years a different Member State produces a collection of the most up-to-date statistics on housing in the European Union. The data used here for Europe were published in 2006 by Italy (Ministry of Infrastructure of the Italian Republic, 2006).

The Committee on Housing and Land Management of the United Nations Economic Commission for Europe (UNECE) used to produce a Bulletin of housing statistics every two years. The latest Bulletin was published in 2006 and since then the service has been discontinued (UNECE, 2006).

The German statistical office has long time series on housing statistics publicly available (in German) from its website. These data cover, among other things, the stocks of buildings and dwellings, as well as the flows of completed buildings and dwellings, and of buildings and dwellings demolished or otherwise removed from the housing stock (Federal Statistical Office, 2010a, 2010b).

LCI data for house production were taken from the IMPRO study (Nemry et al., 2008). These figures are for the production stage only. For the use stage in EU-27, statistics for consumption of electricity, natural gas and water, and for collection of solid waste were sourced from Eurostat (2009, 2011a, 2011c, 2011e). For the use stage in Germany, statistics for natural gas, electricity and municipal waste collection were sourced from Eurostat (2009, 2011a, 2011c) and water from the German Federal Environment Agency (2009) and German Federal Statistical Office (2007). In both cases it was assumed that the production of waste water going to municipal treatment was equivalent to the consumption of fresh water. Only natural gas and electricity were considered for space heating and cooking; all other fuels, e.g. fuel oil and wood, were omitted.

EXAMPLE: SHELTER/HOUSING

For the consumption category "shelter/private housing" of the basket of products, three building sizes are considered as product groups. In each group, lifecycle-wide environmental impact data of representative dwellings are combined with macro data on the stock of dwellings of the same type in a given year in the region under consideration. This section presents an example of such macro-data for dwellings in one and two-family houses in Germany (Table 5).

The data required for linking with life cycle inventory (LCI) data are those regarding the stock, past additions to stock, average lifetime, and population. From these we can calculate the total number of dwellings "consumed" per year, by dividing the stock by the average lifetime. One more division by the population and we obtain the number of dwellings "consumed" per capita and per year.

In the German statistics, dwellings are reported as belonging to residential or non-residential buildings. The difference between the two categories resides in the share of the floor area of the building that is used as residence by households (the threshold is set at 50% of the floor area). Dwellings in residential buildings are further differentiated into dwellings in one-family, two-family, and three-or-more-family houses. Dwellings in non-residential buildings are not further disaggregated according to the size of the building. In Table 5 we have aggregated dwellings in one- and two-family houses and neglected dwellings in non-residential buildings (for which there is no specific data).

Data for the two larger sizes of buildings considered in the consumption category "shelter" of the basket of products (multi-family houses and high-rise buildings) are not directly available. The German statistics do not make the distinction. Auxiliary data from the last report on housing statistics in the European Union can be used to estimate the share of high-rise buildings in the total stock and in the stock of multi-family houses. Such data are, however, only available for 2004. Therefore, assumptions need to be made (e.g. the share of high-rise buildings in the total stock can be assumed constant for some years earlier and later than 2004).

TABLE 5 EXAMPLE OF MACRO-DATA FOR ONE AND TWO-FAMILY DWELLINGS IN GERMANY

One and two-family dwellings in Germany	2004	2005	2006	2007
Completion of new dwellings	177 204	151 456	150 069	124 040
Stock of dwellings	17 933 798	18 087 964	18 240 238	18 365 864
<u>Outflow of dwellings</u>	<u>-2 552</u>	<u>-2 710</u>	<u>-2 205</u>	<u>-1 586</u>
Compare with outflow of dwellings from statistics (all building types)	87 898	53 397	46 998	44 359
Average lifetime (assumption)	40	40	40	40
Population (inhabitants)	82 531 671	82 500 849	82 437 995	82 314 906
<u>Dwellings per 1000 inhabitants</u>	<u>217</u>	<u>219</u>	<u>221</u>	<u>223</u>
<u>Total dwellings "consumed" per year</u>	**<u>298 897</u>**	**<u>301 466</u>**	**<u>304 004</u>**	**<u>306 098</u>**
<u>Dwellings "consumed" per 1000 inhabitants per year</u>	**<u>5.4</u>**	**<u>5.5</u>**	**<u>5.5</u>**	**<u>5.6</u>**

Source: Federal Statistical Office (2010b). Except for <u>underlined data that are calculated</u>.

Data on completed dwellings are also available. Combined with stock data, dwelling outflows can be calculated: outflow(t) = stock(t-1) + completed dwellings(t) - stock(t). As shown in Table 5, calculated outflows are negative. The stock seems to increase faster than it should if only completed new dwellings were added to the stock. It may be due in part to the construction work on existing buildings that are not accounted for in the flows of completed new dwellings but can have an influence on the stock of dwellings. For instance, four apartments, i.e. four dwellings, are created in an existing house (formerly one-family), meaning that the dwelling stock increased by 3, but these are not accounted for as completed new dwellings. Another aspect is that dwelling stocks reported in the statistics are actually estimates resulting from a dynamic modelling starting at the last complete census of building stock and taking as inputs yearly reports of new dwellings and of demolished dwellings.

As for the product group “private transport” (cars are another long-lived product), more detailed modelling would consider not only different sizes of buildings but also different years or periods of construction. The IMPRO-Building study has established building stocks for all EU Member States according to the three size categories already mentioned and three age categories (construction year before 1945, between 1945 and 1990, after 1990). Such data can be used for further developments of the model.

1.4.3 CONSUMER GOODS

GENERAL DESCRIPTION

For the consumption category “consumer goods”, the basket of products consists of three product groups – clothing, white goods, and consumer electronics – for which the following representative products are considered: cotton shirt, shoes, washing machine, refrigerator, dishwasher and laptop.

The choice of the product group clothing is based on the fact that it is a high-volume commodity. Cotton shirts and leather shoes are the most common clothing commodities with available LCI data and hence were chosen to be included in the basket (see also EC 2012a for more details). Cotton shirts also entail significant use-stage impacts from washing and drying. Standard use cycles for washing and drying have been taken from Bole (2006). However, these are included with the washing machine, not the shirt.

White goods, such as washing machines, refrigerators and dishwashers, are everyday household appliances with significant use-stage impacts in terms of power consumption. These are seen as fixed installations in households consuming energy in varying modes of operation including off, standby and active modes.

Laptops represent a rapidly growing share of the consumer electronics market with considerable impacts from the production and use stage. Since only commodities for private consumption are included in the basket, laptops are assumed to be used exclusively at home and are, therefore, treated in a similar manner to white goods in terms of use-stage considerations. Use cycles are sourced from Energy Star version 5 (Energy Star, 2011).

TECHNICAL DESCRIPTION

- Cotton shirt: A non-iron cotton dyed shirt weighing 290 g is assumed for the analysis. Production steps of the cotton shirt include cotton cultivation, ginning and bailing, fabric production, and shirt production. 50 washing cycles are assumed for the lifetime of the shirt (Bole, 2006). Production and external trade statistics of Eurostat (Table 19) resulted in apparent consumption of 8.4 shirts (including shirts, blouses and t-shirts) in 2006 for EU-27.

- Washing machine: A 7 kg load washing machine with 1200rpm spin speed is assumed for the analysis. The energy class for the use stage calculations is EU Class A washing machine. Production and external trade statistics of Eurostat (Table 19resulted in an apparent consumption of washing machines of 0.04 pieces per person and annum in 2006 in EU-27.
- Dishwasher: An 81.5 x 60 cm EU Class A dishwasher is assumed for the analysis. Production and external trade statistics of Eurostat (Table 19) resulted in an apparent consumption of dishwashing machines of 0.02 pieces per person and annum in 2006 in EU-27.
- Refrigerator: A fridge-freezer (fridge + freezer compartments) with approximately 260 l capacity and EU Class A fridge-freezer is chosen for the analysis. Production and external trade statistics of Eurostat (Table 19) resulted in an apparent consumption of 0.04 pieces per person and annum in 2006 in EU-27.
- Laptop: A 15" LCD display laptop weighing approximately 2 kg is chosen for the analysis. The laptop conforms to Energy Star 5 Category A. Production and external trade statistics of Eurostat (Table 19) resulted in an apparent consumption of laptops of 0.03 pieces per person and annum in 2006 in EU-27.

METHODOLOGICAL CONSIDERATIONS

Reference system:

The reference for the calculation of environmental impacts due to representative products from the three product groups clothing, white goods, and consumer electronics is the private consumption of one person in one given year. Consumption from other sources, e.g. commercial use, is excluded from the basket of products.

For ubiquitous consumer goods such as laptops this is a difficult task. First, companies buy products that in many cases do not differ from the ones bought by private households. Second, such company-owned consumer goods are also to some extent used for private purposes. Here, the laptops used by households were assumed to represent on average 40% share of the total (Schlomann, 2005).

Other products (such as dishwashers, refrigerators) exist in consumer and industrial sizes. The latter obviously should not be integrated into the basket of products. However, companies may also purchase items of the former category (e.g. fridges in hotel rooms).

System boundaries:

The system encompasses the production, use and end-of-life of a representative product. The use stage impacts for cotton shirts are primarily from washing and drying. When shirts are laundered professionally, it is the transport to the laundry that causes the main impacts (see also EC 2012a for further details). However, it is assumed here that all shirts are washed domestically. In this case, the impacts of washing are included in the use stage of the washing machine and the impacts of drying are included in the use stage of the house as there is no tumble drier or heater in the basket. Therefore, to avoid double-counting, washing and drying are not included into the lifecycle impacts of the cotton shirt. White goods and laptops have an explicit use-stage consumption which is subtracted from the energy and water consumption of the household.

Stock portfolio, e.g. level of technology: Technological improvements/time series variations in production parameters could be added into the tool if data becomes available. For example, assuming cotton shirts are produced with the same technology everywhere, time series variations in impacts will be observed due to changes in import mixes of finished and semi-finished products. Technological improvements in white goods and laptops will mirror Energy Star standards over the years.

End-of-Life:

Clothing is assumed to have a standard end-of-life scenario based on treatment of household waste as per the EU directive. Because good quality statistical data on the fractions (ferrous metals, plastics, etc.) of scrapped white goods and consumer electronics are not readily available, a "recycling potential" approach has been applied. This assumes that 100% of ferrous metals, aluminium and copper are recycled as these metals make up a significant part of the total products by mass, have economic value and are commonly recycled.

For EU-27, it is assumed that all other inert materials go to landfill. For Germany, it is assumed that the plastics are incinerated with energy recovery and the remaining materials are landfilled. This "recycling potential" approach over-estimates the credits given back to the system. These assumptions were considered justifiable given significant variation in end-of-life practices among Member States (recovery, reuse and recycling statistics for large household appliances under the WEEE Directive in 2006 suggest a 4% recycling/reuse rate in Poland vs. 97% in Greece; Eurostat 2011f, Table 2), the relatively low contribution of the end-of-life stage to total impact (even assuming 100% recycling of certain metals, as above) and relatively poor data on recycling fractions. However, new datasets can easily be added if the user wishes to test these assumptions.

Double counting

It is a potential issue in this consumption category and has therefore been accounted for in the system boundaries of each product. The main issue is energy and water consumption during the use stage of the different products. For instance, the impacts from the washing of clothes are included in the use-stage impacts of washing machines and the use-stage impacts of washing machines could potentially be included in those of the standard household. To avoid double counting, a clear distinction has been made in the definitions of the system boundaries such that the impacts of washing machines are subtracted from those of the household.

Allocation of environmental impacts from the production stage of long-living products

All of the products in this consumption category can be treated as long-living products. Here, the impacts of the production stage are annualised over the lifetime of the product by summing the past impacts due to production of all products still in use in the reference year and then dividing them by the product's lifetime.[20] The annualised impacts of production are then divided by population in order to derive total annualised impacts of the production stage per capita. This approach will, for example, allow close monitoring of energy consumption and its associated environmental impacts.

As all products currently in use will also have to be disposed of at the end of their useful lives, the same approach is used to allocate the impacts from disposal (due to landfill, incineration and recycling). The impacts of past production are equally distributed over the entire life cycle of a product; the same applies to the impacts of future disposal.

Data sources

The statistical data source for EU-27 is PRODCOM (2010). From the same source national data, e.g. for Germany, can be derived. The PRODCOM database hosted by Eurostat consists of data on total production, sold production, imports, and exports of about 4500 manufactured products. Quantities are expressed both in number of pieces and in monetary units. Sold production corresponds to total production minus internal consumption of the manufacturer. Apparent consumption at the national level can be derived from these data (apparent consumption = sold production + imports - exports). The above data cover flows of consumer goods. Regarding the stocks of consumer products in private households, the German statistical office periodically conducts surveys on a sample of

[20] One average lifetime per product is assumed rather than varying lifetimes depending on year of manufacture. See note 7.

households to estimate the average market penetration, i.e. how many products are within each household on average. No time series exist for these data, but snapshots are available for the years 1998, 2003 and 2008 in Germany (Federal Statistical Office, 2008). The LCI datasets for consumer goods are described in Table 6 below.

EXAMPLE: DISHWASHER

For the product group "white goods" of the basket of products, lifecycle-wide environmental impact data of representative electrical appliances are combined with macro data on the stock of such appliances used by private households in a given year in the region under consideration. This section presents an example of such macro data for dishwashing machines in Germany.

The actual data required for linking macro statistics with life cycle inventory data are stock, past production per annum, average lifetime, and population. The German Federal Statistical Office (2008) provides stock estimates for 2003 and 2008, but this is insufficient for a stock-flow analysis. As there are no data for 2006, and in order to make Germany and EU-27 more comparable, data from an EuP preparatory study have been used to estimate stock. This estimated a 77% household penetration rate for Germany (Presutto et al., 2007c, Figure 3.10, p.16). Combining this with an estimated 38971262 households (Federal Statistical Office, 2010b, Table 2.1.1, p. 12), this leads to a stock of 30007872 dishwashers in Germany in 2006. The lifetime of a dishwasher is assumed to be 12.5 years on average. From these data we can calculate the total number of dishwashing machines "consumed" per year by dividing the stock by the average lifetime (Swedish Environmental Protection Agency, 1999). One more division by the population and we obtain the number of dishwashing machines "consumed" per capita per year: 0.03 pieces.

TABLE 6 OVERVIEW OF LCI DATASETS FOR CONSUMER GOODS

Product	Production Stage	Use Stage	End-of-Life Stage
Shoes	Average production of a pair of shoes (US men's size 9 and US women's size 7) in the USA for the 2006 reference year. Based on Albers et al. (2008) but substituted a German electricity mix.	N/A	All materials are incinerated with energy recovery
Cotton Shirt	Based on GaBi dataset "Cotton fabric PE" (GaBi 2006) for Europe in the 2005 reference year.	N/A. Laundering the shirt is included in the use stage of white goods.	All textiles are incinerated with energy recovery
Washing Machine	Data from Presutto et al. (2007c), Table A.3. Average data for the WM 5 kg model.	Data from Presutto, et al. (2007c). Parameters for use stage: #1: 2.9 persons per household (59.7 % families, 52 % living in cities, 38 % with persons below 18); #2: 254.5 cycles per year.	Assumes 100% recycling of ferrous metals, aluminium and copper. For EU-27, all other inert materials go to landfill. For DE, 12% are incinerated and the rest go to landfill. Includes transport to specialist recycling facility and shredding.
Refrigerator	Data from Presutto et al. (2007b), Table A.2: Average data for the Cold7 model.	Data from Presutto, et al. (2007b). Parameters for use stage: #1: 2.9 persons per household (59.7 % families, 52 % living in cities, 38 % with persons below 18); #2: exchange of food: 2 kg per person per day.	Assumes 100% recycling of ferrous metals, aluminium and copper. For EU-27, all other inert materials go to landfill. For DE, 12% are incinerated and the rest go to landfill. Includes transport to specialist recycling facility and shredding.
Dish Washer	Data from Presutto et al. (2007c), Table A.2. Average data for the DW 12ps model.	Data from Presutto, et al. (2007c). Parameters for use stage: #1: 2.9 persons per household (59.7 % families, 52 % living in cities, 38 % with persons below 18); #2: 213.2 cycles per year.	Assumes 100% recycling of ferrous metals, aluminium and copper. For EU-27, all other inert materials go to landfill. For DE, 12% are incinerated and the rest go to landfill. Includes transport to specialist recycling facility and shredding.
Laptop	Global production for the 2009 reference year. Data from Jönbrink (2007) and industry sources. Upstream data from the GaBi Electronics Extension Database.	Use data from Jönbrink (2007)	Recycling is potential, i.e. 100% recycling except for batteries and LCD displays which go to landfill since there is no clear end-of-life pathway. Includes transport to a specialist recycling facility.

1.4.4 MOBILITY

For the consumption category "mobility", the basket of products consists of two product groups: private and public transport. Private transport consists of one product (mid class car) and this is further broken down into four sub-products (cars conforming to Euro 1, Euro 2, Euro 3 and Euro 4 norms). Public transport consists of three products (bus, plane and train). Of these only bus is further disaggregated into sub-products (bus conforming to Euro 1, Euro 2, Euro 3 and Euro 4 norms). The choice of products covers the vast majority of passenger km of travel.

GENERAL DESCRIPTION

For public transportation, the bulk of the impacts occur during the use stage as the impacts of production and end-of-life are shared between many people. Furthermore, no LCI datasets for production or end-of-life for trains or planes could be sourced, so these have been omitted from this study. (Production and end-of-life for buses has been included.) As most of the methodological issues relate to cars, cars will be the focus of this section.

Calculations of environmental impacts relate to the number of passenger cars "consumed" privately per person per year in the region under investigation (EU-27 and Germany). For that purpose, the passenger car fleet in use in a given year needs to be expressed on a per capita and year of service basis (i.e. the number of cars in the fleet needs to be divided by the population and the average lifetime of a passenger car in the region under investigation). Accordingly, the lifecycle-wide environmental impacts of a representative passenger car need to be expressed on an annual basis.

The focus on private households' consumption implies that passenger cars owned by companies and self-employed persons are excluded from the basket of products. It is a reasonable choice at this stage that reconciles the requirement for a basket of products and the macro-level data available for Germany.

Company-owned cars are often used for personal purposes and their lifetimes (as company owned vehicles) are generally much shorter than the average lifetime of cars on the road as they are changed much more frequently than most private owners can afford to. In Germany, statistics show that the stock of company cars is completely replaced in less than three years (assuming companies do not buy second-hand cars).

After their use as company cars, they are generally sold as second-hand cars to private users. It is assumed that all company cars are resold for personal use and, therefore, all cars de-registered are from the personal users' stock. Production burdens are allocated over the entire (average) lifetime of the car and therefore correctly accounted for.

For Germany, statistical data on the average age of deregistered passenger cars are available (Federal Ministry of Transport, Building and Urban Development, 2010b). For EU-27 boundaries, the average lifetime of a vehicle is calculated from macro information on the stock on the road and the annual new registrations that replace this stock. The average age is equal to the number of years that the annual new registrations in the future would take to replace the entire stock from a particular year.

These real-life variations from the reference system described above are left out of the model.

TECHNICAL DESCRIPTION

- Passenger bus transport: A Euro IV diesel bus manufactured in 2005 has been chosen for the analysis. Production and external trade statistics of Eurostat (Table 19) resulted in an apparent consumption of 6.1 E-0.5 pieces per person and annum in 2006 in EU-27.

- Passenger rail transport: The use stage has been modelled as a split of urban and intercity electric trains based on 44 billion passenger-km of urban rail transport vs. 34 billion passenger-km of intercity rail transport in Germany in 2006 (Federal Ministry of Transport, Building and Urban Development, 2010b). Production and end-of-life have been excluded as no LCI dataset was available.
- Passenger air transport: The use stage has been modelled using a Boeing 737 over an assumed average trip length of 500 km. Production and end-of-life have been excluded as no LCI dataset was available.
- Passenger car transport:

The choice of the reference vehicle is a middle class car with an unloaded curb weight of ~1.5 tonnes and a payload of ~500 kg. It is a five seater with a passenger volume of ~2.5-3 m^3 and a cargo volume of ~0.3-0.5 m^3.

The production is based on the bill of materials and required processing steps as well as assembly. The supply chain is the most significant contributor to the production stage burdens. Steel/iron and polymers represent the main mass of an average vehicle on the road today and therefore the curb weight of the vehicle largely determines the production stage impacts.

The use stage is determined by fuel consumption. Various data are found in literature:

- Unleaded petrol 7.9 l/100 km and diesel 7.0 l/100 km (IFEU, 2010), and
- German statistics (Federal Ministry of Transport, Building and Urban Development, 2010b) indicates that fuel consumption of passenger cars went down from 8.6 l/100 km in 2000 to 8.2 l/100 km in 2007 for petrol, and down from 7.1 l/100 km in 2000 to 6.9 l/100 km in 2007 for diesel.

The car is shredded at the end of its life according to the Altautoverordnung (Used Car Ordinance).

METHODOLOGICAL CONSIDERATIONS

- Reference system refers to the per capita consumption of vehicles in Germany and EU-27. To model the use stage, vehicle-km used for private transport and passenger-km for public transport.
- System boundaries: For cars and buses, the system encompasses the production, use stage and end-of-life of a representative model. It includes all materials and energies needed for its manufacture, including upstream processes; all materials and fuel required in the use stage; and EoL treatment. It is a full cradle-to-grave approach. For planes and trains, only the use stage is considered.
- Stock portfolio, e.g. level of technology: For cars in Germany, the stock portfolio is tracked using simplified stock-flow analysis. For example, all new vehicles registered between 1993 and 1995 are counted as Euro I vehicles. Some of these are replaced by Euro II vehicles sold between 1996 and 1999, and so on. For all other vehicles, an estimate of stock is made for the 2006 reference year only.
- End-of-life: It is assumed that cars and buses are recycled at the end of their lives (irrespective of whether they enter a “second” lifetime). Environmental credits from material recycling (Germany and EU-27) and incineration of plastics (Germany only) are included by the “recycled contents” approach in LCI modelling. End-of-life for planes and trains is not included as no data were available.
- Double counting: By definition, the basket of products covers private final consumption within a given geographical area (EU-27, Germany). Here, the consumption of passenger

cars and buses by private households is considered. Most intermediate products that enter the production chain of a passenger car or bus (e.g. steel parts) are not accounted for elsewhere in the basket of products, hence double counting can be neglected at that level.

Another potential double counting issue arises with products that reach end-of-life in one country, are then exported, and start a "new life" as second-hand products in another country. This is particularly relevant for passenger cars within the European Union (e.g. exports of second-hand cars from Germany towards new Member States) and from the EU towards the rest of the world. For instance, a car can be bought new in one country from which it is exported after ten years of use, and be used subsequently ten more years in another country where it is eventually disposed of. This case is not covered here.

- Environmental impacts from production, use and disposal should be annualised over the entire lifetime of x+y years and not of x and y years separately in each country. Deregistered passenger cars in Germany are on average 12 years old (Federal Ministry of Transport, Building and Urban Development, 2010b). This number does not, however, account for subsequent use in another country if the deregistered car is exported.

DATA SOURCES

European macro statistical data on transport for EU-27 are available at (Eurostat, 2011d). The German ministry in charge of transport (Bundesministerium für Verkehr, Bau und Stadtentwicklung) also publishes a yearly statistical book on transport called "Verkehr in Zahlen" prepared by the German Institute for Economic Research. It is the reference for German transport statistics at the macro level. The LCI datasets for mobility are described in Table 7 below.

EXAMPLE: PRIVATE TRANSPORT

For the product group "private transport" of the basket of products, lifecycle-wide environmental impact data for representative passenger cars are combined with macro data on the stock of cars used by private households in a given year in the region under consideration. This section presents an example of such macro data for Germany.

The simplest model consists of one single car that shall represent all passenger cars in the fleet of a given country at any given time. It is assumed in this simple model that, say, a medium-sized car produced in a certain year represents all cars (from small to luxury ones), of any age in use. The macro data for such a model are presented in Table 8.

The actual data required for linking macro statistics with life cycle inventory (LCI) data are the fleet of cars on the road (stock), past production of new cars (i.e. additions to stock), average lifetime, and population. From these we can calculate the total number of passenger cars "consumed" per year by dividing the stock by the average lifetime. One more division by the population and we obtain the number of cars "consumed" per capita and per year.

The data on the average lifetime are reported in German statistics. When a car is deregistered in Germany, however, it can be exported and further used in another country. The average lifetime reported in German statistics does not take this "second lifetime" into consideration, which can lead to double counting as described previously.

Data on new registrations of cars are also available (excluding cars owned by companies and self-employed). Combined with stock data, deregistrations of cars owned by private households can be calculated: deregistrations(t) = stock(t-1) + new registrations(t) - stock(t). As shown in Table 8, calculated deregistrations differ significantly from deregistration data reported in the statistics. The latter accounts for all passenger cars, while the former only covers those owned by private households.

More detailed modelling would consider not only one but several representative cars, according to size and age, for example. LCA data for such representative cars would be combined with detailed macro data on the composition of the car fleet in Germany differentiated by car size (e.g. small, middle class and luxury cars), and age. Regarding the size, data are readily available in German statistics. Data on the age structure of the car fleet are much less common and are often derived from modelling.

TABLE 7 OVERVIEW OF LCI DATASETS FOR MOBILITY

Product	Production Stage	Use Stage	End-of-Life Stage
Mid Class Car	Average of six middle class cars produced in Germany in the 2009 and 2010 reference years. Data are from industry.	Euro 1, 2, 3 and 4 emissions per vehicle-km using GaBi (2006) datasets “Car petrol” and “Car diesel” for each Euro norm assuming 50% diesel and 50% petrol vehicles.	Assumes 100% recycling of ferrous metals and aluminium. For EU-27, all other inert materials go to landfill. For DE, 12% are incinerated and the rest go to landfill. Includes transport to specialist recycling facility and shredding.
Train	LCI data not available	Split of urban and intercity electric trains based on 44B person-km urban vs. 34B person-km intercity in Germany in 2006 (Federal Ministry of Transport, Building and Urban Development, 2010). Urban train load factor = 29.8%, electricity = 0.042 kWh/seat-km; city train load factor = 39.0% and electricity use = 0.29 kWh/seat-km (IFEU, 2008).	LCI data not available
Bus	Production of a Euro 4, 12- metre-long inner-city bus with 100 passenger capacity in Germany in the 2005 reference year (Faltenbacher 2006; Wiedemann & Faltenbacher 2007).	Representative emissions per passenger-km for a Euro 3 and Euro 4 12-metre-long inner-city bus in Stuttgart, Germany travelling the SORT 2 route (INFRAS 2004; Faltenbacher 2006; Wiedemann & Faltenbacher 2007).	LCI data not available
Plane	LCI data not available	Passenger-km for a Boeing 737 over an assumed average trip length of 500 km (EEA, 2006).	LCI data not available

TABLE 8 EXAMPLE OF MACRO DATA FOR PRIVATE TRANSPORT IN GERMANY

Private transport in Germany	Unit	2004	2005	2006	2007
Registrations of passenger cars	1000	1 552	1 538	1 643	1 201
Stock (car fleet)	1000	40 283	40 608	41 233	41 617
Deregistrations of passenger cars	1000	1 181	1 213	1 018	817
Deregistrations of passenger cars from statistics (*)	1000	3 068	3 183	3 202	8 071
Average lifetime (*)	years	11.9	12	12	*12*
Population	1000	82 532	82 501	82 438	82 315
Cars per 1000 inhabitants	pieces	488	492	500	506
Total cars "consumed" per year	**1000**	**3 385**	**3 384**	**3 436**	**3 468**
Cars “consumed” per 1000 inhabitant per year	**pieces**	**41**	**41**	**42**	**42**

Source: Federal Ministry of Transport, Building and Urban Development (2010b) Verkehr in Zahlen 2009/2010. Except for underlined data that are calculated.

(*) These data from the statistics include passenger cars owned by companies and self-employed persons. All other data in this table exclude cars owned by companies and self-employed persons.

1.5 BACKCASTING AND FORECASTING

When attempting to apply forecasting or backcasting to the basket-of-products indicators, it is important to consider three factors, all of which are subject to change over time:

1. The composition of the basket of products, i.e. the selection of a group of products and services that will be broadly representative of total private consumption in a given reference region and reference year;
2. The volume of consumption of each item within the basket (macro level); and
3. The specific environmental performance of each product based upon the implementing technology used at the time (micro level).

