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Consumer Footprint

Basket of Products indicator on Household goods

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