Regarding the first and second points, backcasting is likely to be simpler than forecasting in that in most cases it is possible to find historic statistics and records to determine which products were the most popular in a given region at a given time. Depending on the timescale for forecasting, it should also be possible to approximate the future composition of the basket. If the timescale is only a few years, there is good reason to assume that past trends will continue, e.g. changing diets in Asia to include higher meat and dairy consumption. Over periods of decades, such an assumption is no longer valid. One alternative approach would be to separate out those products that have not changed significantly over the last few decades (e.g. cotton shirts) from those that have (e.g. laptops). This would then allow for scenario analysis where the slow-changing products become the “predetermined elements” (i.e. common to all scenarios) and the fast-changing products become the variables that define the differences between the scenarios.

The third point is more challenging. The first reliable LCI data were generated in the early 1990s so backcasting to this point in time can be achieved for certain products using past LCA studies. Backcasting of LCI data prior to that point is possible in theory by adjusting the energy mixes of the products under consideration. However, little reliable information is available on older technologies, production processes, etc. Forecasting in this case would involve prediction of how technologies might change over time. One approach to achieve this would be to look at the difference between the current performance or efficiency of a product and its theoretical maximum. For example, the efficiency of a large-scale hydroelectric power plant can be in the range of 95% so it is therefore unlikely that this technology will be improved significantly in the future. This is in contrast to very low efficiencies for biofuels, for example. By assuming that these mature technologies remain the same, it would also be possible to conduct scenario analyses for possible improvements to immature technologies. However, such a forecast would likely result in highly simplified LCI data that focus on what is considered to be the dominant impacts of a particular technology. This is because it would be difficult to forecast changes in all necessary upstream processes (electricity production, water infrastructure, waste treatment, etc.) that would be needed to produce a detailed LCI. In these cases, sensitivity analysis would be an invaluable tool to determine where to focus time and effort.

2 CALCULATION OF BASKET-OF-PRODUCTS INDICATORS

2.1 DESCRIPTION OF THE CALCULATIONS

The purpose of the prototype is to calculate, for a given reference year, an environmental profile for an average citizen in EU-27 or one of its Member States. This is done by matching regional consumption statistics to product-specific life cycle inventory datasets for a basket of products designed to represent domestic consumption in that region. The results should be presented as both a total and disaggregated by consumption categories (e.g. mobility), sub-categories/groups (e.g. private transportation) and product types (e.g. mid-class cars).The information available to this prototype includes statistical consumption data, product-specific life cycle inventories and characterisation factors to translate LCI profiles to a life cycle impact assessment.

In order to fulfil these requirements, the prototype must:

1. Allow consumption statistics for an "average" citizen of a given nation/region to be matched to corresponding product-specific life cycle inventories;
2. Scale each LCI dataset by the appropriate level of consumption;
3. Aggregate these consumption LCI profiles by products, groups and categories;
4. Perform life cycle impact assessment based upon these LCI profiles; and
5. Aggregate the Life Cycle Inventory (LCI) and Life Cycle Impact Assessment (LCIA) data to give a total environmental profile per citizen.

EU-27 and Germany were selected as the regions for this prototype. Germany was chosen as it has good statistical information and life cycle inventory (LCI) data in the databases/sources chosen . In both cases the selected reference year was 2006. Setting the reference period several years in the past is important because statistical data, particularly for stocks and flows of products, are often between one and five years old at their time of publication.

Life cycle impact assessment is carried out for a range of different midpoint impact categories, such as climate change and eutrophication, as defined in the framework (EC, 2012a) and methodology of the ILCD Handbook (JRC, 2010c).

2.2 STRUCTURE OF THE PROTOTYPE

The prototype is organised into five sections, starting from zero: (0) configuration settings; (1) regional consumption statistics by product and life-cycle stage; (2) life cycle inventory by product and life-cycle stage; (3) life cycle impact assessment by impact indicator and product; and (4) summary/results of the life cycle inventory and impact assessment. A breakdown of individual worksheets and their respective purposes is included below. Worksheets that contain intermediate results (e.g. stock-flow analyses for different product types) have been omitted from this table as they will vary by region depending on data availability within that region.

2.3 DATA REQUIREMENTS AND AVAILABILITY

To enable macro statistical consumption data to be linked to life cycle inventory data, the statistical data must be available for well-defined individual products. Where product-level (i.e. disaggregated) data exist or can be calculated for the reference year, the following data are required for all products: (1) domestic production; (2) imports disaggregated by country of export; and (3) exports.

These data must be in physical quantities (e.g. pieces, pairs, kg, l), not economic units, or there must be a way to convert them to physical units.

For long-lived products, such as motor cars and white goods, the following additional data are required at minimum: (4) the stock of products in service during the reference year; and (5) the average lifetime of the product. Where available, the following information is also desirable, preferably for a greater number of years than the average life of the product: (6) past domestic production quantities; (7) past imports disaggregated by country of export; and (8) past quantities disposed of, exported or otherwise removed from stock. If items 6-8[21] are available then the product lifetime can be calculated from stock-flow analysis.

To convert macro statistical consumption data from national/regional to per person, the population of the region in the reference year must also be known.

Population data are readily available. So are data on imports and exports and, in Eurostat at least, these data are disaggregated by country of export/import. Production data are commonly available; however, if there are few producers of a given product within a given region then production quantities can be withheld for commercial reasons and must be estimated. This is the case for refrigerator production in Germany in 2006, for example, which is withheld by the German Statistical Office and Eurostat (Presutto, 2007a, p. 17).

Data on stocks of products are more problematic. There are two main requirements that stock data need to fulfil. First, they should correspond to products owned (and used) by private households, hence excluding products owned by companies or even self-employed persons, even though it is often difficult in such cases to draw the line between private and professional usage. Second, stock data should encompass product groups that may be more or less broadly defined. For instance, it is one thing to consider all passenger cars owned by private households, and it is another to try to establish the fleet of such cars with a given cylinder capacity, manufactured before a given year. Average product lifetimes must often be based on values in literature or calculated from product stock/flow analyses.

For stock/flow analyses, it is generally easier to find data for additions to stock (new registrations of cars, completion of new dwellings, production, import and export of consumer products, etc.) than data on the stocks themselves. Output flow data (end-of-life products) are also scarce and, when they are available, are often highly aggregated. This implies that when estimating missing stock data with simple dynamic stock-flow models, the quality of the estimates depends heavily on the quality of the initial conditions (e.g. assumptions of the stock at time zero), and of the outflows (waste). As a rule of thumb, more detailed data are available over longer time series at the national level of certain Member States (such as Germany) than at the EU level.

2.4 OPENING THE PROTOTYPE

The prototype contains macros written in Visual Basic for Applications (VBA). When opening the prototype you may see a security warning appear. All of the standard functionality of the prototype will work with macros disabled. The only time macros must be enabled is if you need to update the number of columns in the LCI calculation worksheets (found in section 2). This is necessary in only three cases: (1) when a new product is added; (2) when a new import country is specified for an existing product; and (3) when a new use type is specified for an existing product. Macros are not required if only the production, use or end-of-life statistics or matching LCI datasets are updated for an existing product.

[21] Here, the items 6-8 were used for cars and dwellings for Germany only.

TABLE 9 SECTIONS AND WORKSHEETS WITH THE PROTOTYPE

Sheet	Title
INFO	Table of Contents
REF	List of References
DOC	Documentation of LCI Datasets
0. Configuration Settings	
0.1 Settings	0.1 Configuration Settings (Top-Level)
0.2 Columns	0.2 Configuration of Product Groups
0.3 Products	0.3 Products by Category and Group
0.4 Use Types	0.4 Consumption Types During the Use Stage
1. Regional Consumption Statistics by Product and Life-Cycle Stage	
1.0 Consumption	1.0 Annual Production and Consumption Statistics
1.1 Production	1.1 Mapping Annual Production and Import Statistics to LCI Datasets
1.2 Use	1.2 Mapping Annual Use Statistics to LCI Datasets
1.3 EoL	1.3 Mapping Annual End-of-Life Statistics to LCI Datasets
1.4 Coverage	1.4 Coverage of "Basket of Products" Relative to Total Consumption
2. Life Cycle Inventory (LCI) Data by Product and Life Cycle Stage	
2.0.1 LCI Mass	2.0.1 LCI Import 1: Mass
2.0.2 LCI Energy	2.0.2 LCI Import 2: Energy
2.0.3 LCI Waste Heat	2.0.3 LCI Import 3: Waste Heat
2.0.4 LCI Radioactive	2.0.4 LCI Import 4: Radioactive Materials
2.0.5 LCI Translated	2.0.5 LCI Translated to ILCD Format
2.1 Production	2.1 Production LCI
2.2 Use	2.2 Use LCI
2.3 EoL	2.3 End-of-Life LCI
2.4 Total LCI	2.4 Total Life Cycle Inventory
3. Life Cycle Impact Assessment (LCIA)	
3.0 LCIA Factors	3.0 LCIA Characterisation Factors
3.1 GWP	3.1 Global Warming Potential (GWP) Midpoint
...	... other LCIA calculation sheets ...
3.16 Resource Mineral	3.16 Resource Depletion (Minerals, Fossil and Renewables) Midpoint
4. Results	
4.0 Results Table	4.0 Results Table
4.1 Results Breakdown	4.1 Breakdown of LCIA Results By Sub-Product, Product, Group and Category

2.5 CONFIGURATION SETTINGS (SECTION 0)

The first section (section 0) contains high-level configuration settings. The sheets in this section allow the following to be configured:

- Reference region, reference year and reference population;
- Annualise production/end-of-life: set to “false” to account for the environmental impacts of production and end-of-life in the year of production/disposal or “true” to distribute them evenly across the life of each product (NB: this is only valid for long-lived products);
- Layout and formatting of the life cycle inventory and impact assessment worksheets (NB: this will not usually need to be altered);
- List of categories, groups, products and sub-products to be included in the basket of products for analysis; and
- List of use stage types and corresponding LCI datasets.

Each product defined above is given a fully qualified name and a short name. Both names must be unique as they are used to refer to the product in other parts of the prototype. The fully qualified name is the category, group, product and sub-product names concatenated together and separated by colons, e.g. “Consumer Goods: White Goods: Dish Washer”. Only unique entries are used to create this name. For example, if both the sub-product and the product share the same name (as is the case with the dishwasher) then the product/sub-product name is only included once.

The use stage list in sheet "0.4 Use Types" assigns a name to each use stage dataset. This allows the datasets to be used by more than one product type. The next section provides more information.

2.6 REGIONAL CONSUMPTION STATISTICS BY PRODUCT AND LIFE-CYCLE STAGE (SECTION 1)

The worksheets in this section allow macro consumption statistics to be mapped to LCI datasets. All mapping should be done within this section. With the exception of the first part of section 2 which allows new LCI data to be imported, the later sections (2-4) are solely for calculating the life cycle inventory and impact assessment and should not need to be updated by the user of the prototype. These sheets can be updated to reflect a new mix of products and/or import countries by pressing the "Update" button on sheet 0.3 as described in the previous section.

Several of the sheets in section 1 provide supporting information that is region-specific and so are omitted from this discussion. The main sheets used for calculations are:

1.0 Annual Production and Consumption Statistics;

1.1 Mapping Annual Production and Import Statistics to LCI Datasets;

1.2 Annual Use Statistics;

1.3 Annual End-of-Life Statistics; and

1.4 Coverage of "Basket of Products" Relative to Total Consumption.

Sheet 1.0 contains overall information on production, imports, exports and stocks of products. It is used to calculate consumption in the other worksheets in this section. Sheets 1.1, 1.2 and 1.3 take these consumption statistics and map them to LCI datasets.

2.6.1 ANNUAL PRODUCTION AND CONSUMPTION STATISTICS

The sheet is comprised of the following column headings:

- Product: The fully qualified name for each product (i.e. name with categories).
- Container: The fully qualified name of the current product's parent category.
- Unit: Unit for production/consumption statistics (e.g. kg) for each product type.
- Life (yr): The average number of years over which the product is assumed to be consumed. Any product with a life of less than one year, e.g. food and beverages, are assigned a life of 1 year.
- Scaling Factor: An optional factor to scale the data by, e.g. to convert between units or to separate consumption of households from that of industry.
- Domestic Production: Products manufactured domestically in the reference year.
- Import: Products imported into the reference region in the reference year.
- Exports: Products exported from the reference region in the reference year.
- From Storage: Net change in storage, e.g. government stores. A negative number represents a net flow to storage in the reference year.
- Apparent Production = Domestic Production + Imports + From Storage - Exports

- Opening Stock: Stock at the start of the period, either taken from a stock-flow analysis on a separate sheet or from an estimate in the literature.
- Consumable Stock = Opening Stock + Apparent Production
- Outflow: For long-lived products, this is the number of items at the end of their useful life leaving the stock-flow analysis. If no stock or waste data are available, and if the quantity of items produced has remained approximately constant over time, it can be assumed that outflow = apparent production. NB: This field is not used for products that are consumed in their year of production.
- Closing Stock = Consumable Stock - Outflow. For products consumed in the same year as they are produced, closing stock is zero by definition.
- Apparent Consumption: If the “annualise production/eol” setting is set to “false” then apparent consumption equals apparent production, i.e. all impacts of producing products occur in their year of production. If this setting is “true” then apparent consumption of the product equals total stock (“Consumable Stock” above) divided by expected life.[22]
- Apparent Consumption pp = Apparent Consumption / Reference Population.
- EoL: If the “annualise production/eol” setting is set to “false” then EoL equals apparent production, i.e. the impact of landfilling/incinerating/recycling products are allocated to the year they are produced. If this setting is “true” then EoL = Outflow.
- EoL pp = EoL / Reference Population.
- Domestic Production (Scaled): “Apparent Production” scaled by the ratio of “Domestic Production” to “Imports”. If “annualise production/eol” is “true” and there is a stock of products to be consumed but no production or imports during the period than the average ratio of “Domestic Production” to “Imports” across the sub-product’s parent category is used instead. For example, for Euro 1 and Euro 2 cars which were no longer manufactured but still in use (i.e. in stock) in 2006, the average ratio of “Domestic Production” to “Imports” for “Mid Class Car” (i.e. from Euro 3 and Euro 4) was calculated and applied.[23]
- Foreign Production (Scaled): As above, but scaled by the ratio of “Imports” to “Domestic Production”.

2.6.2 MAPPING ANNUAL PRODUCTION AND IMPORT STATISTICS TO LCI DATASETS

The most important fields in each row are: “Product”, “Source” (i.e. country from where the import came), “LCI Dataset”, “Volume” and “Volume pp”. The volume of domestic production is taken directly from “Domestic Production (Scaled)” in Sheet 1.0. For non-food products this figure is based on the Eurostat PRODCOM database, table “Prodcom Annual Sold (NACE Rev. 1.1) (DS_043408)”, but for food products a range of data sources have been used as documented in the prototype itself.

[22] This implicitly assumes that the production of products remains approximately constant each year. A better calculation would be to average historic apparent production figures over a period equal to the life of the product. This is possible within the preliminary calculations. However, stock/flow information over the full period is often unavailable and so this simple calculation is used instead.

[23] This implicitly assumes that the ratio of domestic production to imports, and also the mix of import countries, has remained constant over the life of the product. The preliminary calculations could be extended to account for the ratio of domestic production to imports and the mix of imports from each country by year of production. However, the additional data required to implement this for what would likely result in a small improvement in accuracy was not seen to be justified.

The import mix by country of export was extracted from Eurostat for EU-27 trade since 1988 by HS2-HS4, HS6 and CN8 (tables DS-016894, DS-016893 and DS-016890 respectively).[24] Eurostat trade data are available by economic value and weight of product traded. However, often the production data are in pieces/pairs produced and in many cases the PRODCOM categories, while similar, do not directly align with the import/export categories. For this reason the import statistics are used to calculate the percentage of trade from any given country. Trade in physical units is calculated by multiplying this percentage by the total imports in the column "Foreign Production (Scaled)", which are derived from PROCOM for non-food products and other sources for food. While the preliminary calculations allow a virtually unlimited number of import countries/regions, the decision rule employed for the analyses of EU-27 and Germany was to start with domestic production and then to add import countries until coverage of apparent production was greater than or equal to 80%[25].

As has already been noted, scaling is done using the "Domestic Production (Scaled)" and "Foreign Production (Scaled)" columns above. In principle it should be possible to scale based upon the ratio of products produced for domestic consumption (i.e. "Domestic Production" - "Exports") to "Imports". However, in the Eurostat data for Germany there were many cases where exports exceeded domestic production, presumably because some goods were imported for the purpose of later export rather than consumption in-country. To account for this, the ratio of domestic production to imports has been assumed to be correct when matching statistics to LCI datasets.

2.6.3 MAPPING ANNUAL USE STATISTICS TO LCI DATASETS

For production and end-of-life, there is a one-to-one mapping between product macro statistics and LCI datasets. However, the use stage allows more than one dataset to be assigned to each product. For example, a building might be assigned six use stage datasets: electricity consumption, natural gas consumption, water consumption, wastewater production, solid waste collection and building refurbishment. For the production and end-of-life stages, all of these impacts would be aggregated into a single dataset, so there will always be a mapping of one product to one dataset. This was not done for the use stage for two reasons:

Many products use a relatively small number of similar inputs, e.g. electricity or water, so it is therefore more time-efficient for the user to have a dataset for each of these common consumption categories than one per product; and

These products are typically used within a house so the consumption of the house (in terms of electricity, water, etc.) must be reduced accordingly to prevent double-counting.

In spite of the above, washing machines and dishwashers have their own use stage datasets as they use detergents as well as electricity and water. Personal cars and buses also have their own datasets because, despite all consuming petrol or diesel, emissions in the use stage depend on the performance of the engine and exhaust gas treatment.

Once each use stage is assigned to a dataset, consumption figures must also be assigned to each row. These figures come from national/regional statistics for households and a range of sources for energy-using products. Importantly, double-counting must be accounted for in this worksheet. Thus, for example, electricity for white goods must be subtracted from household electricity use.

[24] For individual Member States, in the preliminary calculations the EU-27 is treated as a single import country as this reduces the number of LCI datasets required. This was considered a reasonable assumption given shared environmental policies and energy grids within the EU.

[25] Typically European LCI data were available and in many cases these have been used as a proxy for foreign production. As a result, the impacts of production may be underestimated.

2.6.4 MAPPING ANNUAL END-OF-LIFE STATISTICS TO LCI DATASETS

The most important fields in each row are: "Product", "LCI Dataset", "Total to EoL" and "EoL pp". Each product must be assigned a single end-of-life dataset. The "Total to EoL" comes from the "EoL" field on sheet 1.0. This value is calculated from the stock outflow for long-lived products or apparent production for short-lived products which are assumed to be produced and consumed within the reference year. Key design decisions and assumptions are summarised below.

One end-of-life LCI dataset is required per product, rather than one for each end-of-life option (composting, landfill, incineration and recycling). This decision was made on the basis that products typically consist of a wide range of materials and if, for a particular product, the proportion going to any particular waste stream increases or decreases then this would alter the materials going to other waste streams and hence change their LCI profiles. For example, if the proportion of a motor car being recycled increases from 70% to 95%, it is likely that non-metallic parts are also now also being recycled rather than landfilled or incinerated. This would alter the material mix going to, and hence the LCI profile of, each waste stream.

The impact of collecting municipal solid waste should be included in the use stage of the building to prevent small errors in the end-of-life datasets from being magnified. However, transport should be included in the end-of-life dataset for all products that require special treatment, e.g. laptops.

The end-of-life dataset should include impacts from a typical mix of waste treatment options (recycling, incineration, landfill, compost) for each given product in each given reference year.

For food and beverages, only a carbon balance is maintained. This is because the end-of-life of food is more difficult to trace that for other products: some is consumed, some is flushed down the drain and some enters the municipal waste stream.

2.6.5 COVERAGE OF BASKET OF PRODUCTS RELATIVE TO TOTAL CONSUMPTION

As the basket of products is unlikely to ever cover the full range of private consumption, this sheet allows each consumption category to be scaled to account for missing products. This is an optional feature and, while it is present in the prototype, it is not currently used. The table has three fields: "Category/Group/Product", "Coverage" and "Scaling". The first field allows all categories and sub-categories which contain products to be listed. For example, for the category "Mobility", a scaling factor may be directly applied to the category itself, but also to its two sub-categories "Private Transport" and "Public Transport" and to their products "Mid Class Car", "Bus", "Plane" and "Train". Each category/group/product can have a coverage percentage assigned. This percentage represents coverage of groups/products/sub-products in the next level below. For example, if a coverage percentage of 70% was applied to "Public Transport" this would mean that missing products from that group (e.g. public transport by tram and passenger ferry) only account for 30%. In theory this percentage should represent the percentage of environmental impacts covered as it is environmental impacts that will be scaled. However, as the aim of the tool is to calculate environmental impacts, in practice this percentage should be set on the basis of domestic spending per category/group/product or, where available, the total mass of items consumed in each category/group/product. The "Scaling" field is simply the reciprocal of "Coverage". If no "Coverage" is set then "Scaling" is automatically set to 100% (i.e. no scaling). Due to limited data available at the time the preliminary calculations were done, all coverage values have been omitted for EU-27 and Germany. This means that no scaling is applied and the environmental impacts calculated reflect the basket of products directly. However, these scaling factors to be introduced at any time.

A separate use for these scaling factors is to help the user perform sensitivity analysis on their results, i.e. the scaling factors can be adjusted and the user can instantaneously see the effect on the output and judge the significance of the product to the final result.

2.7 LIFE CYCLE INVENTORY BY PRODUCT AND LIFE-CYCLE STAGE (SECTION 2)

This section has three main purposes: (1) to allow new LCI data exported from LCA software to be imported; (2) to translate the elementary flows used in the LCA software to elementary flows in ILCD format (EC, 2010c); and (3) to scale these flows according to the macro consumption statistical data defined in section 1.

The sheets starting with 2.0 ("2.0.1 LCI Mass", "2.0.2 LCI Energy", "2.0.3 LCI Waste Heat" and "2.0.4 LCI Radioactive") allow data to be imported via copy-and-paste from a pre-defined life cycle inventory balance within the LCA software. The final sheet in this group "2.0.5 LCI Translated" matches the flows from each of the previous LCI balances to elementary flows in ILCD format (JRC, 2010b). When new LCI data are added, the new column headings should be appended to the header row and the cell formulae filled across.

The sheets numbered 2.1, 2.2 and 2.3 scale the LCI data from sheet "2.0.5 LCI Translated" by the appropriate macro consumption statistic for the production, use and end-of-life stages respectively then sum them by product, group and category and apply the scaling factors specified on sheet "1.4 Coverage". The final sheet in this group "2.4 Total LCI" presents the total life cycle inventory across all life cycle stages for all products.

2.8 LIFE CYCLE IMPACT ASSESSMENT BY IMPACT INDICATOR AND PRODUCT (SECTION 3)

Section 3 applies different life cycle impact assessment methodologies to the scaled total LCI profiles in section "2.0.5 LCI Translated". These sheets do not require any user input. They can be updated to reflect a new mix of products and/or import countries by pressing the "Update" button on sheet 0.3.

2.9 RESULTS (SECTION 4)

Section 4 presents a summary of the life cycle inventory and impact assessment results, both as a total per citizen of the reference region in the reference year and disaggregated by consumption categories, groups and products.

3 BASKET-OF-PRODUCTS RESULTS

The results of the preliminary calculations can be displayed either as a life cycle inventory (emissions and resource use) or as a life cycle impact assessment. The full impact assessment results for an average EU-27 citizen in the 2006 reference year based upon the basket of products is included in Table 20 on page 80. The full impact assessment for an average German citizen in the 2006 reference year is included in Table 21 on page 80.

From a comparison of these two tables, the LCIA results suggest that EU-27 citizens have a larger impact for seven of the fourteen indicators (ozone depletion, human toxicity [non-cancer], particulate matter, ionizing radiation [human health], ionizing radiation [ecosystems], acidification and freshwater eco-toxicity) while Germany has a larger impact for the remaining seven (climate change, human toxicity [cancer], photochemical ozone formation, terrestrial eutrophication, freshwater eutrophication, marine eutrophication and resource depletion [non-water]).

Overall there are sixteen impact categories in the preliminary calculations, but two of these categories have no characterisation factors (land use and resource depletion, water) so have been excluded. Rather than discuss the remaining fourteen in detail in the body of this report, the indicators have been grouped by the dominant driver of the impacts and one or two representative samples from each group will be discussed. Graphs for the remaining indicators (for EU-27 only) are included in the Annex and any relevant differences between these graphs and those shown in the body of the report will be discussed in this section.

The indicators have been grouped in the following way:

- Indicators dominated by fossil fuel consumption (i.e. from electricity, oil, coal, etc.) and for which the use stage of shelter and private transportation are particularly significant:
  - Climate change midpoint (lead indicator)
  - Particulate matter/Respiratory inorganics midpoint
  - Photochemical ozone formation midpoint, human health
  - Eutrophication marine midpoint
- Indicators related to the above, but specifically dominated by electricity consumption:
  - Ozone depletion midpoint
  - Ionizing radiation midpoint, human health (lead indicator)
  - Ionizing radiation midpoint, ecosystems
  - Indicators dominated by the production stage of nutrition:26
  - Human toxicity midpoint, non-cancer effects
  - Eutrophication terrestrial midpoint (lead indicator)
  - Eutrophication freshwater midpoint (lead indicator)
- Indicators dominated by a combination of the use stage of shelter and the production stage of nutrition:
  - Human toxicity midpoint, cancer effects
  - Ecotoxicity freshwater midpoint

[26] Unlike other groups, the indicators dominated by the production of food and beverages show the most variation. For this reason, two indicators from this group have been chosen.

– Acidification midpoint (lead indicator)

The indicator "Resource depletion, mineral, fossils and renewables, midpoint" will also be discussed independently as it does not fall into any of the groups above.

3.1 CLIMATE CHANGE

The climate change midpoint is a good example of an impact indicator dominated by the burning of fossil fuels. Of all the products in the basket, the biggest energy consumers are buildings followed by personal cars. This is reflected in Figure 1 and Figure 2 for EU-27 and Germany respectively as the use stage of shelter has the largest impact followed by the use stage of mobility. The small negative result for the end-of-life of mobility reflects recovered and avoided energy during the end-of-life treatment of personal cars.

When the results are further disaggregated by product group in Figure 3 (EU-27) and Figure 4 (Germany), it is possible to see that only three product groups contribute approximately 75% of the impact: single-family houses, multi-family houses and private transport (i.e. personal cars). The other impact indicators in this group follow a similar pattern (all percentages refer to EU-27): particulate matter/respiratory inorganics midpoint (61%); photochemical ozone formation midpoint, human health (73%); and eutrophication marine midpoint (67%). For particulate matter, where the contribution from the three indicators is slightly lower, the next biggest contributors are dairy products and meat.

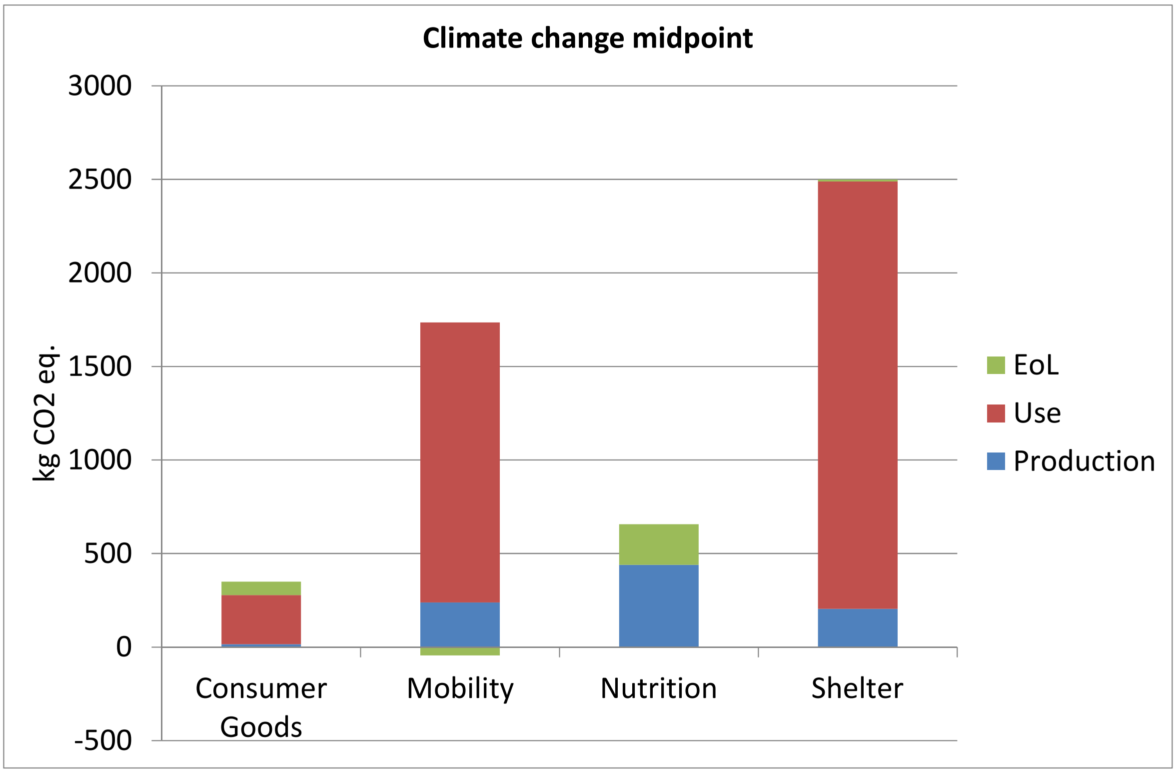

FIGURE 1 CLIMATE CHANGE FOR EU-27 BY LIFE CYCLE STAGE

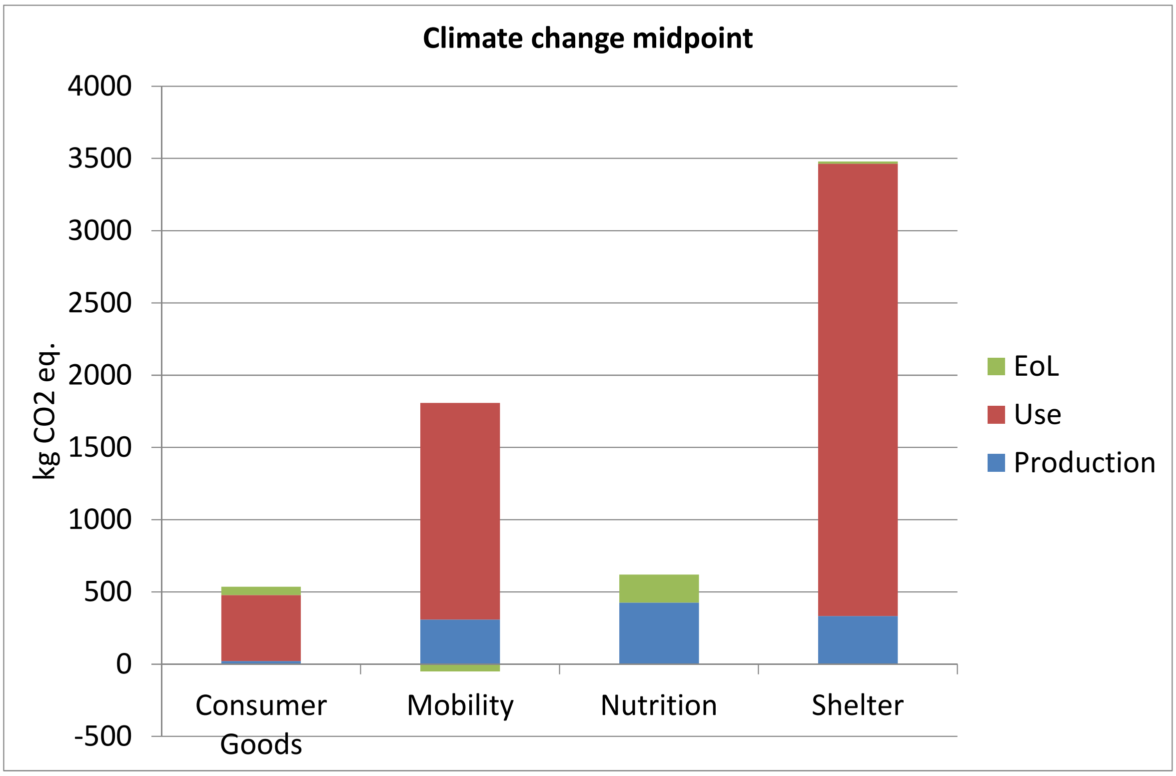

FIGURE 2 CLIMATE CHANGE FOR GERMANY BY LIFE CYCLE STAGE

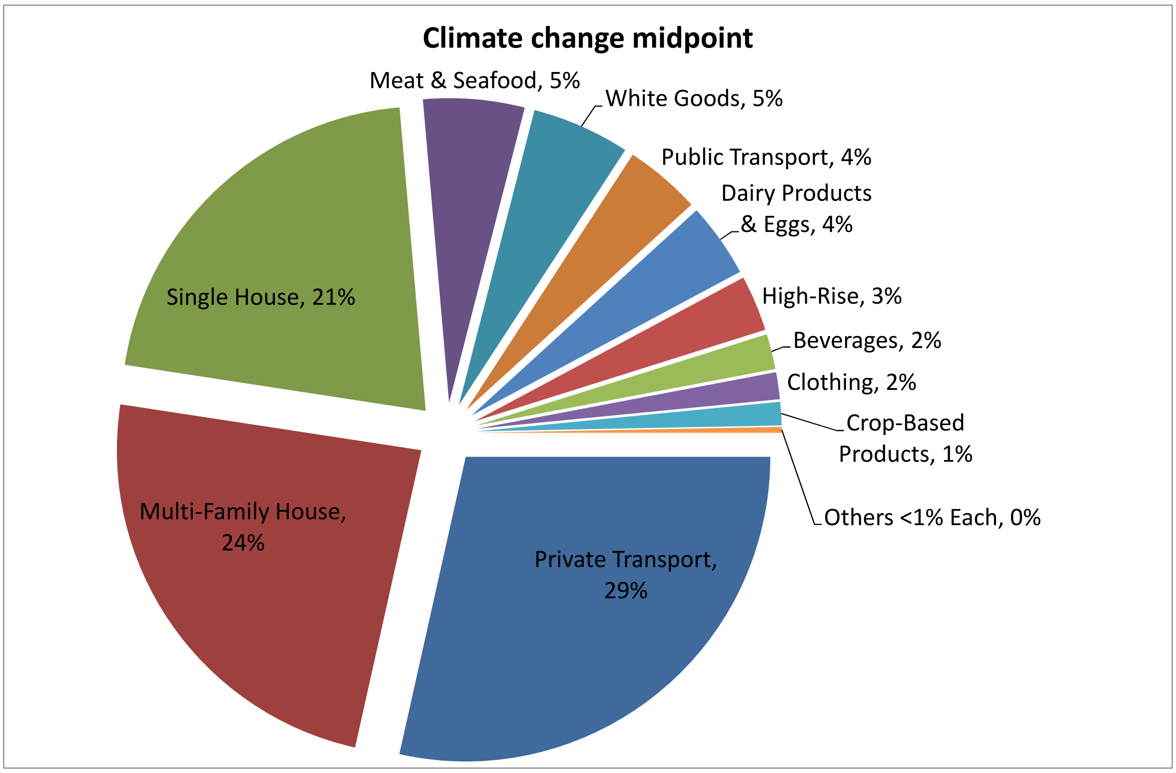

FIGURE 3 CLIMATE CHANGE FOR EU-27 BY PRODUCT GROUP

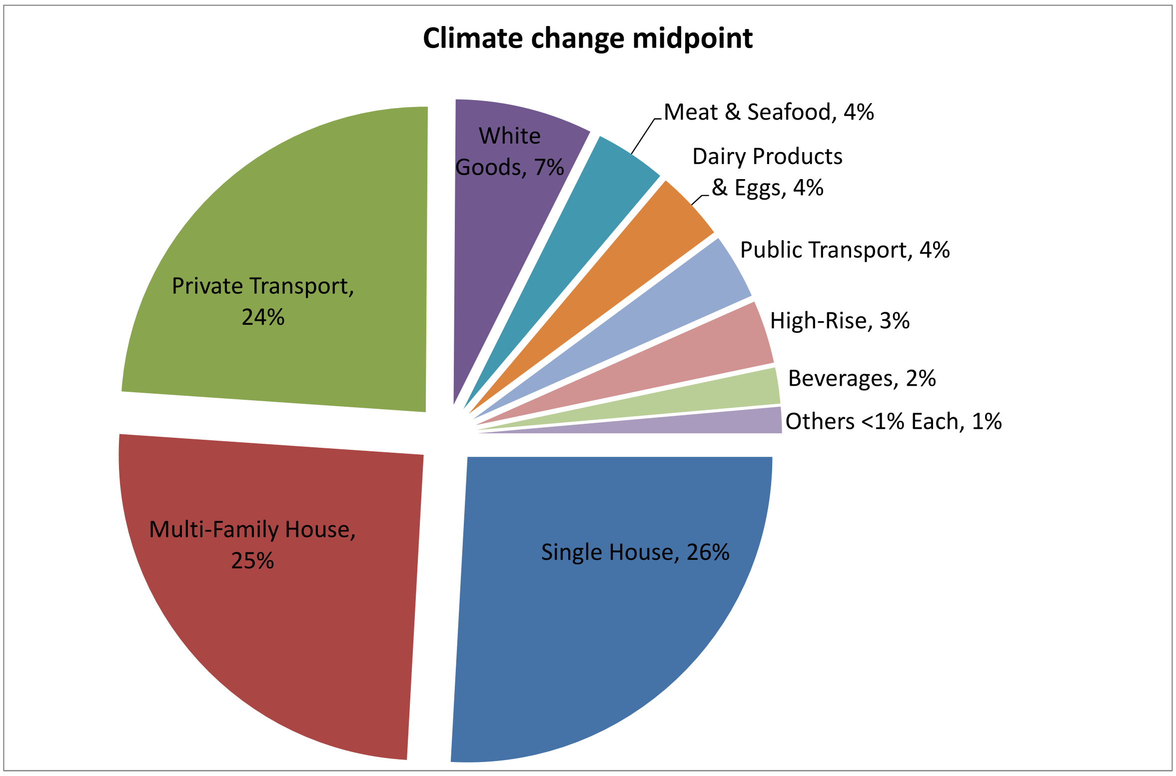

FIGURE 4 CLIMATE CHANGE FOR GERMANY BY PRODUCT GROUP

3.2 IONIZING RADIATION, HUMAN HEALTH

Ionizing radiation midpoint (human health) is a good example of an indicator dominated by the impacts of electricity production and consumption. Two other indicators are also dominated by electricity in the same way: ionizing radiation midpoint (ecosystems) and ozone depletion midpoint. For the two ionizing radiation impact indicators, the impact is largely due to the use of nuclear power stations to generate electricity.

All of the graphs in this group which disaggregate by life cycle stage (Figure 5, Figure 6, Figure 31 and Figure 33) illustrate that the use stage of shelter clearly dominates. When the results are disaggregated by product group (Figure 7, Figure 8, Figure 32 and Figure 34), more than 75% of the impact in all cases is caused by the use stage of single-family houses, multi-family houses and white goods.

3.3 EUTROPHICATION TERRESTRIAL

Figure 9 and Figure 10 clearly show that the production stage of nutrition dominates the results for the terrestrial eutrophication indicator. In this case, the impact is dominated by meat and dairy (Figure 11 for EU-27 and Figure 12 for Germany). Drilling down further within the preliminary calculations, these impacts are due primarily to ammonia emissions from the production of cheese and beef. Other significant impacts come from nitrogen dioxide emissions from cars and energy for houses.

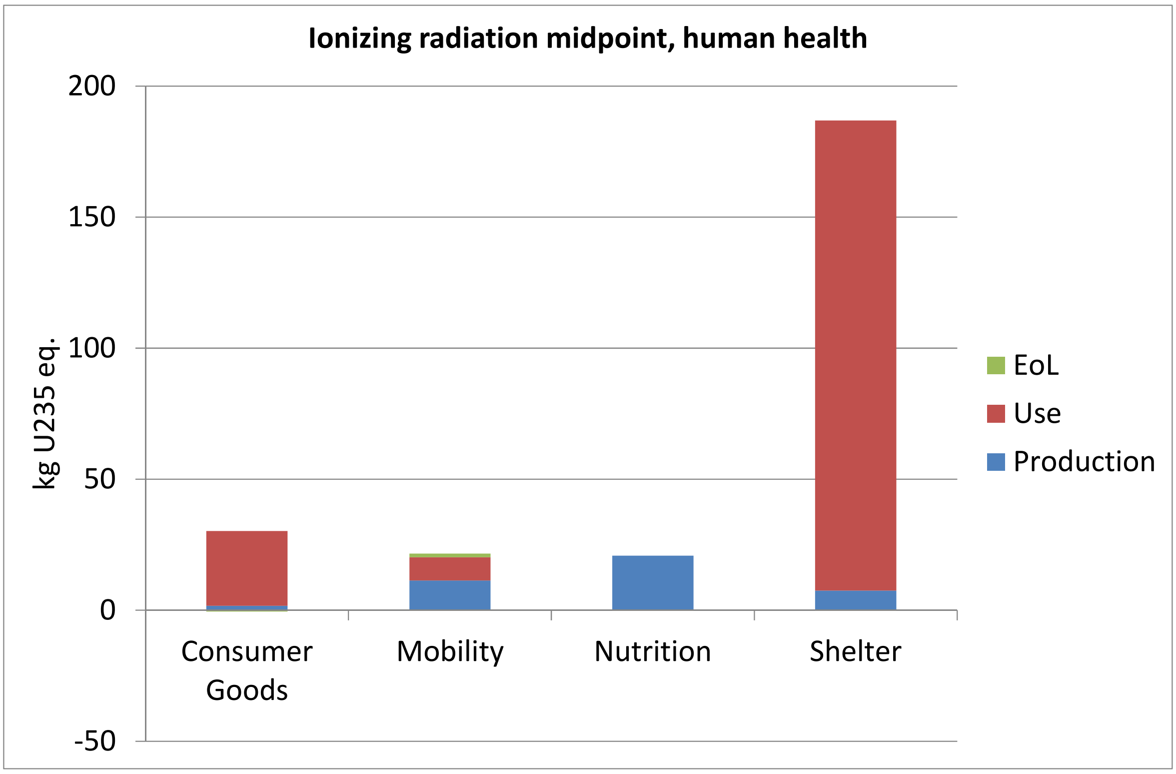

FIGURE 5 IONIZING RADIATION (HUMAN HEALTH) FOR EU-27 BY LIFE CYCLE STAGE

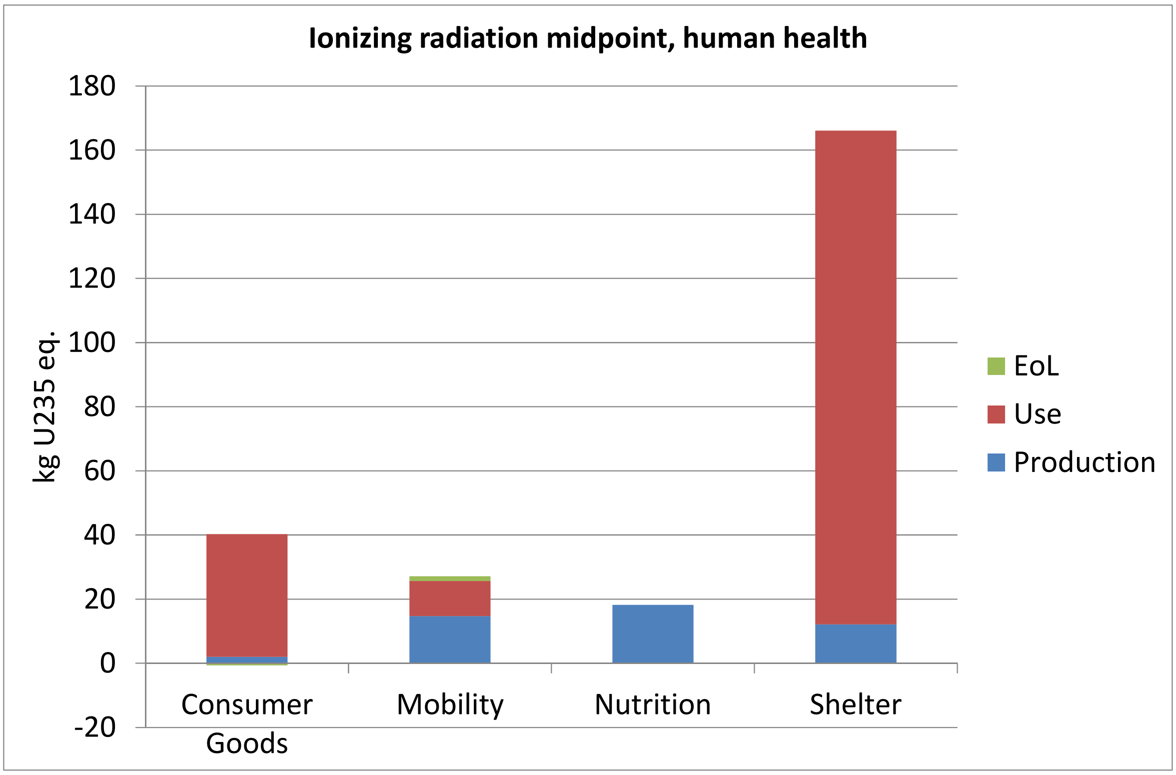

FIGURE 6 IONIZING RADIATION (HUMAN HEALTH) FOR GERMANY BY LIFE CYCLE STAGE

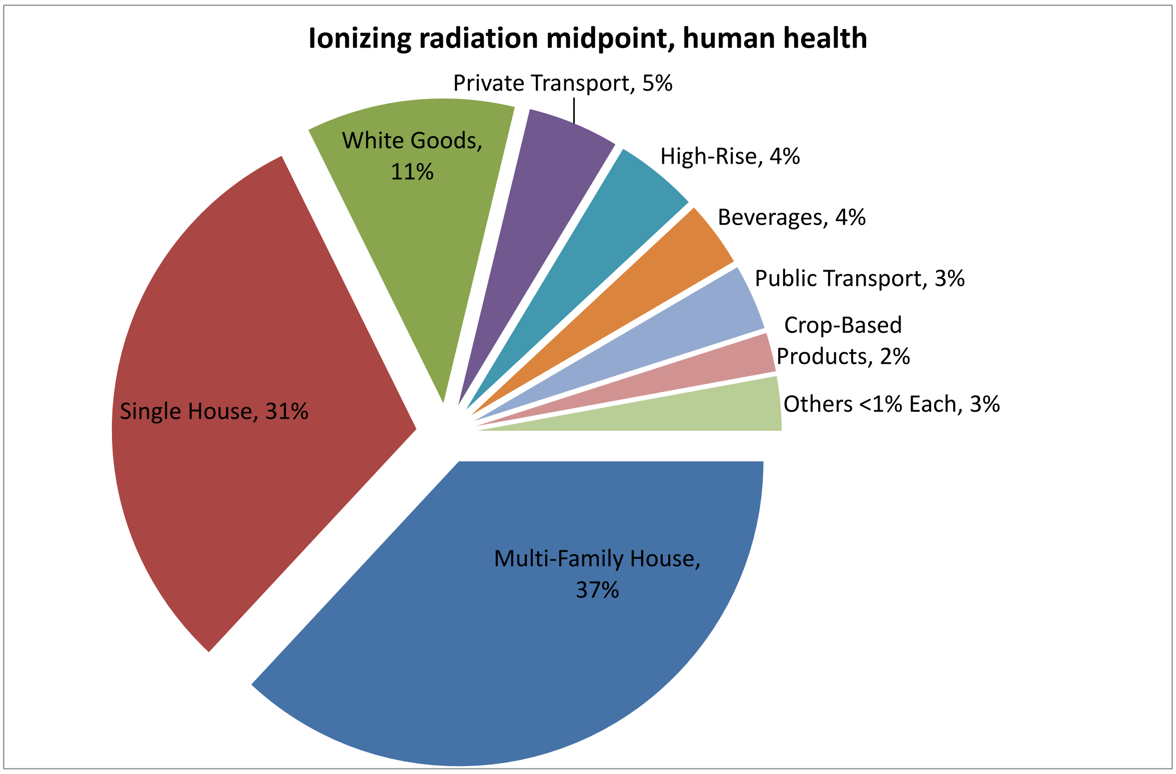

FIGURE 7 IONIZING RADIATION (HUMAN HEALTH) FOR EU-27 BY PRODUCT GROUP

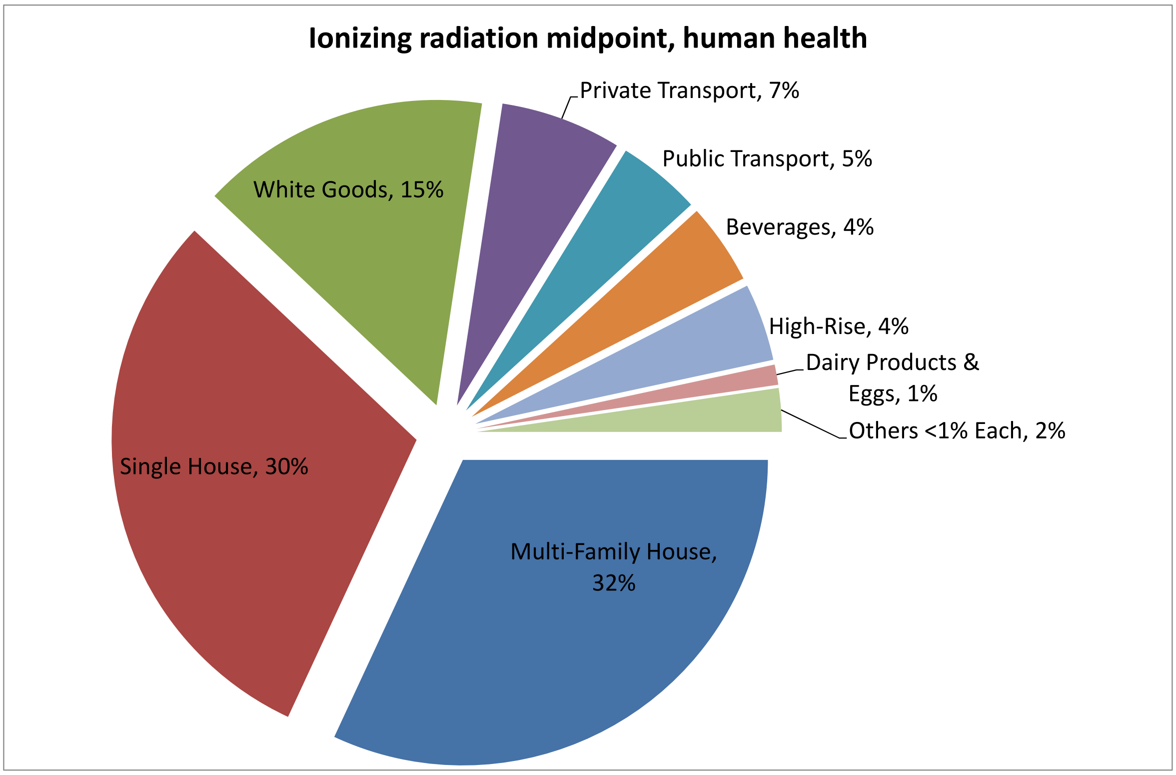

FIGURE 8 IONIZING RADIATION (HUMAN HEALTH) FOR GERMANY BY PRODUCT GROUP

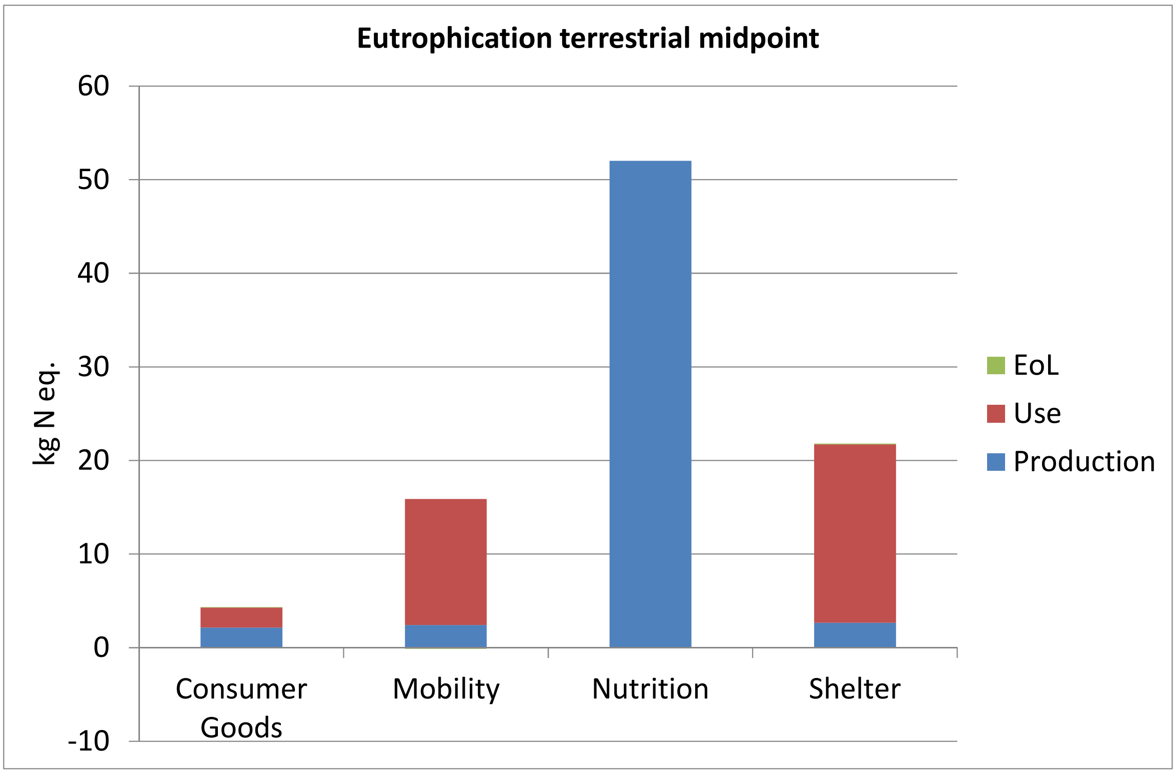

FIGURE 9 EUTROPHICATION TERRESTRIAL FOR EU-27 BY LIFE CYCLE STAGE

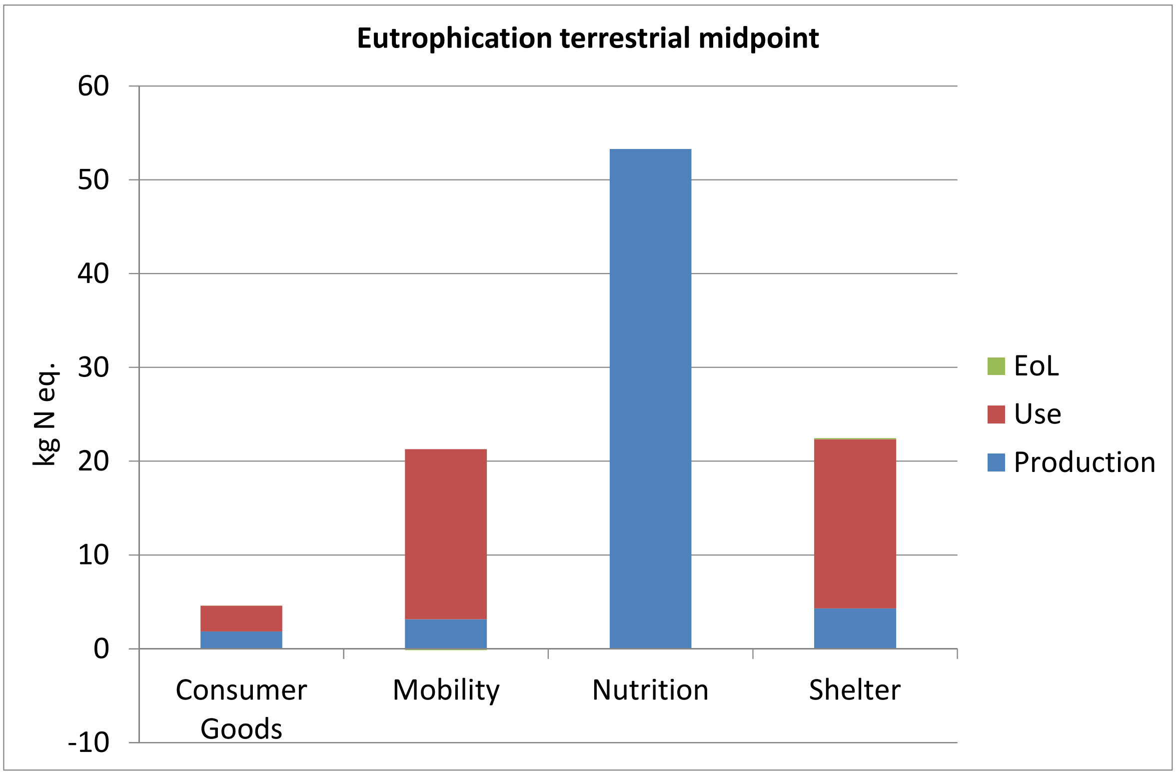

FIGURE 10 EUTROPHICATION TERRESTRIAL FOR GERMANY BY LIFE CYCLE STAGE

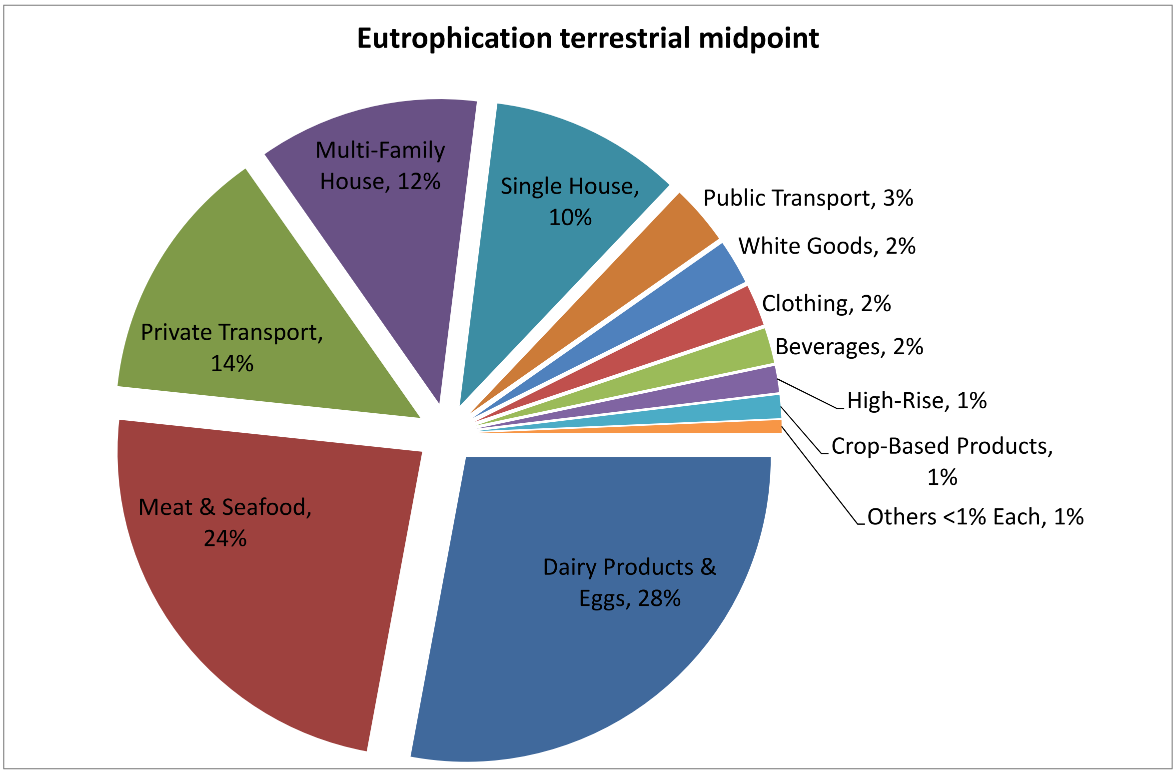

FIGURE 11 EUTROPHICATION TERRESTRIAL FOR EU-27 BY PRODUCT GROUP

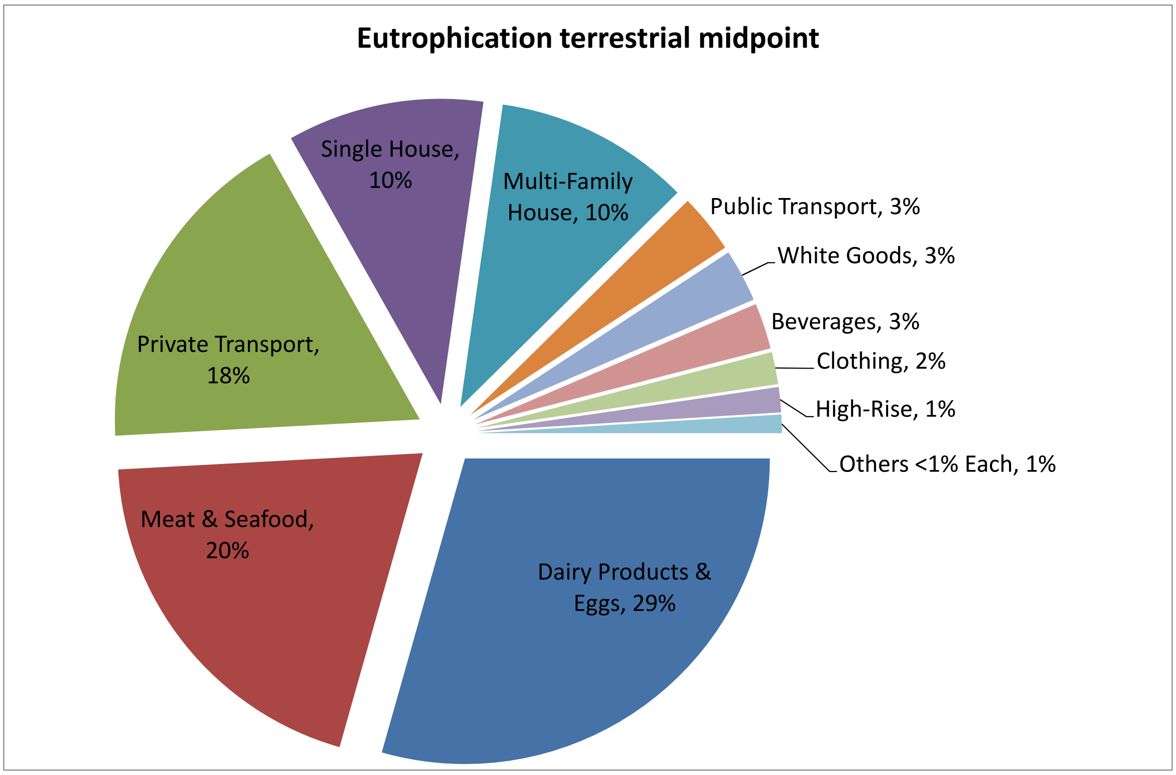

FIGURE 12 EUTROPHICATION TERRESTRIAL FOR GERMANY BY PRODUCT GROUP

3.4 EUTROPHICATION FRESHWATER

The eutrophication freshwater midpoint is almost completely caused by the production of food and beverages as can be seen in Figure 13 for EU-27 and Figure 14 for Germany. When this is disaggregated by product group (Figure 15 for EU-27 and Figure 16 for Germany), it is clear that the majority (61-64%) of the impact comes from meat products. The next most significant contributors are beverages (i.e. coffee and beer), dairy products and crop-based products.

If meat products are further disaggregated within the preliminary calculations, it is clear that the impacts are due to phosphate emissions (from fertilizer and manure) to fresh water. Poultry is the most significant contributor, followed by pork and then beef.

Similar results can be observed for the human toxicity midpoint (non-cancer) indicator. Figure 35 illustrates that the production of food and beverages is the dominant contributor. Figure 36 shows that meat products account for 72% of the total impacts. From further analysis this is primarily due to beef production.

Figure 35 also shows a small negative impact for the consumer goods category. This has been caused by the production stage of cotton shirts and shoes. The reason for this is because as cotton grows it absorbs zinc from the soil as a micronutrient. This lowers the toxicity (due to zinc) in the soil, hence the negative result for toxicity (non-cancer). However, at the end of the products' lives in which this cotton is used, any zinc which remains in the product may be re-released to the environment (depending on waste treatment).

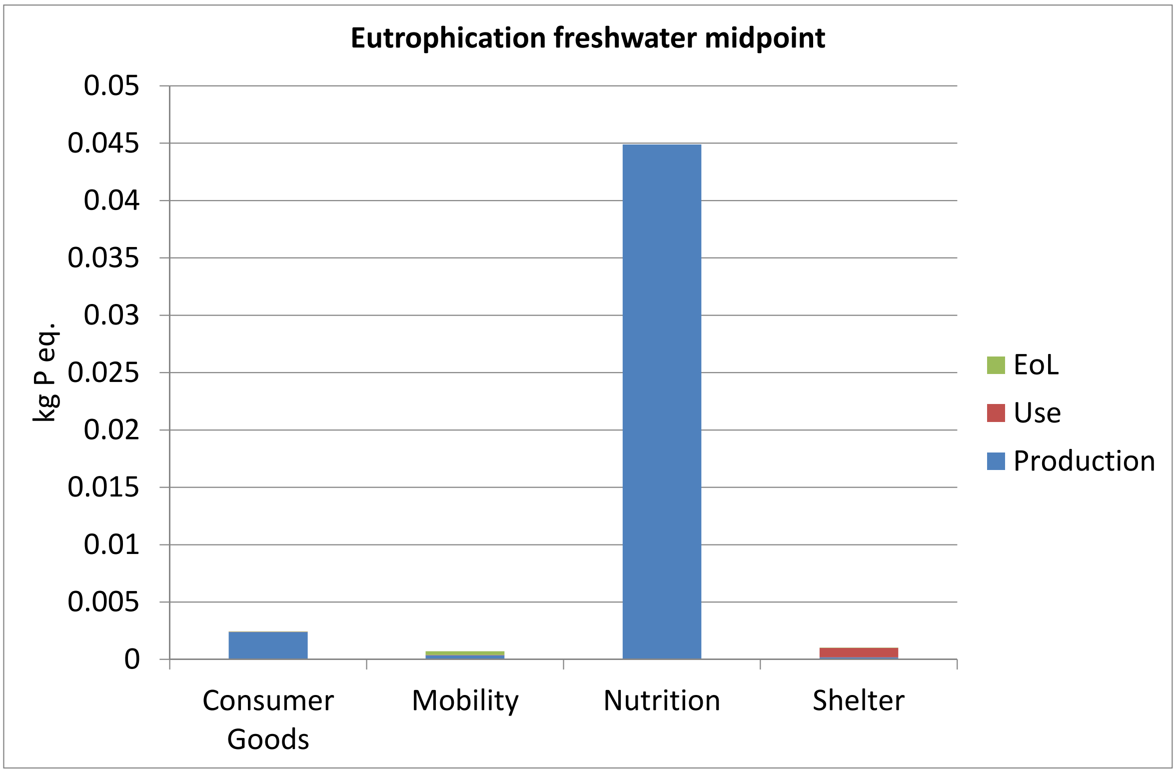

FIGURE 13 EUTROPHICATION FRESHWATER FOR EU-27 BY LIFE CYCLE STAGE

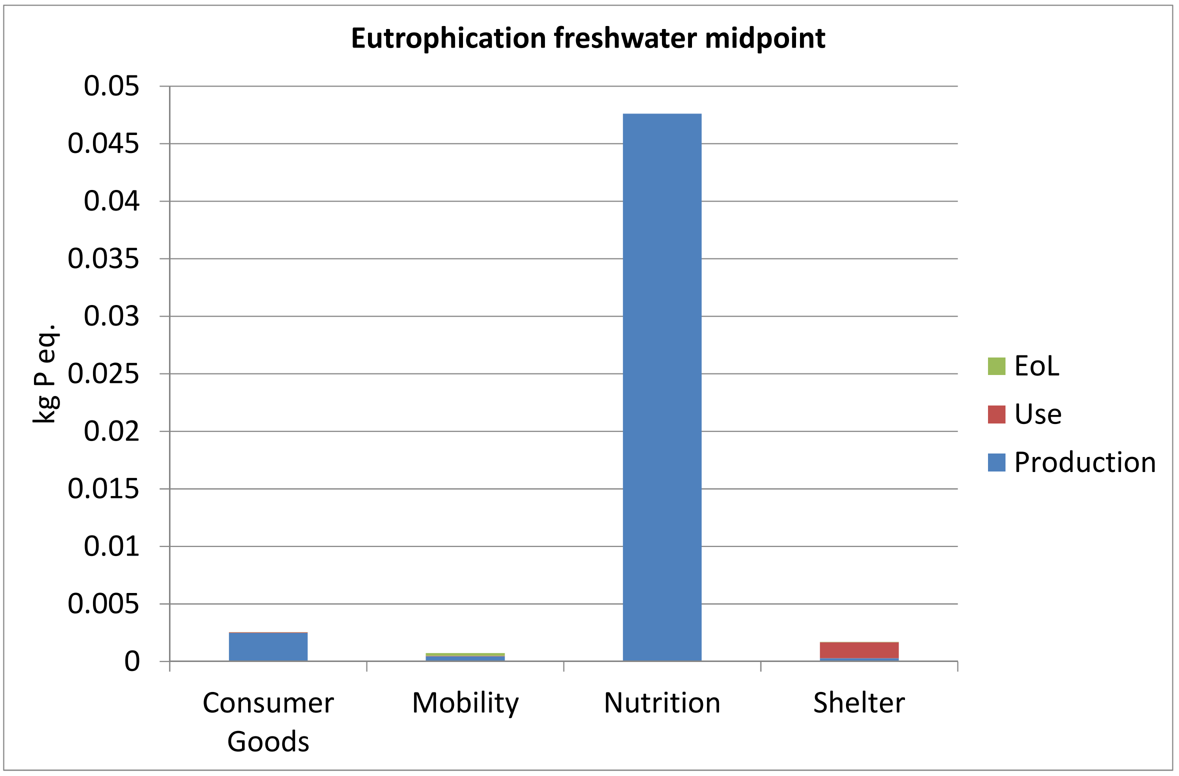

FIGURE 14 EUTROPHICATION FRESHWATER FOR GERMANY BY LIFE CYCLE STAGE

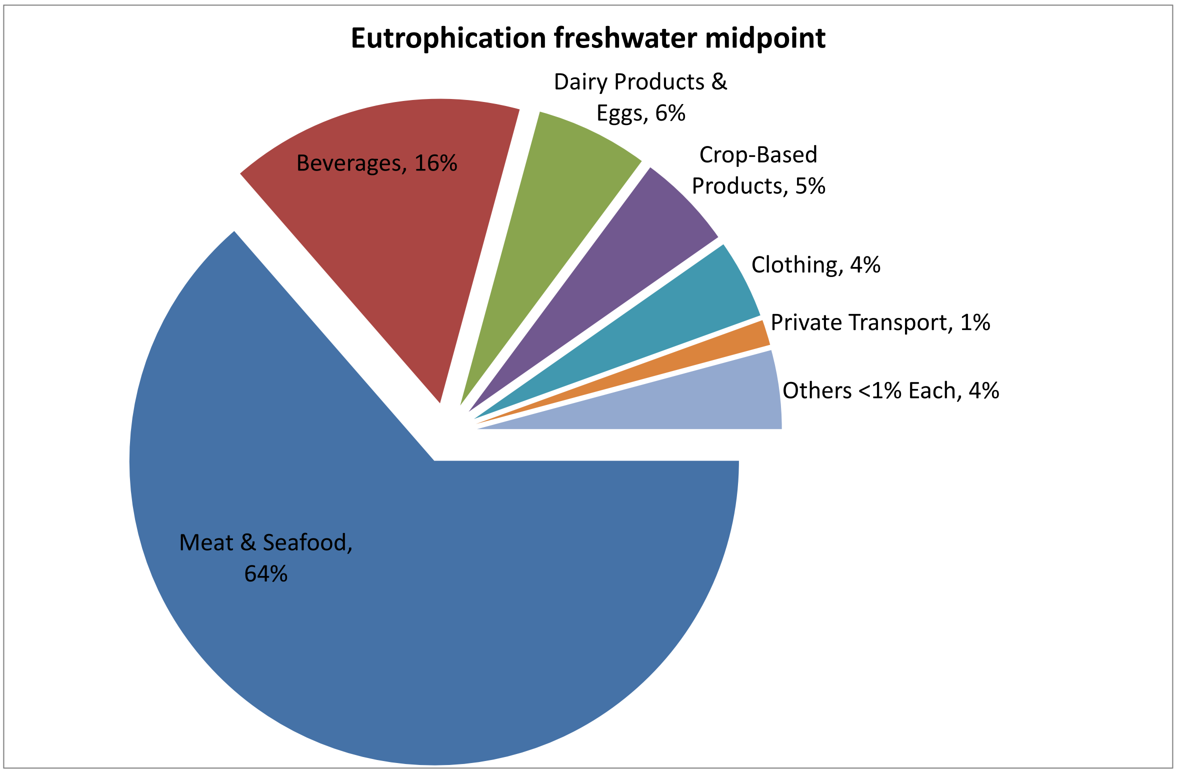

FIGURE 15 EUTROPHICATION FRESHWATER FOR EU-27 BY PRODUCT GROUP

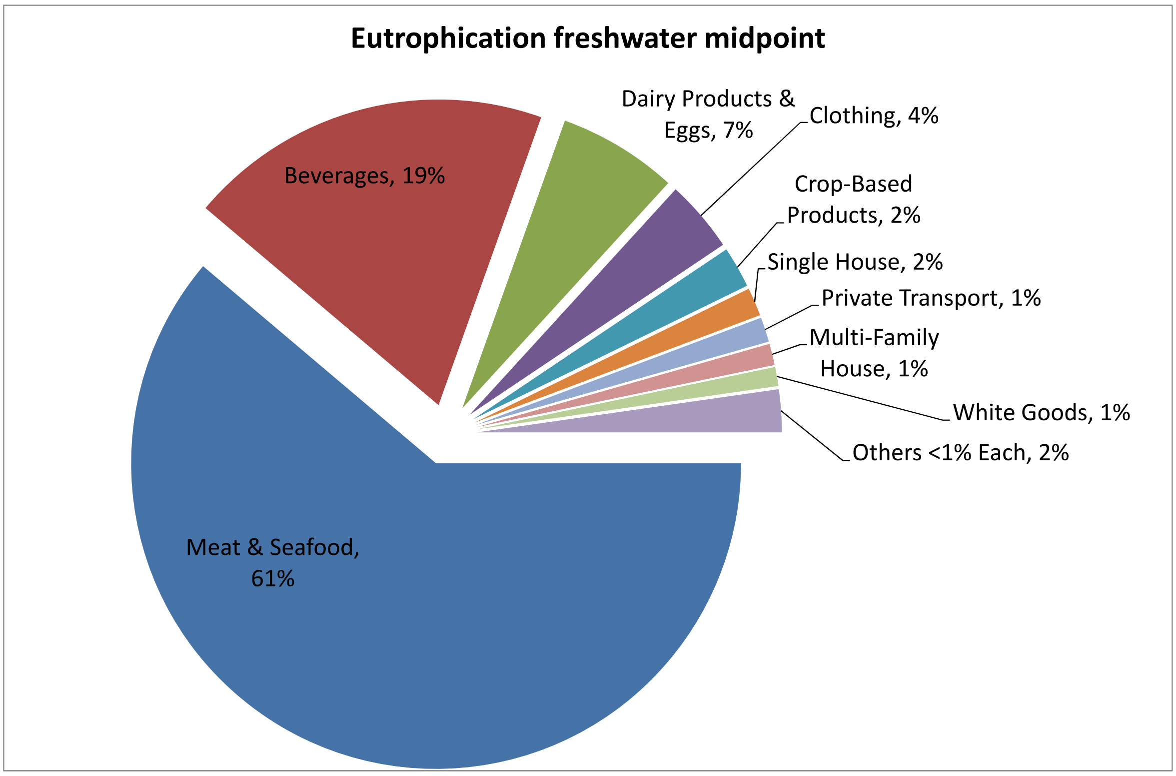

FIGURE 16 EUTROPHICATION FRESHWATER FOR GERMANY BY PRODUCT GROUP

3.5 ACIDIFICATION

The acidification midpoint is a good example of an indicator where the production stage of food/beverages and the use stage of housing are both very significant (Figure 17 for EU-27 and Figure 18 for Germany). In the specific case of acidification, private transportation is also very significant. Collectively, single- and multi-family houses, dairy products, meat products and private transport account for 83-86% of the total impact (Figure 19 and Figure 20).

The indicators human toxicity midpoint (cancer effects) and ecotoxicity freshwater midpoint also take on a similar profile in that both nutritional products and buildings play a significant role. However, each indicator also presents a result that might be unexpected. For human toxicity (cancer), it is clear from Figure 37 that shelter is very significant. However, from Figure 38, “beverages” is listed as the second most important item. This is due to the beer LCI dataset, specifically Chromium VI emissions to water from growing barley. The barley datasets come from Ecoinvent (2011) and could potentially be further investigated.

For the ecotoxicity freshwater midpoint, it is clear from Figure 39 that the most significant category is nutrition. Drilling down in Figure 40, meat contributes 51% and by far the largest contributor to this value is beef. This high value assigned to beef is due to emissions of zinc followed by copper and to a lesser extent nickel. These emissions could come from a number of sources, e.g. metals taken up by plants that are then ingested by the animal and later excreted; however, in this case the net effect to the soil should be zero.

This leads to a general point that can be made about toxicity indicators: their precision is generally quite low relative to other impact indicators. For example, the USEtox™ characterisation factors are said to have a precision in the order of 100-1,000 for human toxicity and 10-100 for freshwater ecotoxicity (Rosenbaum et al,. 2008). This factor should be considered when interpreting toxicity indicators.

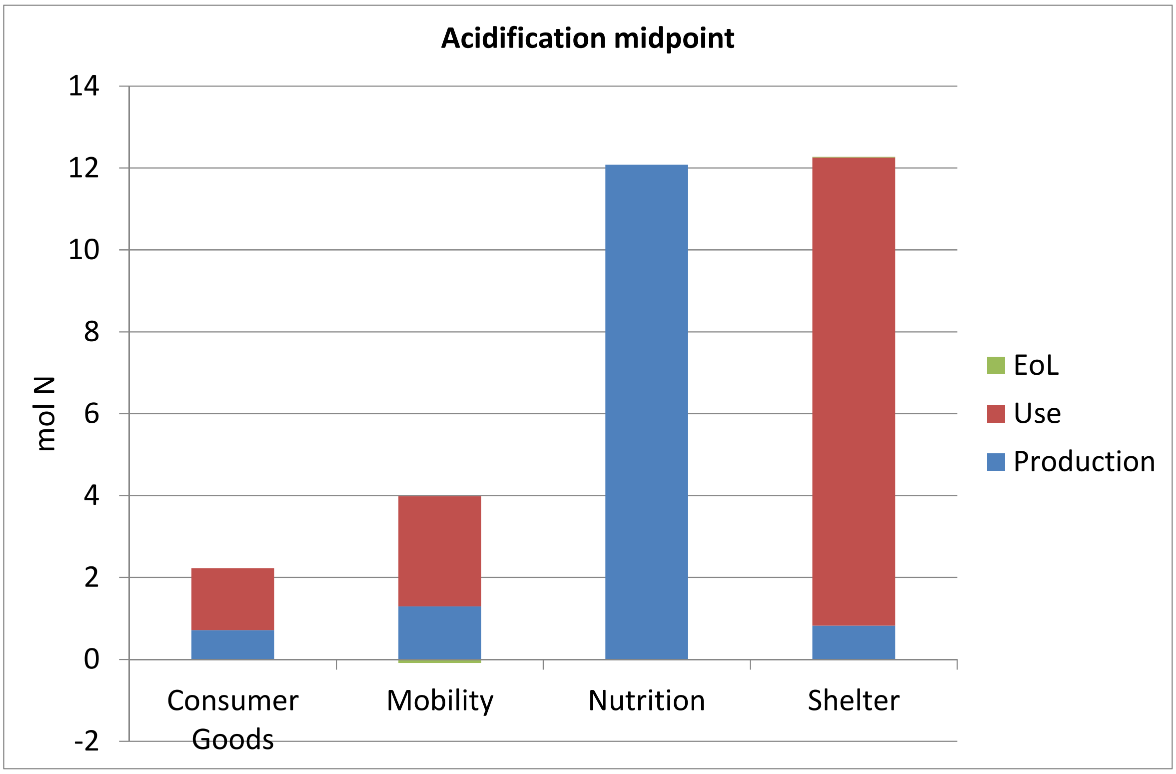

FIGURE 17 ACIDIFICATION FOR EU-27 BY LIFE CYCLE STAGE

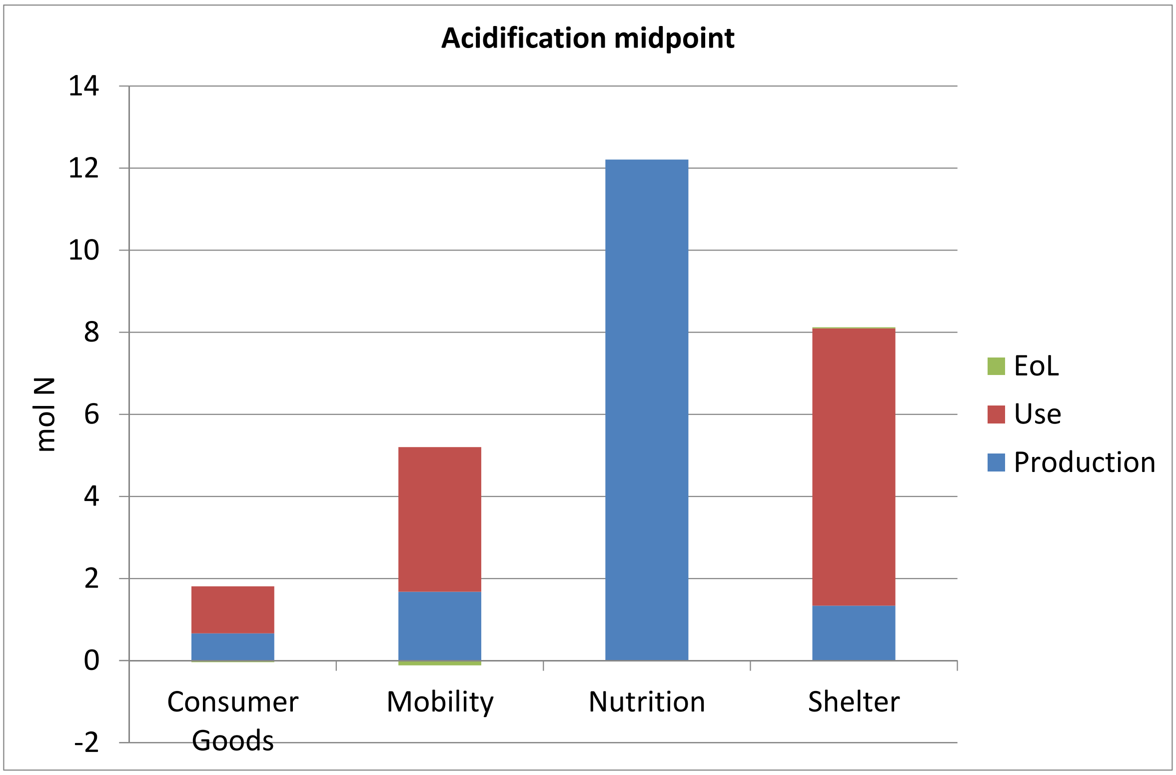

FIGURE 18 ACIDIFICATION FOR GERMANY BY LIFE CYCLE STAGE

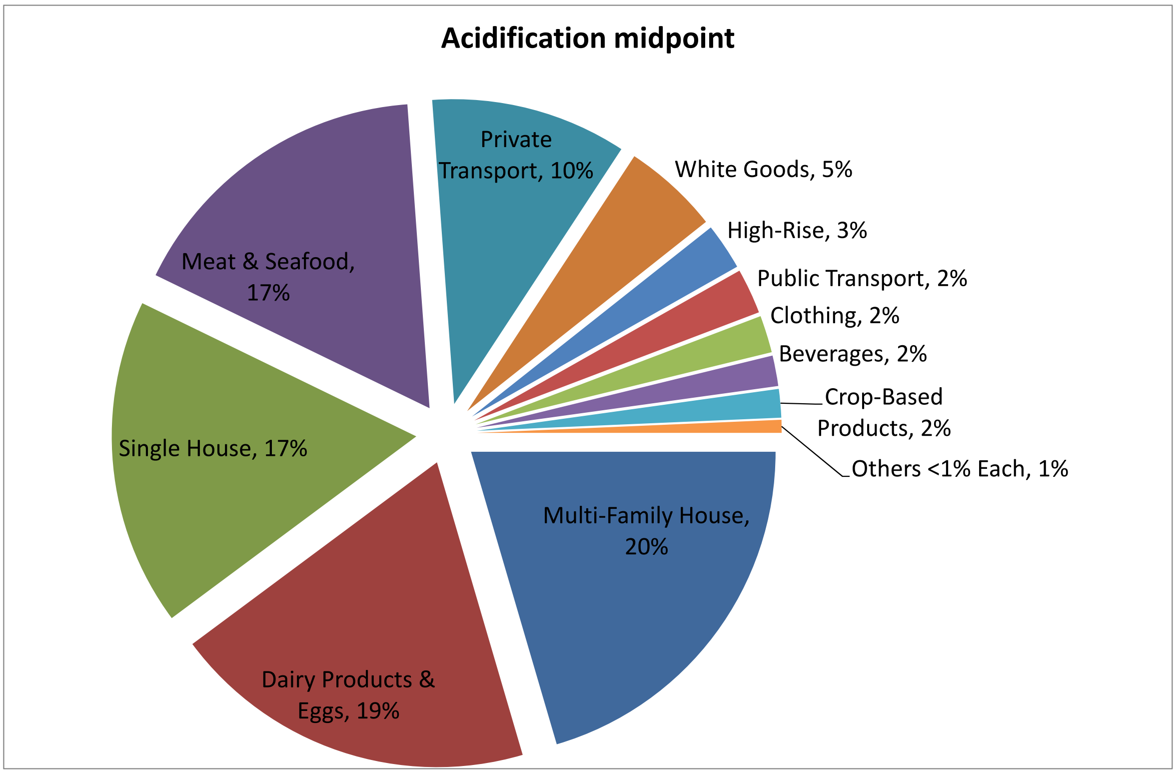

FIGURE 19 ACIDIFICATION FOR EU-27 BY PRODUCT GROUP

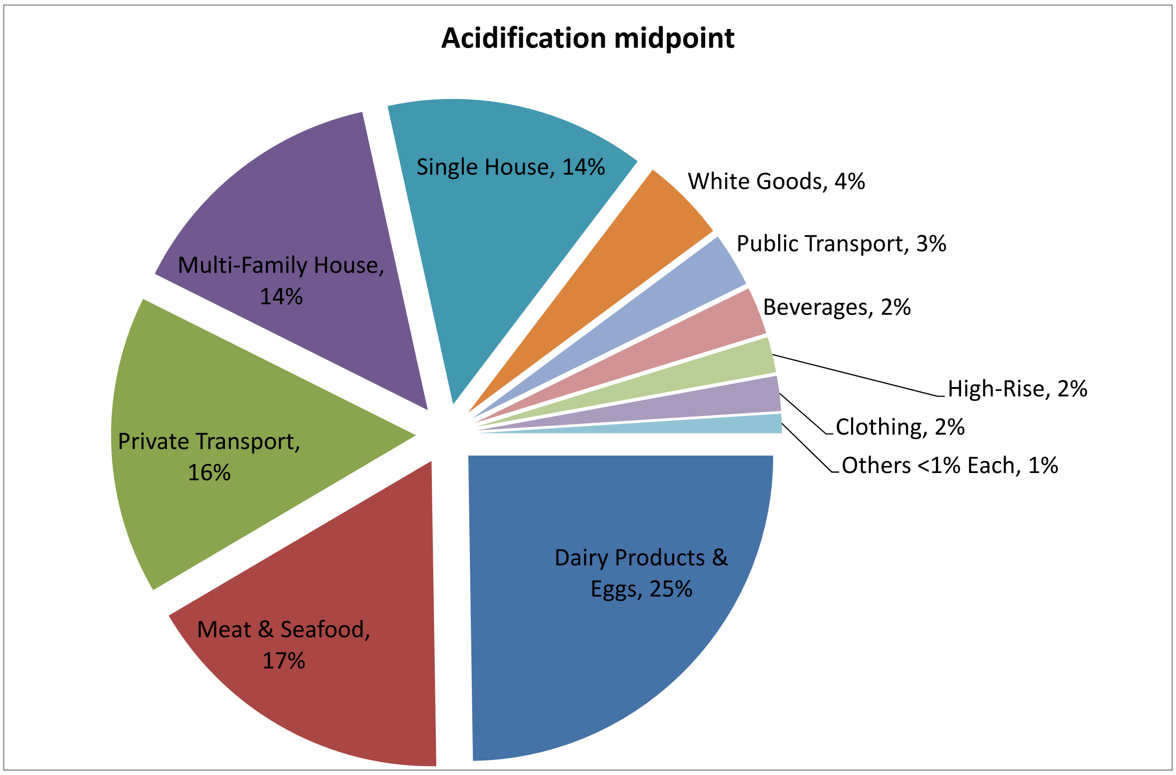

FIGURE 20 ACIDIFICATION FOR GERMANY BY PRODUCT GROUP

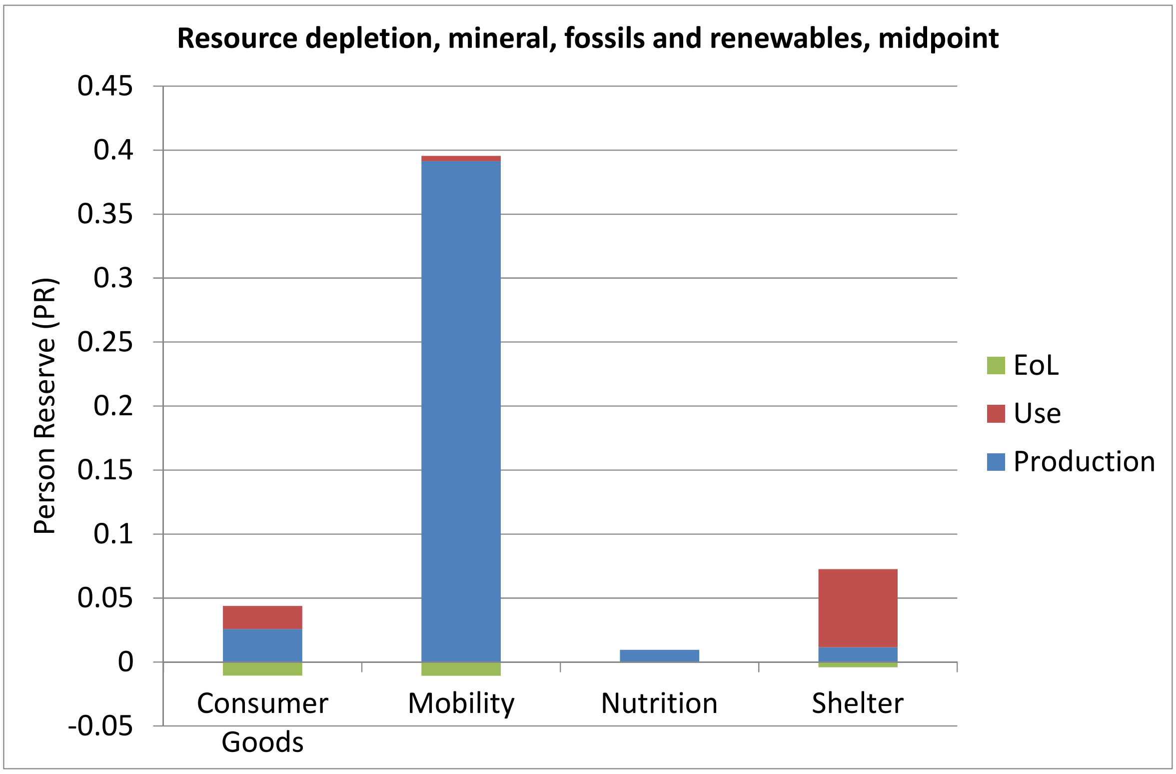

FIGURE 21 RESOURCE DEPLETION (MINERAL, FOSSILS AND RENEWABLES) FOR EU-27 BY LIFE CYCLE STAGE

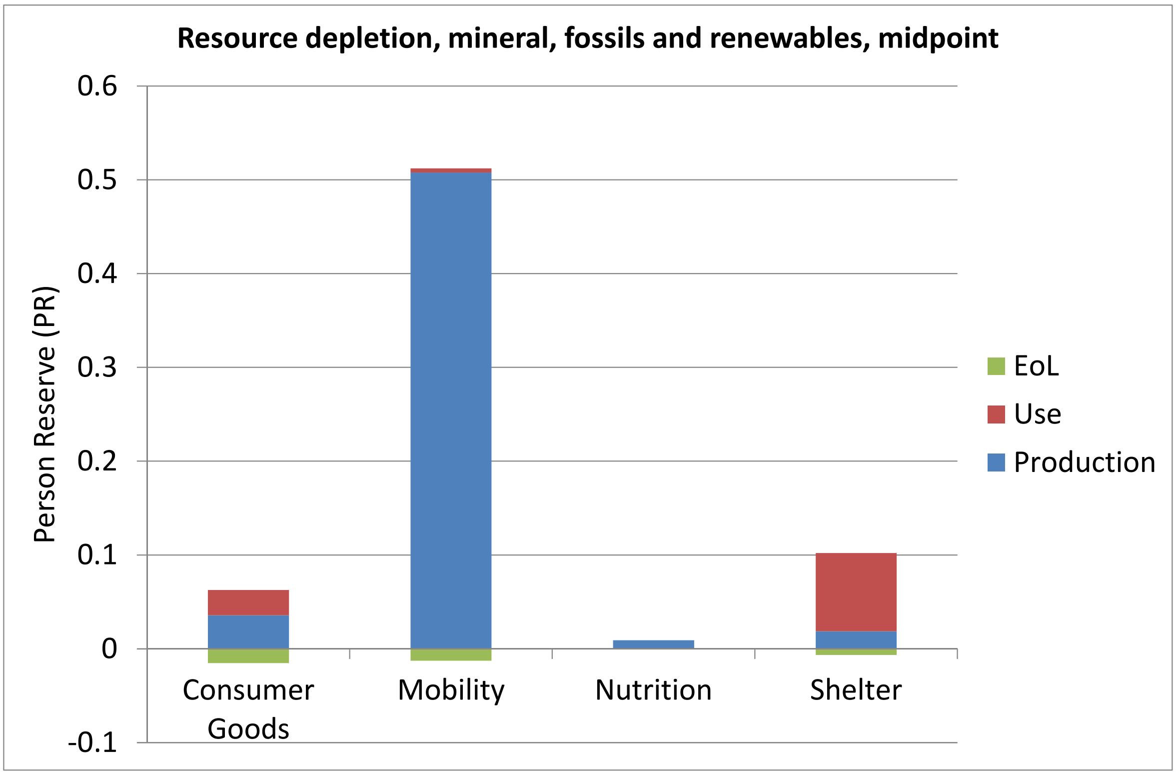

FIGURE 22 RESOURCE DEPLETION (MINERAL, FOSSILS AND RENEWABLES) FOR GERMANY BY LIFE CYCLE STAGE

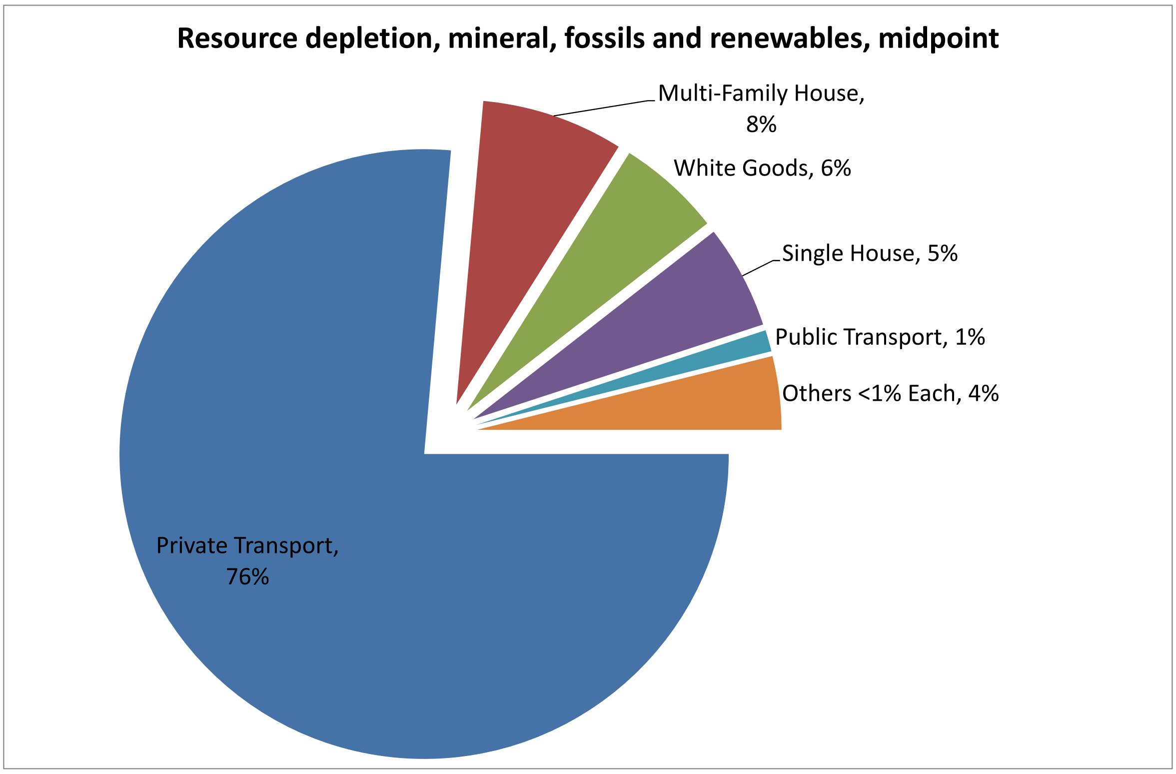

FIGURE 23 RESOURCE DEPLETION (MINERAL, FOSSILS AND RENEWABLES) FOR EU-27 BY PRODUCT GROUP

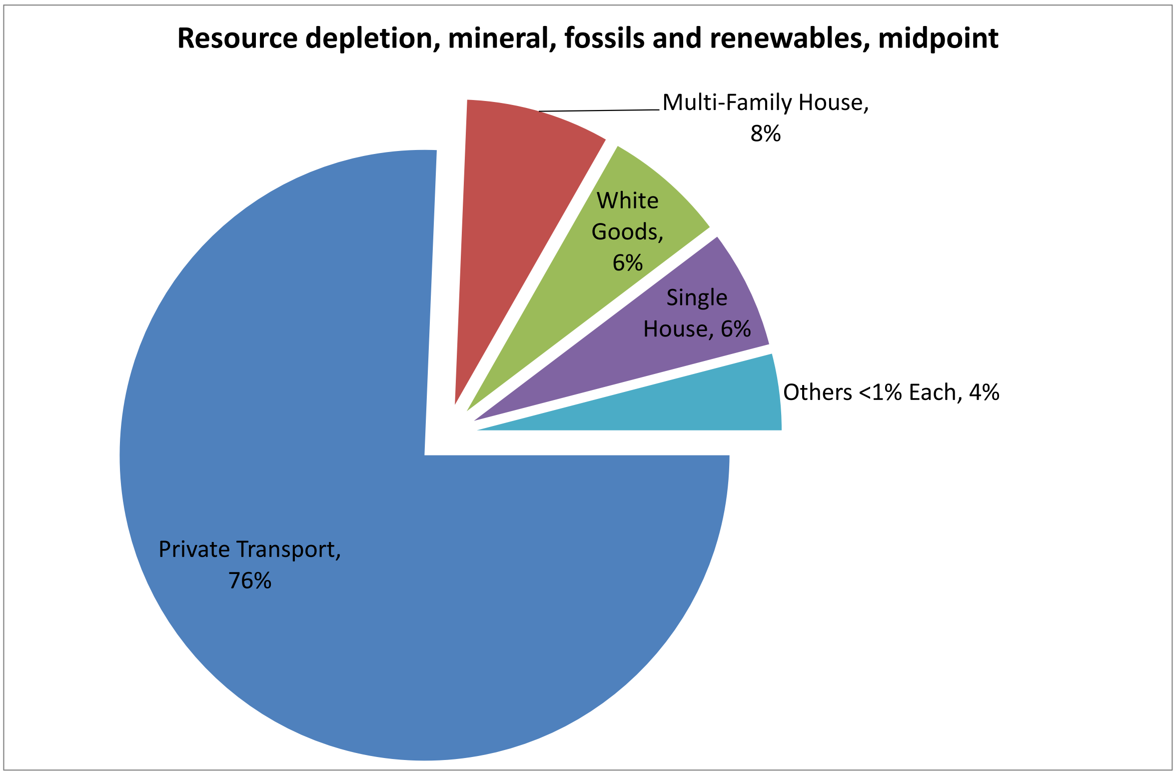

FIGURE 24 RESOURCE DEPLETION (MINERAL, FOSSILS AND RENEWABLES) FOR GERMANY BY PRODUCT GROUP

3.6 RESOURCE DEPLETION, MINERAL, FOSSILS AND RENEWABLES

Figure 21 for EU-27 and Figure 22 for Germany both suggest that resource depletion is dominated by mobility. Figure 23 and Figure 24 both suggest that 76% of this category is due to private transportation (i.e. personal cars). These high impacts are due to the large characterisation factors applied to the platinum group metals platinum and palladium to calculate the value of this indicator. The platinum and palladium content of the car is primarily due to the catalytic converter used to treat exhaust gases, but small amounts of platinum group metals are also used in the car's electronics. This particular assessment seems to place too much weight on cars and yet gives very little weight to laptops and white goods, for example.

3.7 GENERAL POINTS TO NOTE WHEN INTERPRETING THE RESULTS

The life cycle inventory and impact assessment results produced by the preliminary calculations can be compared between regions and across reference years to establish benchmarks and to monitor progress over time. However, when drawing conclusions from the results of the preliminary calculations, it is important to note that, the service consumption category has been omitted, as discussed in Chapter 1.

While the environmental impact indicators for Germany and EU-27 are the same, the source data used to derive them are different in some cases because the same data sources could not always be used for both regions. Where this is the case, there may be differences in the scope of each product category (in terms of the sub-products included, for example) and the way the data was collected. An example of this is for sugar. The German preliminary calculations includes a figure for sugar consumed directly by households whereas EU-27 uses total sugar available for consumption, including sugar that goes into other food items (i.e. other products).

There was incomplete information on stocks and flows of most products and, therefore, assumptions were made to fill data gaps. These assumptions are documented in Chapter 1.

In many cases production LCI datasets were based on German, American or Chinese data and may therefore not be fully representative of the regions in which production actually occurred. For more information on LCI datasets, see section 1.4.

The end-of-life stage for food products only includes a release of carbon so that carbon balance is correct. See Chapter 1for more.

The use stage for food products is zero because domestic food preparation is included with appliances and dwellings.

Production and end-of-life LCI data were not available for planes and trains and have therefore been omitted. However, use stage LCI data were included for all consumption items. These omissions are not likely to significantly affect the results given (a) the relative significance of the use stage for energy-using products to total environmental impact, (b) the large population amongst which the impacts of producing and disposing planes and trains are divided, and (c) the relatively small impact of the end-of-life stage compared with total impact for most durable goods.

The impact indicators reflect the impact of the basket of products only. While the preliminary calculations include an optional scaling table that allows the impacts of each consumption category to be increased by a certain percentage to account for products missing from the basket, this feature was not used as there were insufficient data to accurately account for missing consumption. However, in principle each consumption category can be scaled to reflect missing consumption, allowing the total environmental impacts per citizen of a given region to be estimated.

4 OVERALL ENVIRONMENTAL IMPACT INDICATOR

4.1 NORMALISATION

4.1.1 GENERAL ASPECTS

In general, the normalisation step within LCA is done to gain a better understanding of the relative magnitude for each indicator result (ISO, 2006). Within this project, normalisation is required before indicators can be weighted and aggregated into one overall environmental impact score. Within the normalisation step, the result for a specific impact category is divided by the total impact for the same impact category within a reference region and reference year.

The relevant normalisation factors for the reference regions EU-27 and Germany are obtained from calculation of the resource life cycle indicators (EC, 2012b). The normalisation factors presented in Table 10 represent the impacts for the domestic inventory in 2004 for EU-27 and Germany.

Some of the impact categories need to be excluded from the normalisation and weighting step for several reasons. The impact categories ozone depletion and resource depletion (water) could not be assessed in the domestic inventory of the resource indicators. The results of the domestic inventory of the resource indicators for the impact categories human toxicity (cancer effects), ecotoxicity (freshwater) and land use are not considered to be robust enough to be included in the normalisation and weighting step (see chapter on weighting for more information).

4.1.2 NORMALISED RESULTS

The normalised results for EU-27 and Germany are presented in Table 11 below. Each normalisation factor represents the total emissions within a given region, meaning that impacts can be compared within a region, but they cannot be compared between regions.

Each elementary flow is multiplied by a characterisation factor to reflect the significance of the particular resource and the each product is then summed together to create a total score. Rare materials, e.g. precious metals, are typically assigned a large characterisation factor. However, there is relatively little extraction of these rare materials within Europe, and particularly within Germany, compared to other regions of the world. This indicator therefore suggests that both EU-27 and Germany are highly dependent on countries outside of the EU for precious resources. In Germany's case, this resource dependence is particularly noticeable.

There are also potential precision issues that arise with toxicity indicators. For example, the precision of the current USEtox™ characterisation factors is generally considered to be within a factor of 100-1,000 for human toxicity and 10-100 for freshwater ecotoxicity (Rosenbaum et al., 2008). This will vary depending on the actual substance and the associated data.

Looking beyond resource depletion and human toxicity, it is significant to note that the next three most significant indicators for both preliminary calculations are climate change, acidification and terrestrial eutrophication (albeit not in the same order for each region). Each of these indicators was discussed in detail in the previous chapter.

In order to facilitate comparisons between EU-27 and Germany, two additional columns have been appended to Table 11. These columns present the normalisation factor multiplied by the population in each region in the chosen reference year (2006). Leaving human toxicity and resource depletion aside, these scaled normalisation factors show higher impacts in all remaining categories for Germany than for EU-27. However, this could be an artefact of the relatively small geographical scale in which the German normalisation factors were calculated. Alternatively, the impacts moght be normalised by population and then compared (e.g. impacts per capita in each impact category) which will yield different results and implications.

TABLE 10 NORMALISATION FACTORS DERIVED FROM THE DOMESTIC INVENTORY OF THE RESOURCE INDICATORS

Impact category (midpoint)	Unit	EU-27	Germany
Climate change	kg CO_2 eq.	4 897 798 498 804	1 055 285 757 898
Ozone depletion	kg CFC11 eq.	0	0
Human toxicity, cancer effects	CTUh	2 496	214
Human toxicity, non-cancer effects	CTUh	248 184	34 017
Particulate matter/Respiratory inorganics	kg PM2.5 eq.	2 707 507 805	246 669 829
Ionizing radiation, human health	kg U235 eq.	1 905 100 000 105	287 020 505 243
Ionizing radiation, ecosystems	CTUe = PAF*m^3*year	13 299 396	2 003 674
Photochemical ozone formation, human health	kg C_2H_4 eq.	16 581 055 979	2 048 353 851
Acidification	mol H+	31 878 744 303	3 669 929 073
Eutrophication terrestrial	kg N eq.	104 907 336 164	14 689 864 624
Eutrophication freshwater	kg P eq.	175 105 845	11 876 780
Eutrophication marine	kg N eq.	8 389 304 517	967 785 382
Ecotoxicity freshwater	CTUe = PAF*m^3*year	4 742 069 627 752	194 145 476 275
Land use	kg $C_{deficit}$*year	25 438 570 822 185	-5 525 447 750 900
Resource depletion water	Environmental Load (EL)	0	0
Resource depletion, mineral, fossils and renewables	Person Reserve (PR)	298 196 201	4 421 246

Source: EC, 2012b

TABLE 11 NORMALISED RESULTS FOR EU-27 AND GERMANY

Results	Normalised Result		Normalised x Population	
Impact category (midpoint)	EU-27	Germany	EU-27	Germany
Climate change	1.0608E-09	6.0576E-09	0.523	0.499
Ozone depletion	0	0	0	0
Human toxicity, cancer effects	2.91986E-09	4.01725E-08	1.440	3.312
Human toxicity, non-cancer effects	2.89505E-09	1.59563E-08	1.428	1.315
Particulate matter/Respiratory inorganics	4.48701E-10	4.0798E-09	0.221	0.336
Ionizing radiation, human health	1.35948E-10	8.74447E-10	0.067	0.072
Ionizing radiation, ecosystems	2.83322E-10	1.82721E-09	0.140	0.151
Photochemical ozone formation, human health	7.2173E-10	6.63127E-09	0.356	0.547
Acidification	9.55309E-10	7.40687E-09	0.471	0.611
Eutrophication terrestrial	8.95139E-10	6.90885E-09	0.441	0.570
Eutrophication freshwater	2.80124E-10	4.42781E-09	0.138	0.365
Eutrophication marine	5.00591E-10	4.90506E-09	0.247	0.404
Ecotoxicity freshwater midpoint	1.22413E-10	2.64911E-09	0.060	0.218
Land use	0	0	0	0
Resource depletion water,	0	0	0	0
Resource depletion, mineral, fossils and renewables	1.66416E-09	1.47453E-07	0.821	12.156
Total	1.28831E-08	2.4935E-07	6.354	20.556

4.2 WEIGHTING

4.2.1 GENERAL ASPECTS

The list of recommended environmental impact categories is provided by the ILCD Handbook (EC, 2010c). The ILCD Handbook also gives recommendations on environmental impact assessment models and factors for LCA (EC, 2011c), which constitute the starting point for the development of the weighting scheme.

Arriving at an overall eco-efficiency indicator starts with a large number of environmental interventions, covering emissions, extraction of resources and land use. These correspond to the life cycle inventory (LCI) results (or elementary flows) of a life cycle assessment (LCA).

Next, relatively simple and stable models link this large number of flows to a much smaller number of midpoint effects, like radiative forcing in the context of climate change, primary resource depletion or acidification. Ultimately, there are effects which are directly important for judgment: health effects, effects on the natural environment, and effects on human welfare. These ultimate endpoint effects are much more difficult to model.

The weighting methods methodologies can be grouped into three main categories: midpoint methods, endpoint methods, and integrated methods. Integrated methodologies include both midpoints and endpoints.

There are several operational weighting methods available which apply to these three main approaches. In this report, an average weighting set for midpoint assessment has been used (Huppes and van Oers, 2011a). It has been adapted from the weighting factors of three panel weighting sets (EPA Science Advisory Board, BEES Stakeholder Panel and NOGEPA). The weighting scheme used (Table 12) is described in detail in the Huppes and van Oers (2011a and 2011b).

In this project, not all impact categories recommended by the ILCD Handbook (EC, 2011c) have been included in the weighting procedure (Table 12 which summarises the reasons for exclusion). For the categories that are included in the aggregation process, the simple additive weighting scheme is applied. This calculates the sum-product by multiplying the normalised impact category scores with their respective weights (Hwang and Yoon, 1981 and Yoon and Hwang, 1995).

It should be noted that the weighting step and calculation of a single environmental impact score is done only for demonstration purposes and should not be considered a recommendation or official weighting set endorsed by the European Commission.

4.2.2 WEIGHTED RESULTS

The weighted results and single environmental score for EU-27 and Germany are presented in Table 13 below. Once again, two additional columns have been included to show the results multiplied by population. On the surface, the impact of German citizens (1.766) appears significantly higher than that of EU-27 citizens (0.4947). However, if the resource depletion (mineral, fossils and renewables) indicator is omitted, the single score drops back to 0.4056 for an EU-27 citizen and 0.4465 for a German citizen, i.e. the impact of a German citizen is approximately 10% higher than that of an EU-27 citizen. Given the relative wealth of German citizen's vs. non-German citizens in the EU-27 – in 2006 the Gross Domestic Product (GPD) in Purchasing Power Standards (PPS) for Germany was 116, 16% above the EU-27 average of 100 (Eurostat, 2011g) – such a difference seems quite plausible. However, further testing among other members states and with different items in the basket would be required before such an indicator could be established as robust.

TABLE 12 AVERAGE AND ADJUSTED WEIGHTING SCHEME

Impact category (midpoint)	Weight [%]	Adjusted weighting [%]	Reasons for exclusion
Climate change	23.21	36.37	
Ozone depletion	3.62	0.00	Data availability and quality for domestic emissions are poor
Human toxicity, cancer effects	6.49	0.00	Emissions incomplete for domestic inventory; model uncertainties
Human toxicity, non-cancer effects	4.05	6.35	
Particulate matter/Respiratory inorganics	6.56	10.29	
Ionizing radiation, human health	3.23	5.06	
Ionizing radiation, ecosystems	3.23	5.06	
Photochemical ozone formation, human health	5.38	8.44	
Acidification	4.21	6.59	
Eutrophication terrestrial	2.33	3.66	
Eutrophication freshwater	2.33	3.66	
Eutrophication marine	2.33	3.66	
Ecotoxicity freshwater	10.87	0.00	Highest impacts from pesticide emissions which were calculated using the PEST LCI model; PEST was originally developed to conduct LCA of specific agricultural products and not macro-scale analysis of the entire agriculture industry
Land use	10.15	0.00	High variations for domestic inventory due to impact assessment methodology; not included in imports and exports
Resource depletion water	5.08	0.00	Not covered in domestic inventory; country-specific information not available within LCI data used for import and export
Resource depletion, mineral, fossils and renewables	6.92	10.85	

Source: based on Huppes and van Oers (2011a)

TABLE 13 WEIGHTED RESULTS FOR EU-27 AND GERMANY

Results	Weighted Result		Weighted x Population	
Impact category (midpoint)	EU-27	Germany	EU-27	Germany
Climate change	3.85854E-10	2.20338E-09	0.1903	0.1816
Ozone depletion	n/a	n/a	n/a	n/a
Human toxicity, cancer effects	n/a	n/a	n/a	n/a
Human toxicity, non-cancer effects	1.83952E-10	1.01387E-09	0.0907	0.0836
Particulate matter/Respiratory inorganics	4.61608E-11	4.19716E-10	0.0228	0.0346
Ionizing radiation, human health	6.8847E-12	4.42837E-11	0.0034	0.0037
Ionizing radiation, ecosystems	1.4348E-11	9.25333E-11	0.0071	0.0076
Photochemical ozone formation, human health	6.09164E-11	5.59701E-10	0.0300	0.0461
Acidification	6.29692E-11	4.88224E-10	0.0311	0.0402
Eutrophication terrestrial	3.27395E-11	2.5269E-10	0.0161	0.0208
Eutrophication freshwater	1.02455E-11	1.61946E-10	0.0051	0.0134
Eutrophication marine	1.8309E-11	1.79401E-10	0.0090	0.0148
Ecotoxicity freshwater	n/a	n/a	n/a	n/a
Land use	n/a	n/a	n/a	n/a
Resource depletion water	n/a	n/a	n/a	n/a
Resource depletion, mineral, fossils and renewables	1.80593E-10	1.60014E-08	0.0891	1.3191
Total	1.00297E-09	2.14171E-08	0.4947	1.7656

5 CONCLUSIONS AND WAY FORWARD

The development of a set of indicators based on a basket-of-products approach is a significant step forward in assessing the environmental impacts of nation states and supra-national bodies like the European Union. A major advantage of this approach is that it allows environmental impacts embodied in imported products and services to be considered alongside local products and services. Perhaps most importantly, the basket-of-products approach allows fine-grained analysis of the environmental impacts of products and services over their full life cycle at a macro-economic level. This makes it a powerful tool for policy analysis, benchmarking, and also for monitoring progress in decoupling economic growth from environmental impacts. By incorporating new products into the basket, the indicators can cover close to 100% of citizens' environmental impacts. By including new life cycle datasets for existing products, it is possible to monitor changes in technological progress over time. By incorporating new macro statistics, it is possible to uncover the environmental relevance of changes in consumer behaviour.

Chapters 3 and 4 illustrated how the basket-of-products indicators can be used to identify important consumption categories—both overall and for specific environmental impacts—and how it is then possible to drill down to those products and those flows to/from the environment that are particularly environmentally relevant. However, such conclusions rely on high-quality data. To this end, the reliability of the results could be improved by:

- Developing highly disaggregated macro statistical data to help prevent double counting, e.g. sugar and oils for direct consumption vs. for use in products, splitting household energy consumption into space heating and cooling, water heating, appliances, etc.;
- Further developing life cycle inventory (LCI) datasets for EU-27 and Member States with fully consistent system boundaries and data quality;
- Further developing LCI datasets for major import markets;
- Developing more reliable information on stocks and flows of products, particularly quantification of existing stocks and outflows of products from these stocks;
- Expanding the basket-of-products to a greater range of products;
- Improving normalisation and weighting factors so that a greater number of environmental impacts can be considered in the single environmental score; and
- Developing a metric to assess the proportion of total consumption that is included within the basket-of-products, and therefore how significant the exclusions are.

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ANNEX 1 DATASETS DOCUMENTATION

TABLE 14 TRANSPORT DISTANCES BY SEA AND TRAIN WITHIN EU-27 WEIGHTED BY 2006 POPULATION

Member State	City	Pop. ('06)	Pop. %	Ship (km)	Train (km)	Weighted Ship (km)	Weighted Train (km)
Austria	Vienna	8254298	1.67	0	710	0	11.8824575
Belgium	Brussels	10511382	2.13	0	395	0	8.418305687
Bulgaria	Sofia	7718750	1.57	0	1735	0	27.15277563
Cyprus	Nicosia	766414	0.16	6475	493	10.06105707	0.766087058
Czech Republic	Prague	10251079	2.08	0	515	0	10.70396268
Denmark	Copenhagen	5427459	1.10	457	493	5.03387311	5.425143718
Estonia	Tallinn	1344684	0.27	1272	493	3.468851703	1.344110376
Finland	Helsinki	5255580	1.07	1320	493	14.07080487	5.253338039
France	Paris	63229635	12.82	0	571	0	73.2022719
Germany	--	82437995	16.71	0	0	0	0
Greece	Athens	11125179	2.26	5845	493	131.8416899	11.12043315
Hungary	Budapest	10076581	2.04	0	970	0	19.81767544
Ireland	Dublin	4208156	0.85	1615	493	13.77898018	4.206360857
Italy	Rome	58751711	11.91	0	1253	0	149.2586011
Latvia	Riga	2294590	0.47	1187	493	5.522959841	2.293611158
Lithuania	Vilnius	3403284	0.69	0	1561	0	10.7713186
Luxembourg	Luxembourg	469086	0.10	0	228	0	0.216847837
Malta	Birkirkara	405006	0.08	4760	493	3.908439014	0.40483323
Netherlands	Amsterdam	16334210	3.31	0	438	0	14.50574445
Poland	Warsaw	38157055	7.74	0	1100	0	85.10112673
Portugal	Lisbon	10569592	2.14	2454	493	52.58754067	10.56508315
Romania	Bucharest	21610213	4.38	0	1781	0	78.03523524
Slovakia	Bratislava	5389180	1.09	0	801	0	8.75231586
Slovenia	Ljubljana	2003358	0.41	0	806	0	3.273869646
Spain	Madrid	43758250	8.87	3674	923	325.9945746	81.88972697
Sweden	Stockholm	9047752	1.83	1032	493	18.92363847	9.043892349
United Kingdom	London	60409918	12.25	837	493	102.5310584	60.38414793
Sum		493210397		30928	19210	688	694
Average		18267052		1145	711		

TABLE 15 DISTRIBUTION MODES AND DISTANCES FOR EU-27 BASED ON A WEIGHTED SUM OF DISTANCES FROM IMPORT COUNTRIES TO FRANKFURT[27]

Product	Ship (km)	Rail (km)	Truck (km)
Consumer Goods: Clothing: Cotton Shirt	9620	550	400
Consumer Goods: Clothing: Shoes	12937	553	400
Consumer Goods: Consumer Electronics: Laptop	10128	593	400
Consumer Goods: White Goods: Dish Washer	688	694	400
Consumer Goods: White Goods: Refrigerator	2802	652	400
Consumer Goods: White Goods: Washing Machine	688	694	400
Mobility: Private Transport: Mid Class Car: Euro 1	0	0	0
Mobility: Private Transport: Mid Class Car: Euro 2	0	0	0
Mobility: Private Transport: Mid Class Car: Euro 3	0	0	0
Mobility: Private Transport: Mid Class Car: Euro 4	0	0	0
Mobility: Public Transport: Bus: Euro 1	0	0	0
Mobility: Public Transport: Bus: Euro 2	0	0	0
Mobility: Public Transport: Bus: Euro 3	0	0	0
Mobility: Public Transport: Bus: Euro 4	0	0	0
Mobility: Public Transport: Plane	0	0	0
Mobility: Public Transport: Train	0	0	0
Nutrition: Beverages: Beer	688	694	400
Nutrition: Beverages: Coffee	688	694	400
Nutrition: Crop-Based Products: Sugar	688	694	400
Nutrition: Crop-Based Products: Vegetable Oils & Fats: Sunflower Oil	688	694	400
Nutrition: Dairy Products & Eggs: Butter	688	694	400
Nutrition: Dairy Products & Eggs: Cheese	688	694	400
Nutrition: Dairy Products & Eggs: Milk	688	694	400
Nutrition: Fruits: Apples	688	694	400
Nutrition: Fruits: Oranges	688	694	400
Nutrition: Meat & Seafood: Beef	688	694	400
Nutrition: Meat & Seafood: Pork	688	694	400
Nutrition: Meat & Seafood: Poultry	688	694	400
Nutrition: Vegetables: Potatoes	688	694	400
Shelter: High-Rise	0	0	0
Shelter: Multi-Family House	0	0	0
Shelter: Single House	0	0	0

[27] Distances are calculated as a weighted sum of fraction of total apparent consumption produced or imported * distribution mix to transport product from the country's capital or major port to Frankfurt, Germany (considered a relatively central point within Europe). If the goods come by sea then they are assumed to arrive in Hamburg and be forwarded by train (493 km) to Frankfurt. 100 km truck transport is estimated at the exporter's side. 300 km truck transport for distribution to/from warehouses and to retailers is considered on the importer's side. In the case of domestic production within Germany (Table 16), only the 300 km figure is used. Only the first 80% of apparent consumption is considered (made up of domestic production + imports) and this distribution mix is assumed to represent the other 20% of the production/import mix. The length of sea journeys were calculated using http://www.searates.com/reference/portdistance/ and train journeys using http://reiseauskunft.bahn.de. All movement of goods within EU-27 is considered to follow the average case in Table 14.

TABLE 16 DISTRIBUTION MODES AND DISTANCES FOR GERMANY BASED ON A WEIGHTED SUM OF DISTANCES FROM IMPORT COUNTRIES TO FRANKFURT

Product	Ship (km)	Rail (km)	Truck (km)
Consumer Goods: Clothing: Cotton Shirt	8681	516	395
Consumer Goods: Clothing: Shoes	9654	542	392
Consumer Goods: Consumer Electronics: Laptop	8242	332	360
Consumer Goods: White Goods: Dish Washer	0	0	300
Consumer Goods: White Goods: Refrigerator	418	422	361
Consumer Goods: White Goods: Washing Machine	298	300	343
Mobility: Private Transport: Mid Class Car: Euro 1	0	0	0
Mobility: Private Transport: Mid Class Car: Euro 2	0	0	0
Mobility: Private Transport: Mid Class Car: Euro 3	0	0	0
Mobility: Private Transport: Mid Class Car: Euro 4	0	0	0
Mobility: Public Transport: Bus: Euro 1	0	0	0
Mobility: Public Transport: Bus: Euro 2	0	0	0
Mobility: Public Transport: Bus: Euro 3	0	0	0
Mobility: Public Transport: Bus: Euro 4	0	0	0
Mobility: Public Transport: Plane	0	0	0
Mobility: Public Transport: Train	0	0	0
Nutrition: Beverages: Beer	0	0	300
Nutrition: Beverages: Coffee	0	0	300
Nutrition: Crop-Based Products: Sugar	0	0	300
Nutrition: Crop-Based Products: Vegetable Oils & Fats: Sunflower Oil	283	285	341
Nutrition: Dairy Products & Eggs: Butter	196	198	328
Nutrition: Dairy Products & Eggs: Cheese	147	148	321
Nutrition: Dairy Products & Eggs: Milk	0	0	300
Nutrition: Fruits: Apples	306	309	345
Nutrition: Fruits: Oranges	688	694	400
Nutrition: Meat & Seafood: Beef	116	117	317
Nutrition: Meat & Seafood: Pork	177	179	326
Nutrition: Meat & Seafood: Poultry	272	275	340
Nutrition: Vegetables: Potatoes	41	42	306
Shelter: High-Rise	0	0	0
Shelter: Multi-Family House	0	0	0
Shelter: Single House	0	0	0

TABLE 17 CARBON CONTENT OF PRODUCTS IN THE NUTRITION CATEGORY

	Absolute Value in the Food*				Mean Carbon Content				Total C	C as CO_2
Product	Protein	Fat	Carb.	Fibre	Protein	Fat	Carb.	Fibre		
Beer	0.0050	0.0000	0.0312	0.0000	0.0027	0.0000	0.0131	0.0000	0.0158	0.0578
Coffee	0.1400	0.1336	0.0150	0.5815	0.0742	0.1016	0.0063	0.2442	0.4263	1.5631
Sugar	0.0000	0.0000	0.9980	0.0000	0.0000	0.0000	0.4192	0.0000	0.4192	1.5369
Sunflower Oil	0.0000	1.0000	0.0000	0.0000	0.0000	0.7600	0.0000	0.0000	0.7600	2.7867
Butter	0.0067	0.8320	0.0060	0.0000	0.0036	0.6323	0.0025	0.0000	0.6384	2.3407
Cheese	0.2010	0.2180	0.0000	0.0000	0.1065	0.1657	0.0000	0.0000	0.2722	0.9981
Milk	0.0333	0.0378	0.0470	0.0000	0.0176	0.0287	0.0197	0.0000	0.0661	0.2424
Apples	0.0034	0.0005	0.1435	0.0201	0.0018	0.0004	0.0603	0.0084	0.0709	0.2599
Oranges	0.0100	0.0020	0.0825	0.0220	0.0053	0.0015	0.0347	0.0092	0.0507	0.1859
Beef	0.2050	0.1400	0.0009	0.0000	0.1087	0.1064	0.0004	0.0000	0.2154	0.7899
Pork	0.2050	0.1400	0.0009	0.0000	0.1087	0.1064	0.0004	0.0000	0.2154	0.7899
Poultry	0.1815	0.1120	0.0000	0.0000	0.0962	0.0851	0.0000	0.0000	0.1813	0.6648
Potatoes	0.0194	0.0001	0.1562	0.0123	0.0103	0.0001	0.0656	0.0052	0.0811	0.2975
Multipliers for calculating C content:					0.53	0.76	0.42	0.42		3.6667
These carbon multipliers are from Palmowski (2000), as cited in Voß (2006), pp. 17-19										
*Nutritional information from http://www.ernaehrung.de/lebensmittel/										

TABLE 18 LITERATURE REFERENCES FOR NUTRITION LCI DATASETS[28]

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Oranges	**Reference**
FAO 2008	FAO: http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor
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TABLE 19 MAPPING BETWEEN PRODUCTS AND EUROSTAT'S PRODCOM AND CN8 CODES

Product	Eurostat HS4/HS6/CN8 codes included to determine import mix	Eurostat PRODCOM codes included for production statistics
Beef	0201 Meat of bovine animals, fresh or chilled 0202 Meat of bovine animals, frozen 020610 Fresh or chilled edible offal of bovine animals 020621 Frozen edible bovine tongues 020622 Frozen edible bovine livers 020629 Frozen edible bovine offal (excl. tongues and livers) 021020 Meat of bovine animals, salted, in brine, dried or smoked 02109041 Edible thick offal of bovine animals, salted, in brine, dried or smoked 02109049 Edible offal of bovine animals, salted, in brine, dried or smoked 02109951 Edible thick skirt and thin skirt of bovine animals, salted, in brine, dried or smoked 02109959 Edible offal of bovine animals, salted, in brine, dried or smoked	Not in PRODCOM; however, Eurostat Farm to Fork statistics are available
Pork	0203 Meat of swine, fresh, chilled or frozen 020630 Fresh or chilled edible offal of swine 020641 Frozen edible livers of swine 020649 Edible offal of swine, frozen (excl. livers) 02090011 Fresh, chilled or frozen subcutaneous pig fat, salted or ... 02090019 Dried or smoked subcutaneous pig fat 02090030 Pig fat, not rendered or otherwise extracted 021011 Hams, shoulders and cuts thereof of swine, salted, in brine... 021012 Bellies "streaky" and cuts thereof of swine, salted, in brine... 021019 Meat of swine, salted, in brine, dried or smoked 02109031 Edible domestic swine livers, salted, in brine, dried or smoked 02109039 Edible domestic swine offal, salted, in brine, dried or smoked 02109941 Edible domestic swine livers, salted, in brine, dried or smoked 02109949 Edible domestic swine offal, salted, in brine, dried or smoked	Not in PRODCOM; however, Eurostat Farm to Fork statistics are available
Poultry	0207 Meat and edible offal of fowls of the species gallus domesticus 02090090 Poultry fat, not rendered or otherwise extracted 02109071 Edible fatty goose or duck livers, salted or in brine 02109079 Edible poultry liver, salted, in brine, dried or smoked 02109971 Edible fatty goose or duck livers, salted or in brine 02109979 Edible poultry liver, salted, in brine, dried or smoked	Not in PRODCOM; however, Eurostat Farm to Fork statistics are available
Milk	0401 Milk and cream, not concentrated nor containing added sugar	Not in PRODCOM; however, Eurostat Farm to Fork statistics are available
Butter	0405 Butter, incl. dehydrated butter and ghee, and other fats ...	Not in PRODCOM; however, Eurostat Farm to Fork statistics are available
Cheese	0406 Cheese and curd	Not in PRODCOM; however, Eurostat Farm to Fork statistics are available
Potatoes	070190 Fresh or chilled potatoes (excl. seed)	Not in PRODCOM; however, Eurostat Farm to Fork statistics are available
Oranges	080510 Fresh or dried oranges	Not in PRODCOM; however, Eurostat Farm to Fork statistics are available
Apples	080810 Fresh apples	Not in PRODCOM; however, Eurostat Farm to Fork statistics are available
Coffee	090111 Coffee (excl. roasted and decaffeinated) 090112 Decaffeinated coffee (excl. roasted) 090121 Roasted coffee (excl. decaffeinated) 090122 Roasted, decaffeinated coffee	15861130 Decaffeinated coffee, not roasted 15861150 Roasted coffee, not decaffeinated 15861170 Roasted decaffeinated coffee
Sunflower Oil	151219 Sunflower-seed or safflower oil and their fractions, whether or not refined	15421140 Refined sunflower-seed and safflower oil and their fractions (excluding chemically modified)
Sugar	170111 Raw cane sugar (excl. added flavouring or colouring) 170112 Raw beet sugar (excl. added flavouring or colouring) 170199 Cane or beet sugar and chemically pure sucrose, in solid form	Not in PRODCOM; however, Eurostat Farm to Fork statistics are available
Beer	2203 Beer made from malt	15961000 Beer made from malt (excluding non-alcoholic beer, beer containing <= 0.5% by volume of alcohol, alcohol duty)

Product	Eurostat HS4/HS6/CN8 codes included to determine import mix	Eurostat PRODCOM codes included for production statistics
Cotton Shirt	610510 Men's or boys' shirts of cotton, knitted or crocheted 610610 Women's or girls' blouses, shirts and shirt-blouses of cotton 610910 T-shirts, singlets and other vests of cotton, knitted or crocheted 620520 Men's or boys' shirts of cotton (excl. knitted or crocheted) 620630 Women's or girls' blouses, shirts and shirt-blouses of cotton (excl. knitted or crocheted)	182311 Men's or boys' shirts and under-shirts, of knitted or crocheted textiles 182313 Women's or girls' blouses, shirts and shirt-blouses, of knitted or crocheted textiles 182321 Men's or boys' shirts (excluding knitted or crocheted) 182323 Women's or girls' blouses, shirts and shirt-blouses (excluding knitted or crocheted) 182330 T-shirts, singlets and vests, knitted or crocheted NB: Data were not disaggregated by cotton in 2006 reference year so have been scaled to the import value attached to the HS6 code.
Shoes	640291 Footwear covering the ankle, with outer soles and uppers of rubber or plastic 640299 Footwear with outer soles and uppers of rubber or plastic 640319 Sports footwear, with outer soles of rubber, plastics, leather or composition leather and uppers of leather 640351 Footwear with outer soles and uppers of leather, covering the ankle 640359 Footwear with outer soles and uppers of leather 640391 Footwear with outer soles of rubber, plastics or composition leather, with uppers of leather, covering the ankle 640399 Footwear with outer soles of rubber, plastics or composition leather, with uppers of leather 640411 Sports footwear 640419 Footwear with outer soles of rubber or plastics and uppers of textile materials 640420 Footwear with outer soles of leather or composition leather and uppers of textile materials 640510 Footwear with uppers of leather or composition leather 640520 Footwear with uppers of textile materials	19301231 Town footwear with rubber or plastic uppers 19301351 Men's town footwear with leather uppers 19301352 Women's town footwear with leather uppers 19301353 Children's town footwear with leather uppers 19301445 Footwear with rubber; plastic or leather outer soles and textile uppers 19301449 Footwear with textile uppers (excluding those with wood; cork; rubber; plastic or leather outer soles, slippers and other indoor footwear) 19302240 Sports footwear with rubber or plastic outer soles and textile uppers 19302310 Sports footwear with outer soles and uppers of rubber or plastic 19302350 Sports footwear with rubber; plastic or leather outer soles and leather uppers NB: Both columns include town shoes and sports shoes, but exclude waterproof footwear, protective footwear, ski boots, sandals and indoor footwear.
Refrigerator	841821 Household refrigerators, compression-type 841822 Household electrical refrigerators, absorption-type 841829 Household refrigerators, non-electrical, absorption-type	29711110 Combined refrigerators-freezers, with separate external doors 29711133 Household-type refrigerators (including compression-type, electrical absorption-type) (excluding built-in) 29711135 Compression-type built-in refrigerators
Dish Washer	842211 Dish-washing machines of the household type	29711200 Household dishwashing machines
Washing Machine	845011 Fully-automatic household or laundry-type washing machines of a dry linen capacity <= 6 kg 845012 Household or laundry-type washing machines, with built-in centrifugal drier (excl. fully-automatic machines) 845019 Household or laundry-type washing machines, of a dry linen capacity <= 6 kg (excl. fully-automatic machines and washing machines with a built-in centrifugal drier)	29711330 Fully-automatic washing machines of a dry linen capacity <= 10 kg (including machines which both wash and dry) 29711350 Non-automatic washing machines of a dry linen capacity <= 10 kg (including machines which both wash and dry)
Laptop	847130 Data-processing machines, automatic, digital, portable	30021200 Laptop PCs and palm-top organisers
Train	860110 Rail locomotives powered from an external source of electricity 860120 Rail locomotives powered by electric accumulators 860210 Diesel-electric locomotives 860290 Rail locomotives (excl. those powered from an external source of electricity or by accumulators and diesel-electric locomotives)	35201100 Rail locomotives powered from an external source of electricity 35201200 Diesel-electric locomotives 35201300 Rail locomotives powered by electric accumulators
Bus	87021011 Motor vehicles for the transport of >= 10 persons, incl. driver, with compression-ignition internal combustion piston engine "diesel or semi-diesel engine", of a cylinder capacity > 2.500 cm^3, new NB: Code 87029011 for used buses is ignored as country of manufacture unknown. Code 87029019 for spark-ignition buses is ignored as almost all would have been diesel in 2006.	34103035 Public transport type vehicles for >= 10 persons, with a compression-ignition internal combustion piston engine (diesel or semi-diesel) of a cylinder capacity > 2500 cm^3 NB: Code 34103053 is for spark-ignition vehicles of a similar type. This is ignored as almost all buses intended for public transportation would have been diesel in 2006.
Motor Car	87032110 Passenger motor vehicles with spark-ignition engine <= 1000 cm^3, new (excl. 8703.10) 87032210 Passenger motor vehicles with spark-ignition engine >	34102133 Motor vehicles with a petrol engine <= 1000 cm^3 34102135 Motor vehicles with a petrol engine

Product	Eurostat HS4/HS6/CN8 codes included to determine import mix	Eurostat PRODCOM codes included for production statistics
	1000 cm^3 but <= 1500 cc, new (excl. 8703.10) 87032219 Passenger motor vehicles (other than those of heading nr. 87.02) with spark-ignition engine > 1000 cm^3 but <= 1500 cc, new (excl. 8703.10-10 and 8703.22-11) 87032310 Passenger motor vehicles with spark-ignition engine > 1 500 cc but <= 3 000 cc, new (excl. 8703.10) 87032319 Passenger motor vehicles for the transport of 1 to 9 persons with spark-ignition engine > 1500 cc but <= 3000 cc, new (excl. 8703.10 and motor caravans) 87032410 Passenger motor vehicles with spark-ignition engine > 3000 cc, new (excl. 8703.10) 87033110 Passenger motor vehicles with a diesel or semi-diesel engine <= 1500 cm^3, new (excl. 8703.10) 87033210 Passenger motor vehicles with a diesel or semi-diesel engine > 1500 cc but <= 2500 cc, new (excl. 8703.10) 87033219 Passenger motor vehicles with a diesel or semi-diesel engine > 1500 cc but <= 2500 cc, new (excl. 8703.10) 87033310 Passenger motor vehicles with a diesel or semi-diesel engine > 2500, new (excl. 8703.10) 87033319 Passenger motor vehicles with a diesel or semi-diesel engine > 2500 cm^3, new (excl. 8703.10) NB: The above are short names	greater than 1000cc but =< 1500cc 34102136 Other motor vehicles (including motor caravans) with spark-ignition engine of a cylinder capacity > 1.000 cm^3 but <= 1.500 cm^3 34102230 Motor vehicles with a petrol engine > 1500 cm^3 (including motor caravans of a capacity > 3000 cm^3) 34102310 Motor vehicles with a diesel or semi-diesel engine <= 1500 cm^3 34102330 Motor vehicles with a diesel or semi-diesel engine > 1500 cm^3 but <= 2500 cm^3 34102340 Motor vehicles with a diesel or semi-diesel engine > 2500 cm^3 NB1: The above are short names. all entries exclude vehicles for carrying >= 10 passengers, snowmobiles, golf carts and other special vehicles NB2: Motor caravans are included above because the data are often not disaggregated and motor caravans will hold a small share relative to motor cars.
Plane	880240 Aeroplanes and other powered aircraft of an of an unladen weight > 15000 kg (excl. helicopters and dirigibles)	35303400 Aeroplanes and other aircraft of an unladen weight > 15 000 kg

ANNEX 2 IMPACT ASSESSMENT RESULTS

TABLE 20 LIFE CYCLE IMPACT ASSESSMENT FOR AN AVERAGE CITIZEN OF EU-27 USING THE BASKET-OF-PRODUCTS APPROACH

Impact category (midpoint)	Unit	Consumer Goods	Mobility	Nutrition	Shelter	Total
Climate change	kg CO_2 eq.	349.6	1691	656.6	2499	5196
Ozone depletion	kg CFC11 eq.	3.76E-05	3.61E-05	2.53E-05	2.32E-04	3.31E-04
Human toxicity, cancer effects	CTUh	3.72E-07	5.97E-07	2.72E-06	3.60E-06	7.29E-06
Human toxicity, non-cancer effects	CTUh	-1.46E-06	4.36E-05	6.36E-04	4.02E-05	7.19E-04
Particulate matter/Respiratory inorganics	mg PM2.5 eq.	0.1104	0.2133	0.2889	0.6023	1.215
Ionizing radiation, human health	kg U235 eq.	29.77	21.61	20.82	186.8	259
Ionizing radiation, ecosystems	CTUe = PAF*m^3* year	4.36E-04	3.20E-04	2.77E-04	2.74E-03	3.77E-03
Photochemical ozone formation, human health	kg C_2H_4 eq.	0.8026	3.843	1.324	5.997	11.97
Acidification	mol H+	2.205	3.897	12.08	12.27	30.45
Eutrophication terrestrial	kg N eq.	4.342	15.75	52	21.81	93.91
Eutrophication freshwater	kg P eq.	2.44E-03	7.04E-04	4.49E-02	1.02E-03	4.91E-02
Eutrophication marine	kg N eq.	0.2571	1.204	0.7571	1.981	4.2
Ecotoxicity freshwater	CTUe = PAF*m^3* year	15.65	59.91	387.8	117.1	580.5
Land use	kg $C_{deficit}$*year	0	0	0	0	0
Resource depletion water	Environmental Load	0	0	0	0	0
Resource depletion, mineral, fossils and renewables	Person Reserve	0.03332	0.3848	0.009572	0.06853	0.4962

TABLE 21 LIFE CYCLE IMPACT ASSESSMENT FOR AN AVERAGE GERMAN CITIZEN USING THE BASKET-OF-PRODUCTS APPROACH

Impact category (midpoint)	Unit	Consumer Goods	Mobility	Nutrition	Shelter	Total
Climate change midpoint	kg CO_2 eq.	536	1758	619.6	3479	6392
Ozone depletion midpoint	kg CFC11 eq.	5.01E-05	4.57E-05	2.23E-05	2.06E-04	3.24E-04
Human toxicity midpoint, cancer effects	CTUh	4.55E-07	7.40E-07	2.50E-06	4.91E-06	8.60E-06
Human toxicity midpoint, non-cancer effects	CTUh	1.18E-06	5.62E-05	4.41E-04	4.42E-05	5.43E-04
Particulate matter/Respiratory inorganics midpoint	mg PM2.5 eq.	0.07555	0.3373	0.2844	0.3091	1.006
Ionizing radiation midpoint, human health	kg U235 eq.	39.63	27.19	18.2	166	251
Ionizing radiation midpoint, ecosystems	CTUe = PAF*m^3* year	5.81E-04	4.02E-04	2.47E-04	2.43E-03	3.66E-03
Photochemical ozone formation midpoint, human health	kg C_2H_4 eq.	0.9294	5.351	1.276	6.027	13.58
Acidification midpoint	mol H+	1.771	5.086	12.21	8.119	27.18
Eutrophication terrestrial midpoint	kg N eq.	4.614	21.11	53.29	22.47	101.5
Eutrophication freshwater midpoint	kg P eq.	2.53E-03	7.31E-04	4.76E-02	1.71E-03	5.26E-02
Eutrophication marine midpoint	kg N eq.	0.3054	1.655	0.7542	2.033	4.747
Ecotoxicity freshwater midpoint	CTUe = PAF*m^3* year	18.65	75.77	283.9	136	514.3
Land use midpoint	kg $C_{deficit}$*year	0	0	0	0	0
Resource depletion water, midpoint	Environmental Load	0	0	0	0	0
Resource depletion, mineral, fossils and renewables, midpoint	Person Reserve	0.04753	0.4996	0.009131	0.09566	0.6519

PARTICULATE MATTER/RESPIRATORY INORGANICS

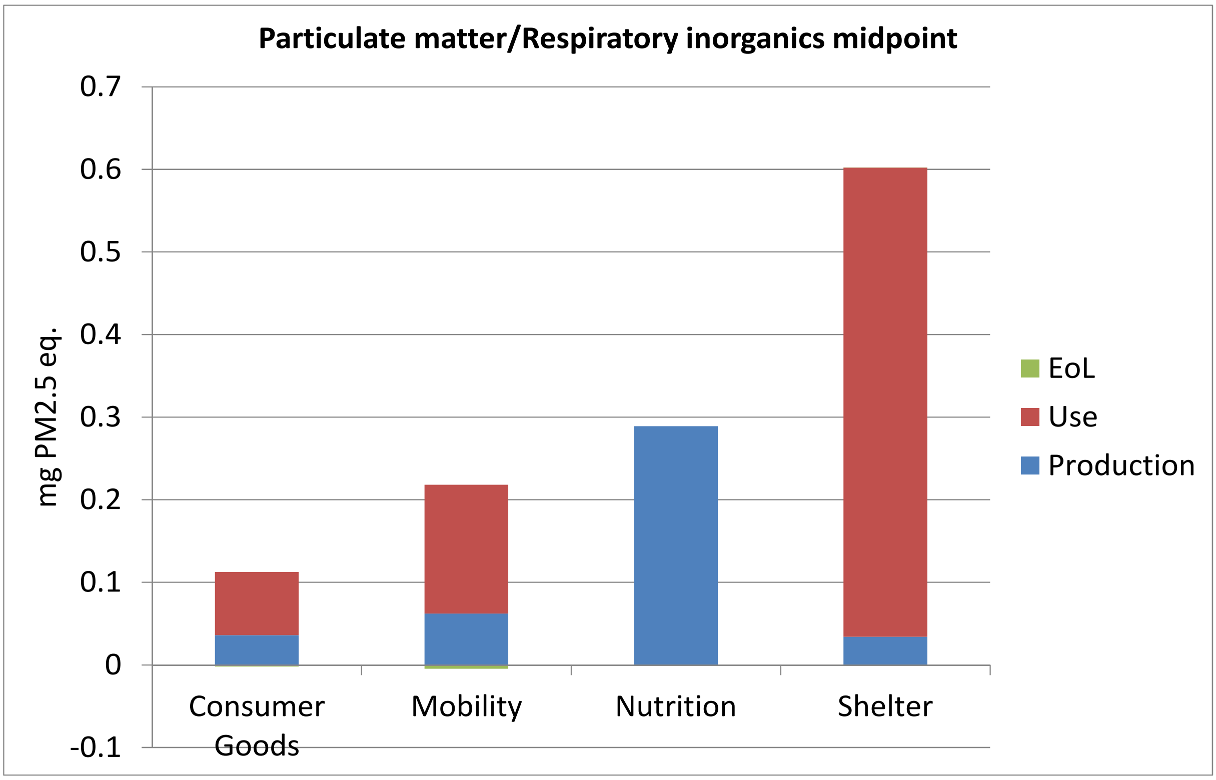

FIGURE 25 PARTICULATE MATTER/RESPIRATORY INORGANICS FOR EU-27 BY LIFE CYCLE STAGE

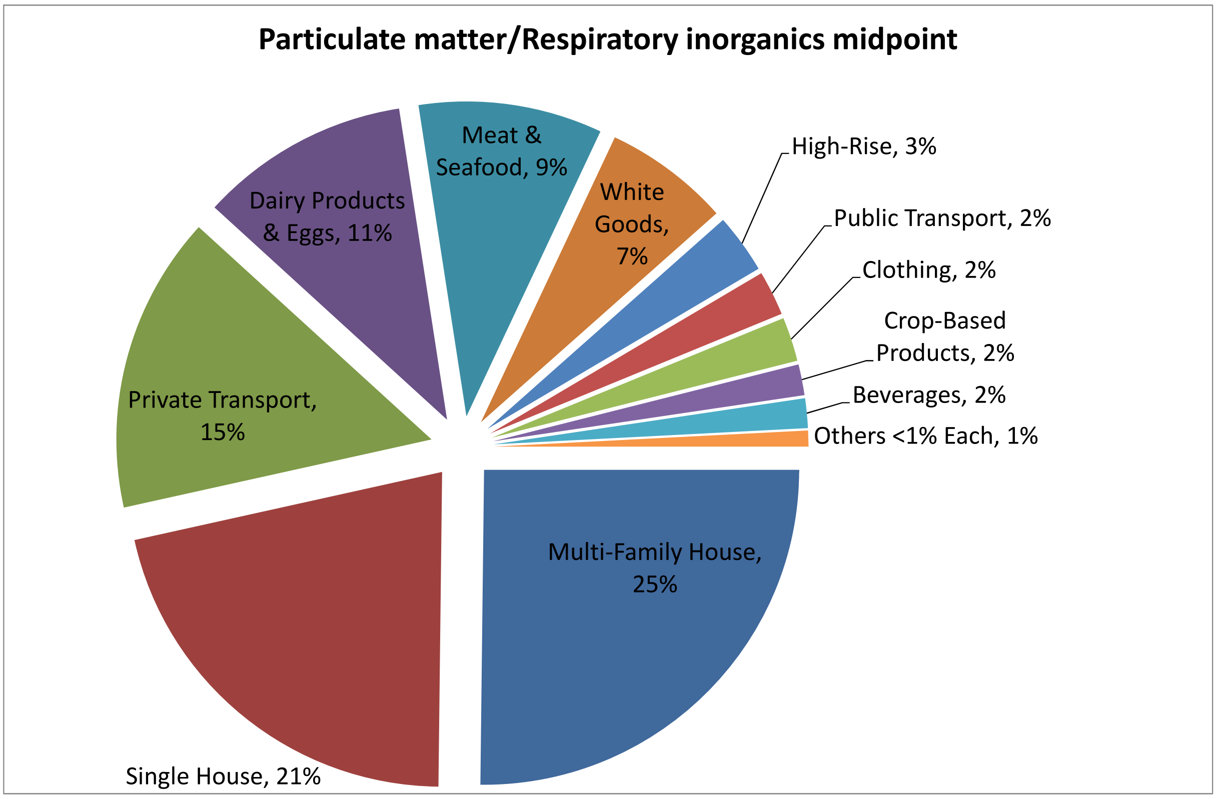

FIGURE 26 PARTICULATE MATTER/RESPIRATORY INORGANICS FOR EU-27 BY PRODUCT GROUP

PHOTOCHEMICAL OZONE FORMATION, HUMAN HEALTH

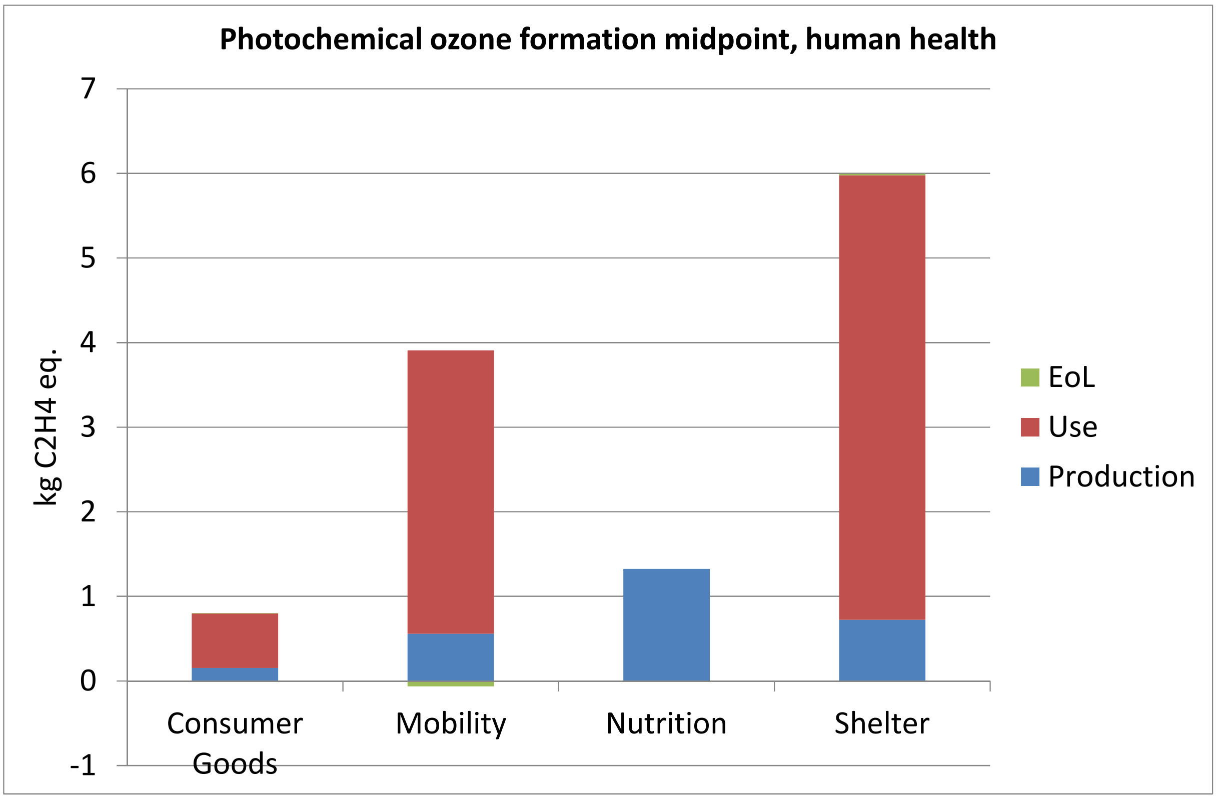

FIGURE 27 PHOTOCHEMICAL OZONE FORMATION (HUMAN HEALTH) FOR EU-27 BY LIFE CYCLE STAGE

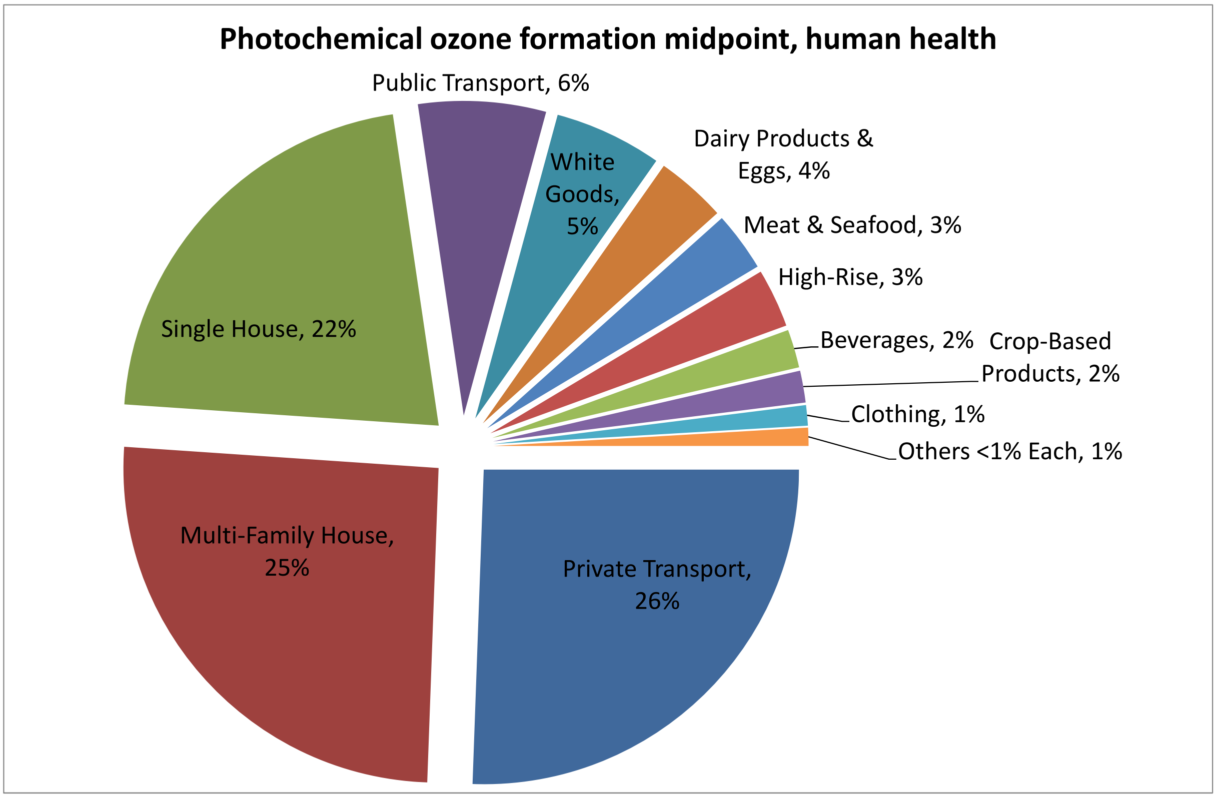

FIGURE 28 PHOTOCHEMICAL OZONE FORMATION (HUMAN HEALTH) FOR EU-27 BY PRODUCT GROUP

EUTROPHICATION MARINE

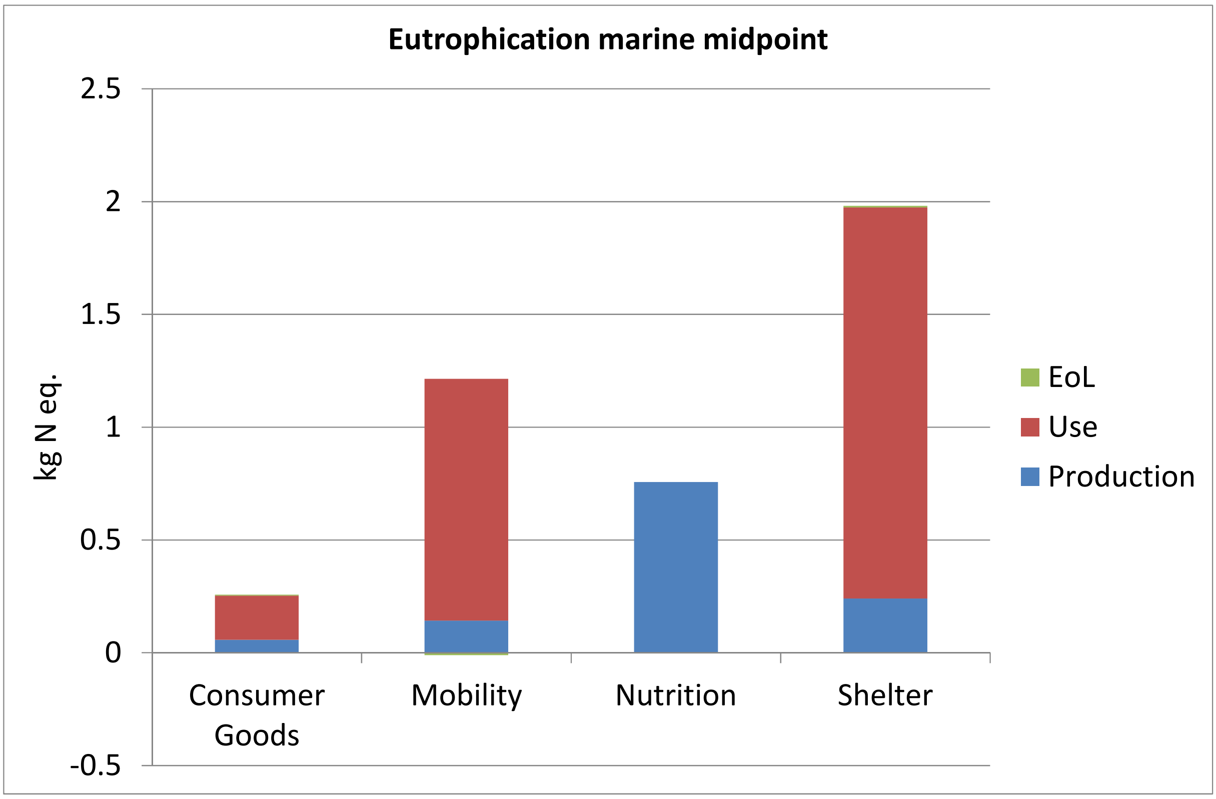

FIGURE 29 EUTROPHICATION MARINE FOR EU-27 BY LIFE CYCLE STAGE

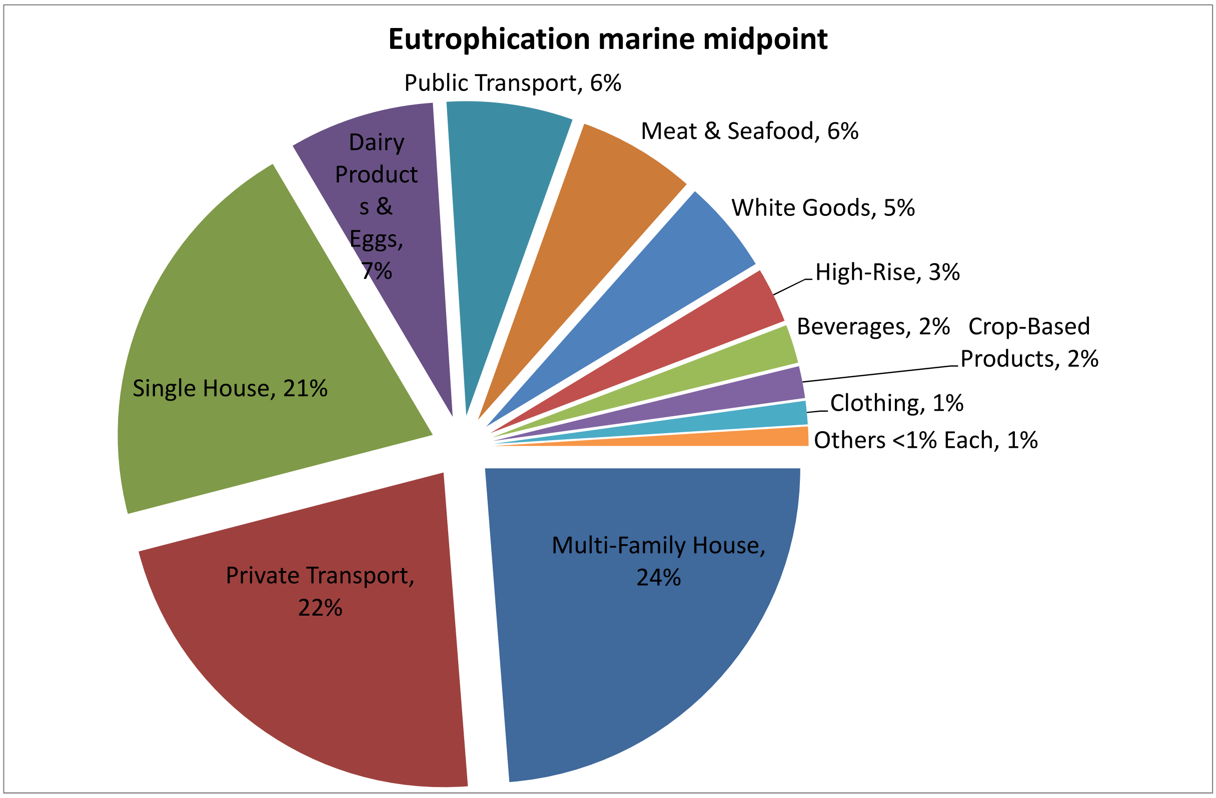

FIGURE 30 EUTROPHICATION MARINE FOR EU-27 BY PRODUCT GROUP

IONIZING RADIATION, ECOSYSTEMS

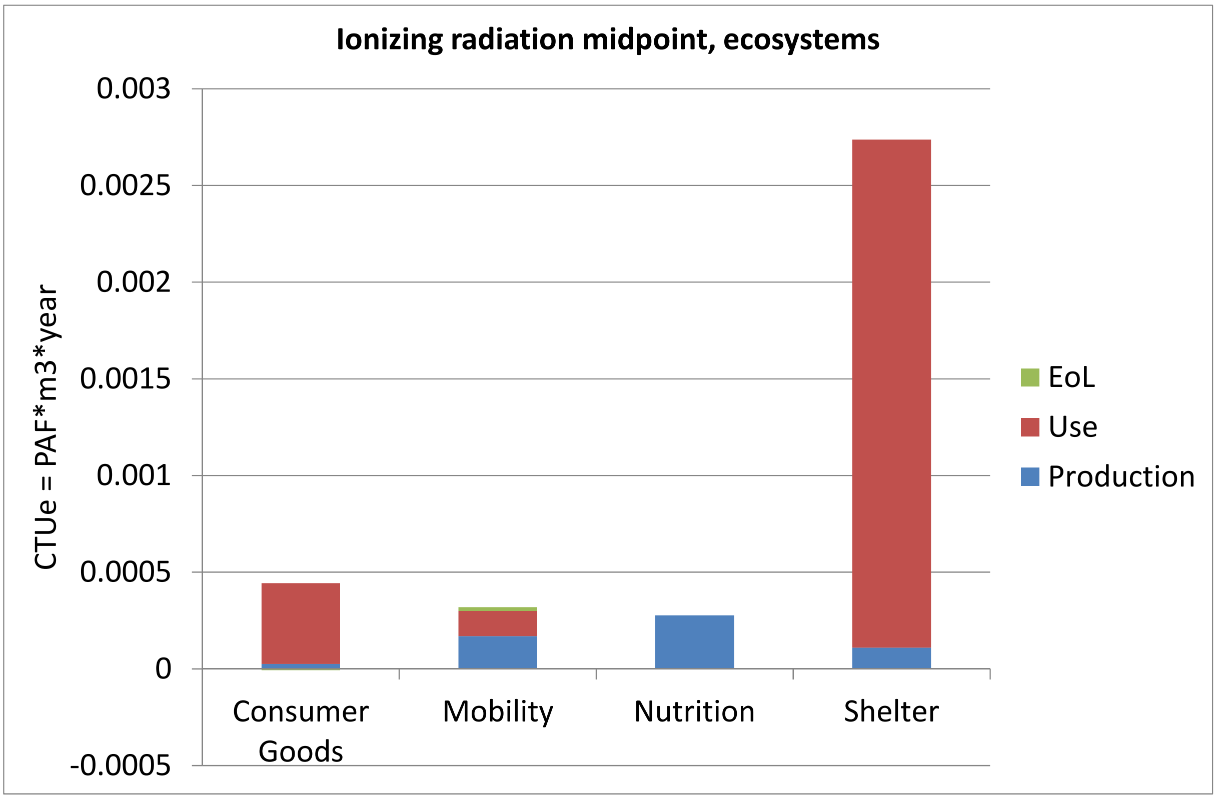

FIGURE 31 IONIZING RADIATION (ECOSYSTEMS) FOR EU-27 BY LIFE CYCLE STAGE

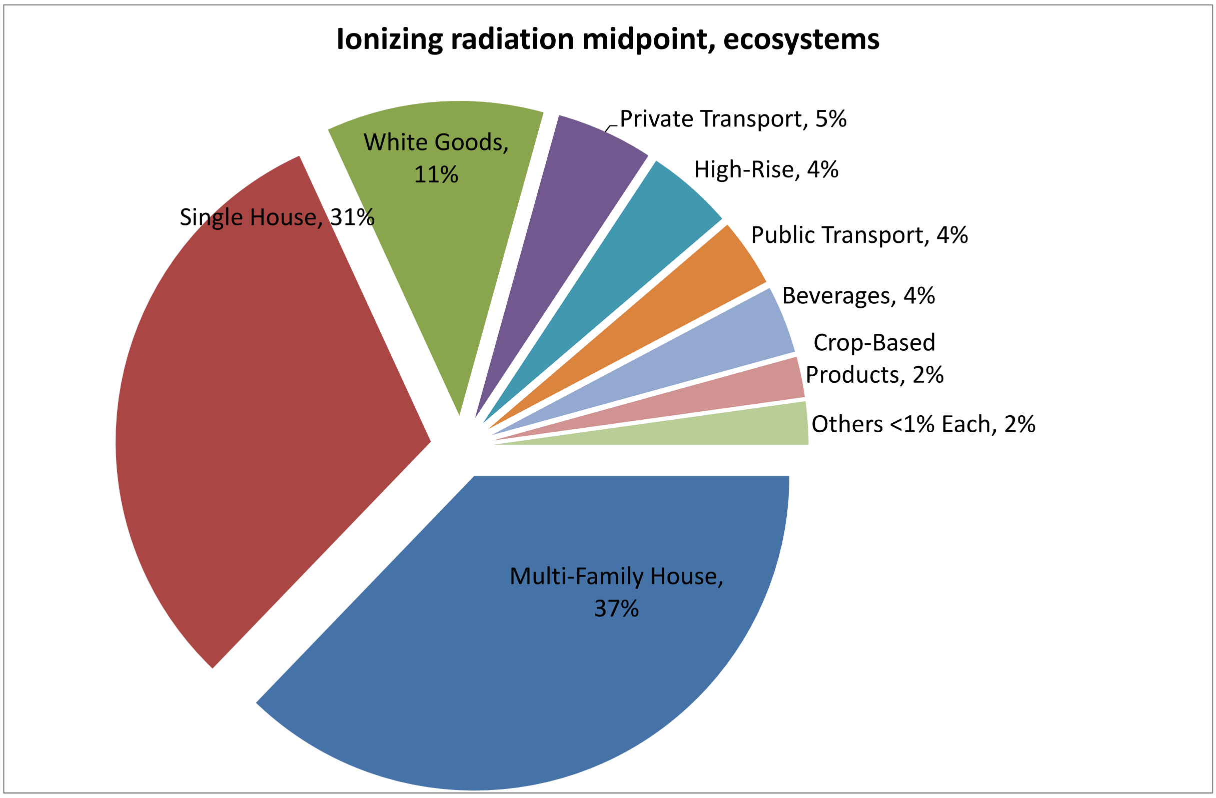

FIGURE 32 IONIZING RADIATION (ECOSYSTEMS) FOR EU-27 BY PRODUCT GROUP

OZONE DEPLETION

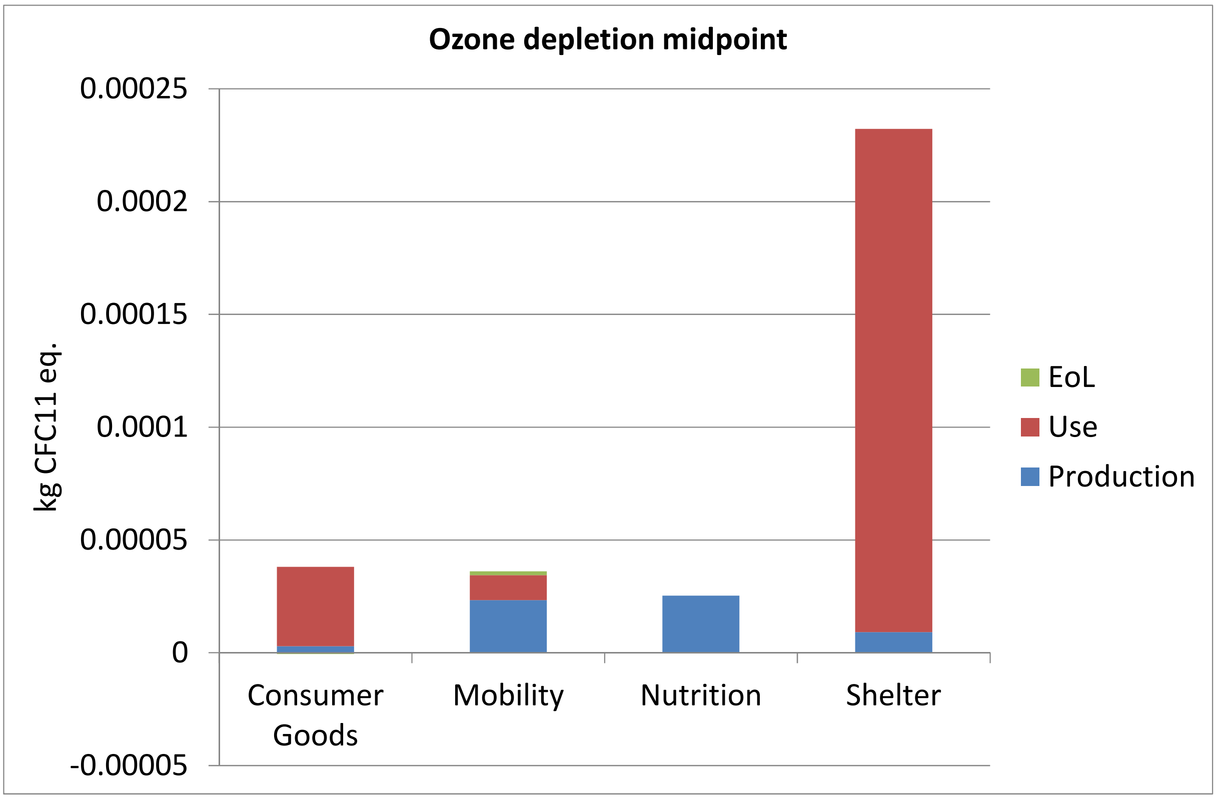

FIGURE 33 OZONE DEPLETION FOR EU-27 BY LIFE CYCLE STAGE

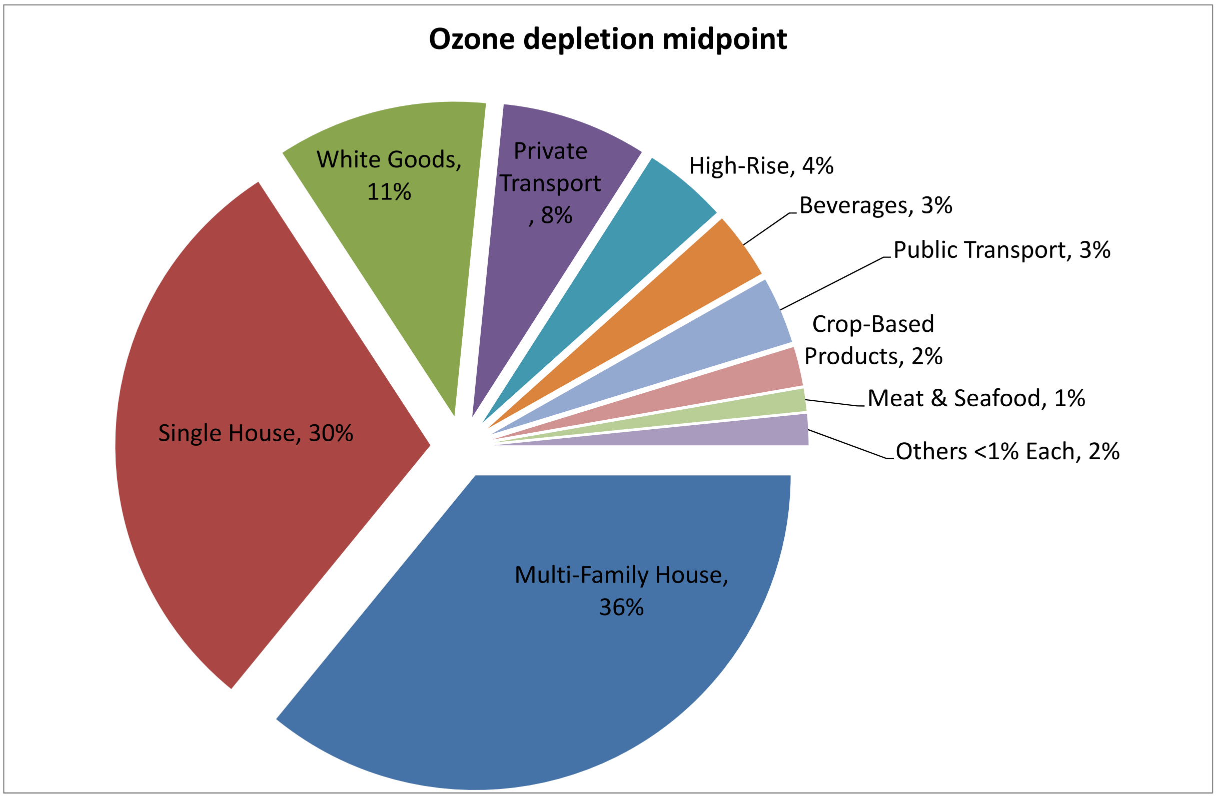

FIGURE 34 OZONE DEPLETION FOR EU-27 BY PRODUCT GROUP

HUMAN TOXICITY, NON-CANCER EFFECTS

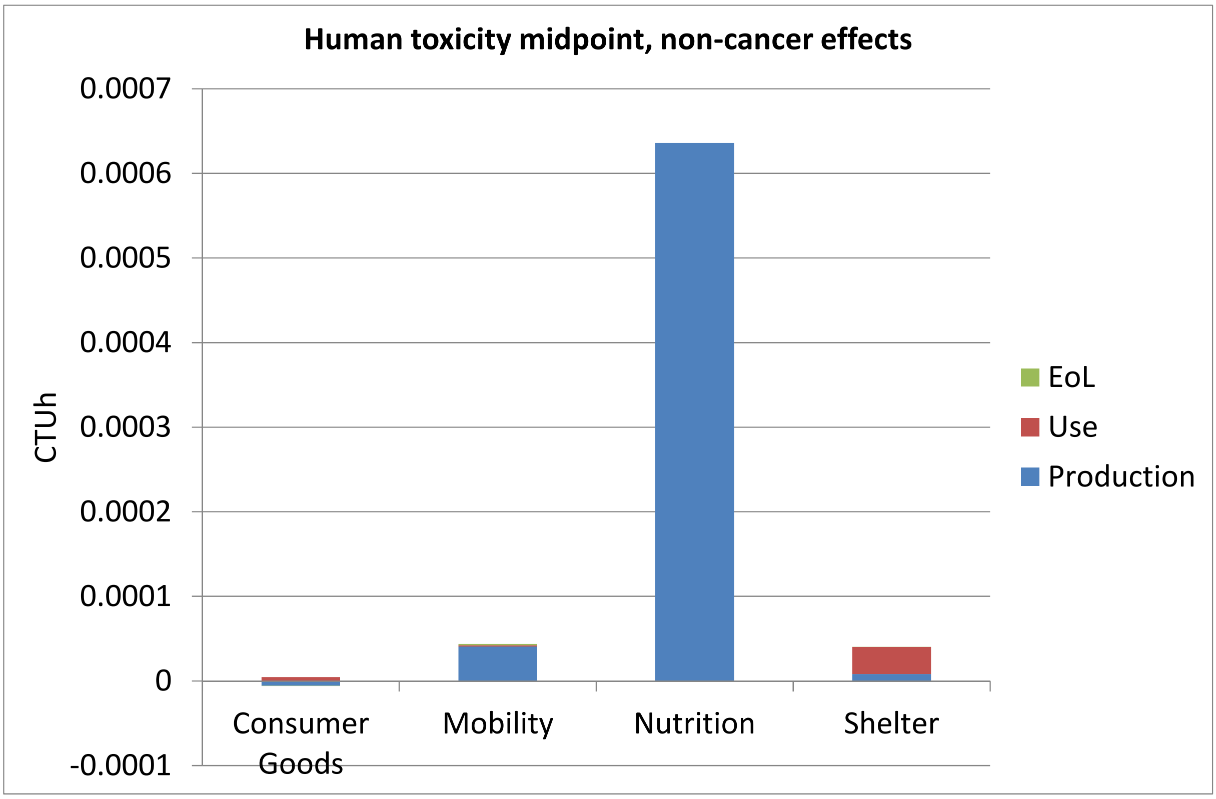

FIGURE 35 HUMAN TOXICITY (NON-CANCER) FOR EU-27 BY LIFE CYCLE STAGE

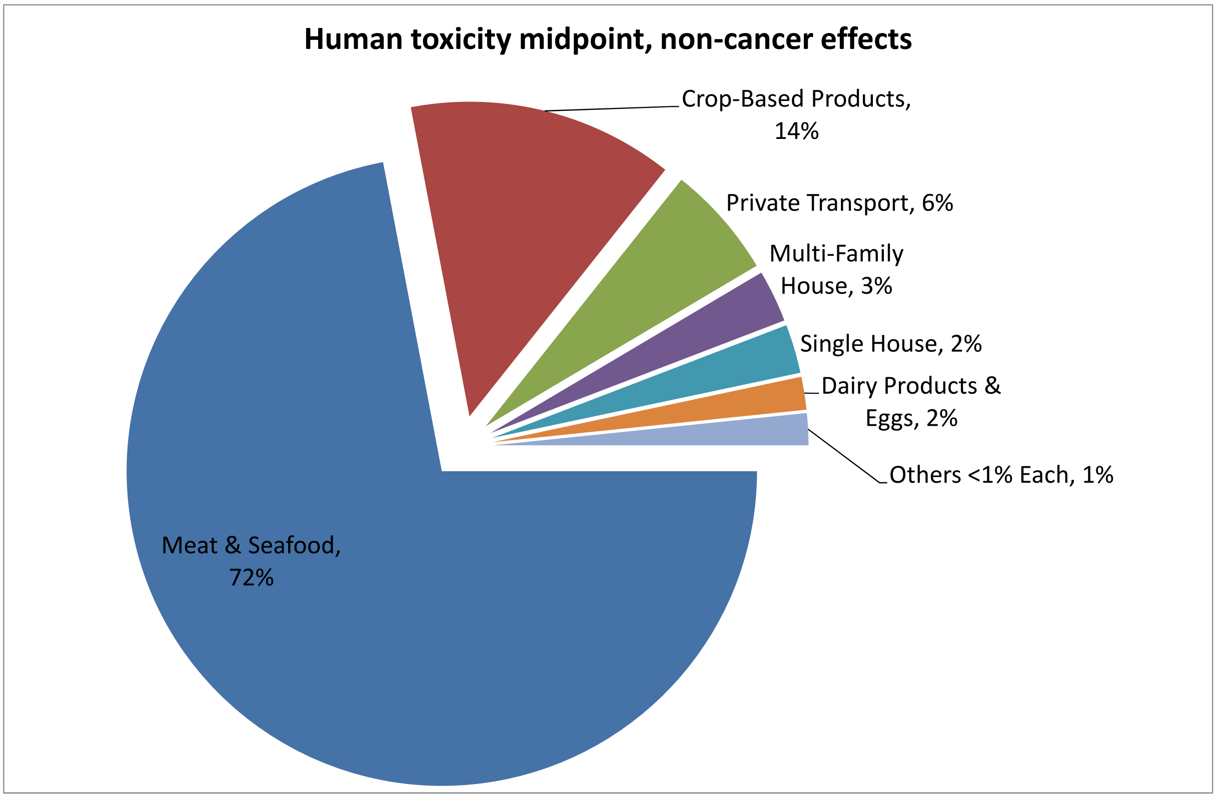

FIGURE 36 HUMAN TOXICITY (NON-CANCER) FOR EU-27 BY PRODUCT GROUP

HUMAN TOXICITY, CANCER EFFECTS

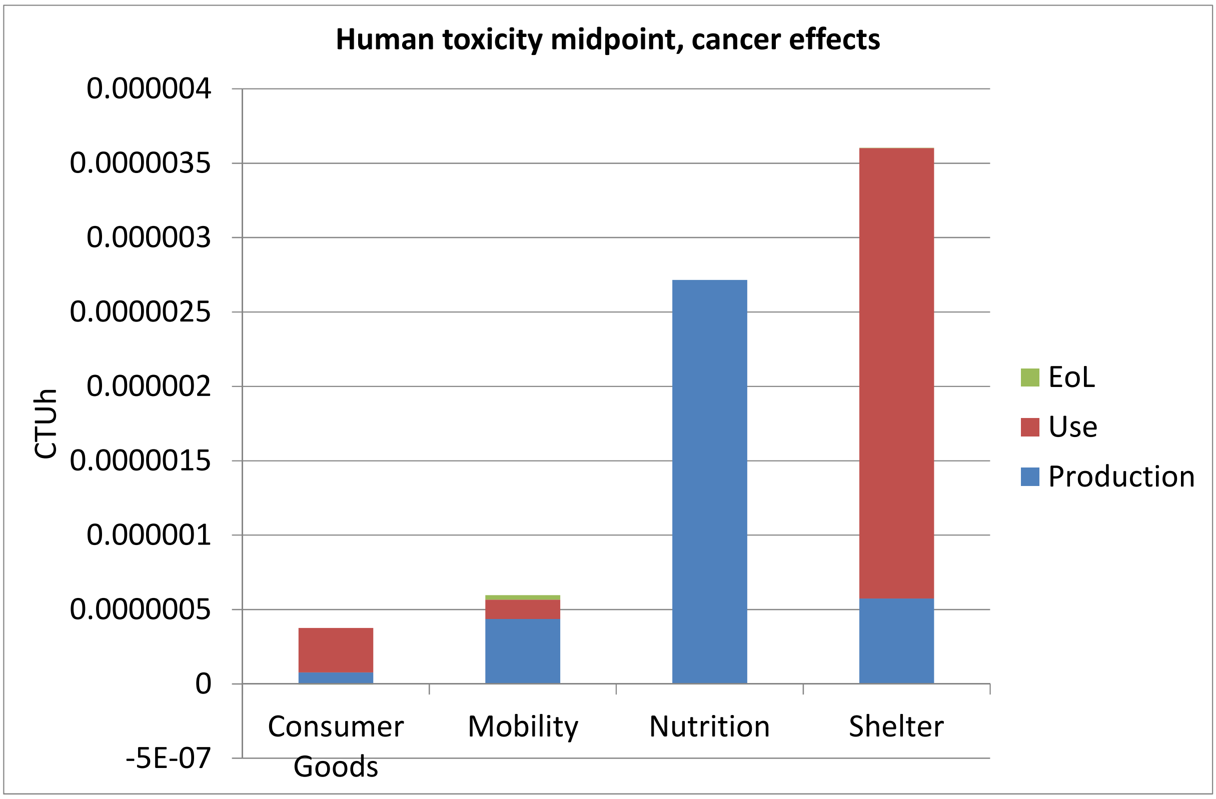

FIGURE 37 HUMAN TOXICITY (CANCER EFFECTS) FOR EU-27 BY LIFE CYCLE STAGE

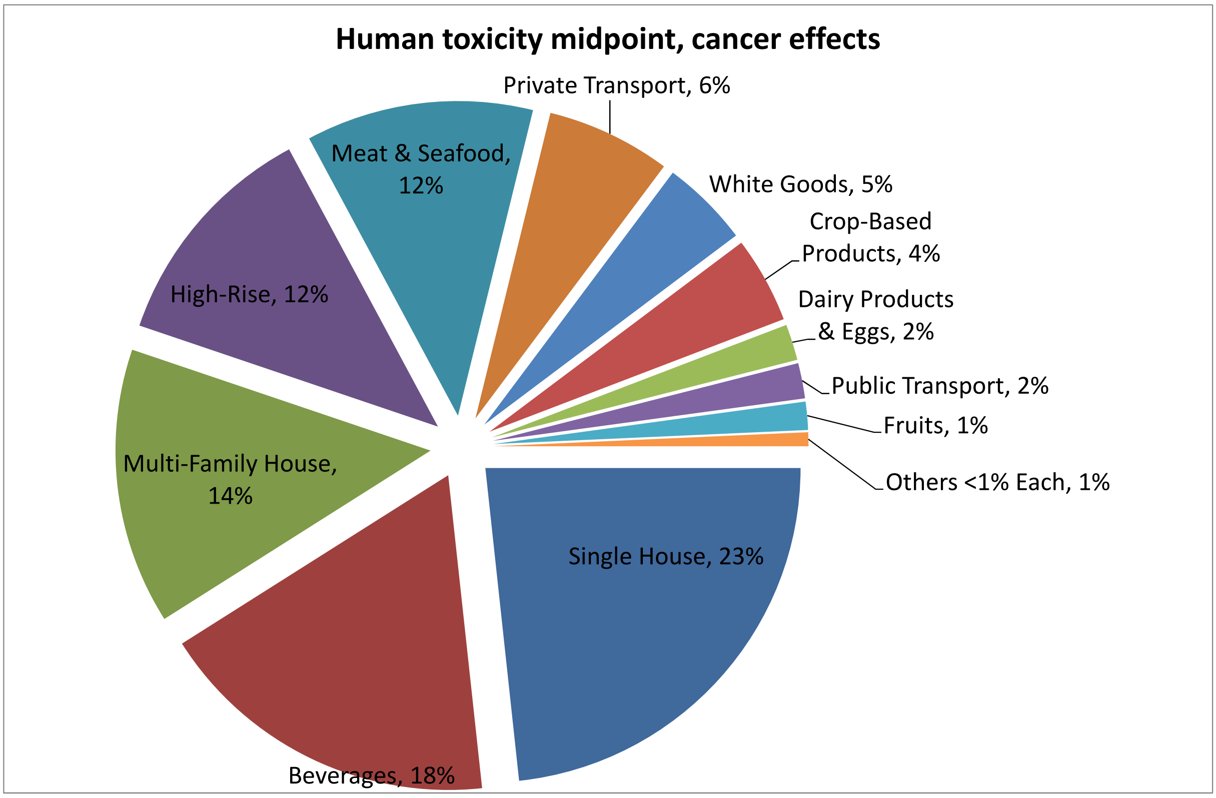

FIGURE 38 HUMAN TOXICITY (CANCER EFFECTS) FOR EU-27 BY PRODUCT GROUP

ECOTOXICITY FRESHWATER

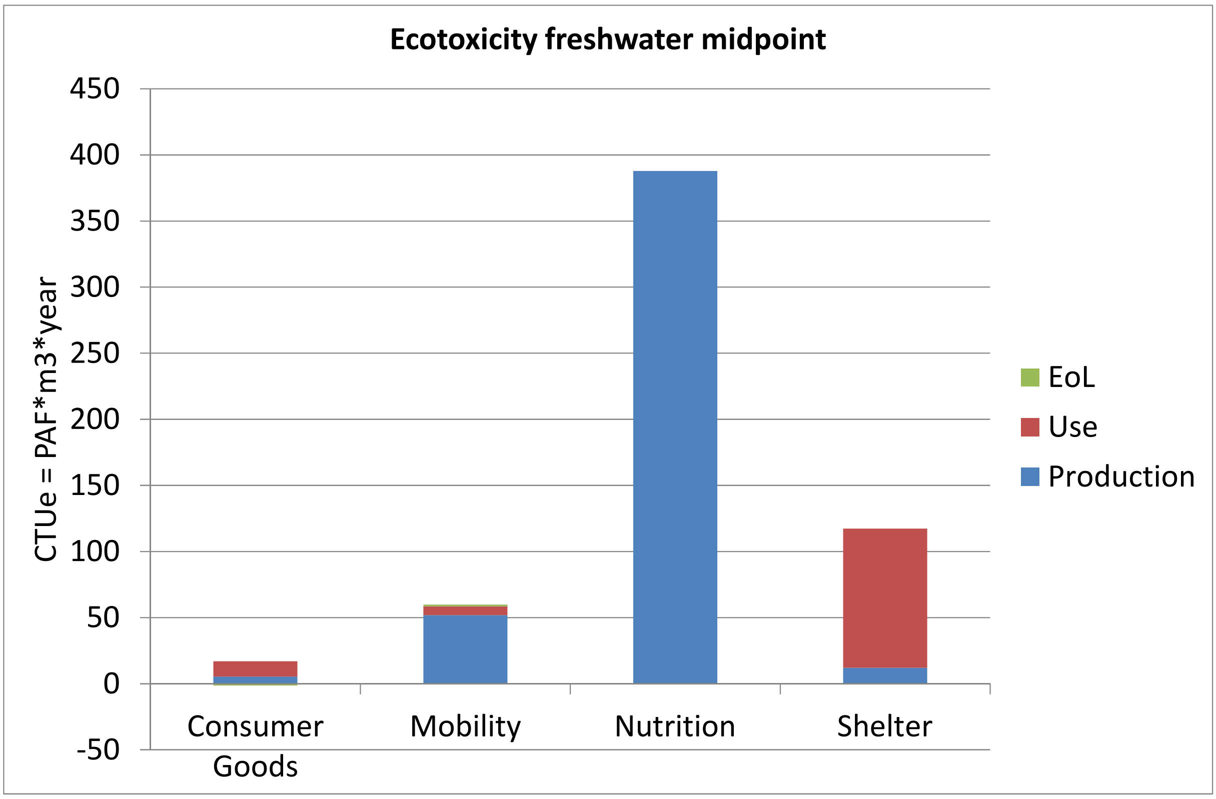

FIGURE 39 ECOTOXICITY FRESHWATER FOR EU-27 BY LIFE CYCLE STAGE

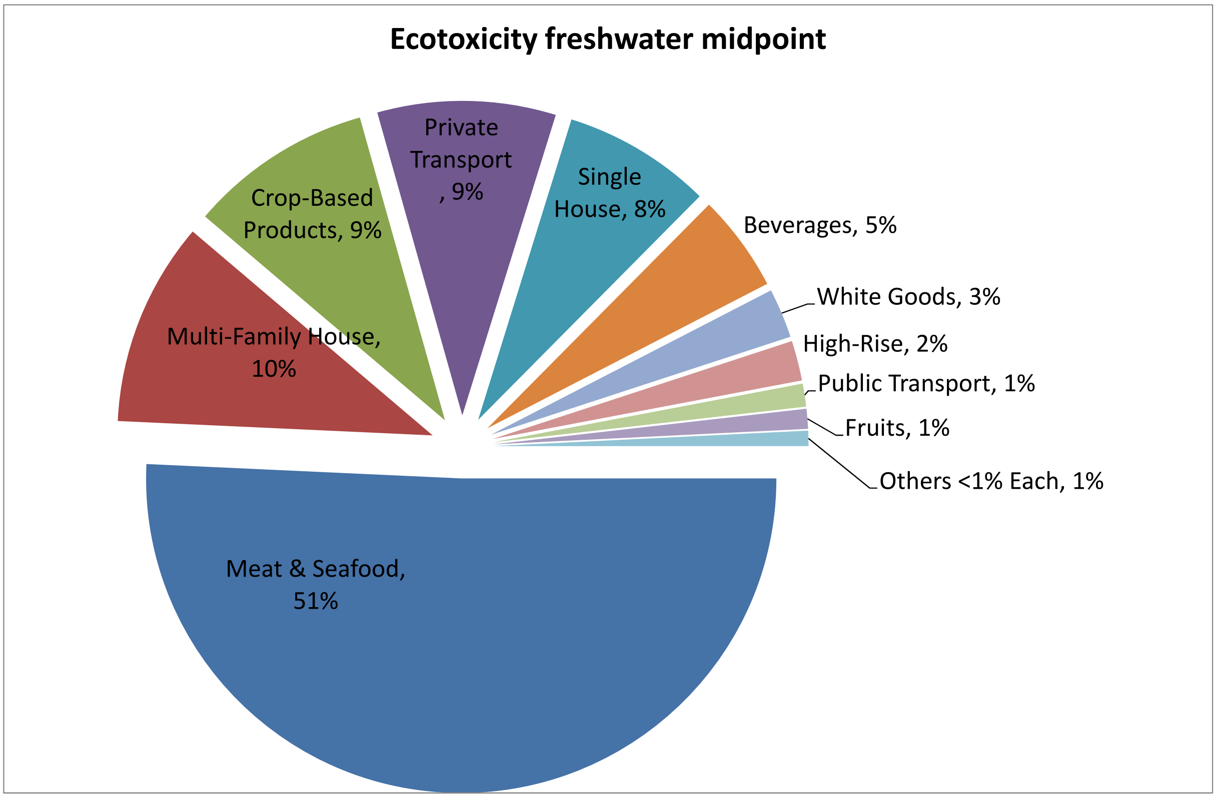

FIGURE 40 ECOTOXICITY FRESHWATER FOR EU-27 BY PRODUCT GROUP

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Abstract
Sustainable development is an underlying objective of the European Union treaties. An important part of sustainable development is its environmental aspect, as reflected in the Europe 2020 strategy and its Resource-efficient Europe flagship initiative.
For quantifying and monitoring our progress towards sustainability in terms of the environmental performance, indicators are needed. These indicators should provide an integrated view on the links between consumption, production, resource depletion, resource use, resource recycling, environmental impacts and waste generation. One of the approaches that facilitate such integrated view is life cycle thinking. This integrative approach underlies the development of life cycle indicators for quantifying and monitoring progress towards the sustainable development of the European Union.
This report outlines development of the basket-of-products life cycle indicators. These indicators are intended to be used to assess the environmental impact of the European consumption.

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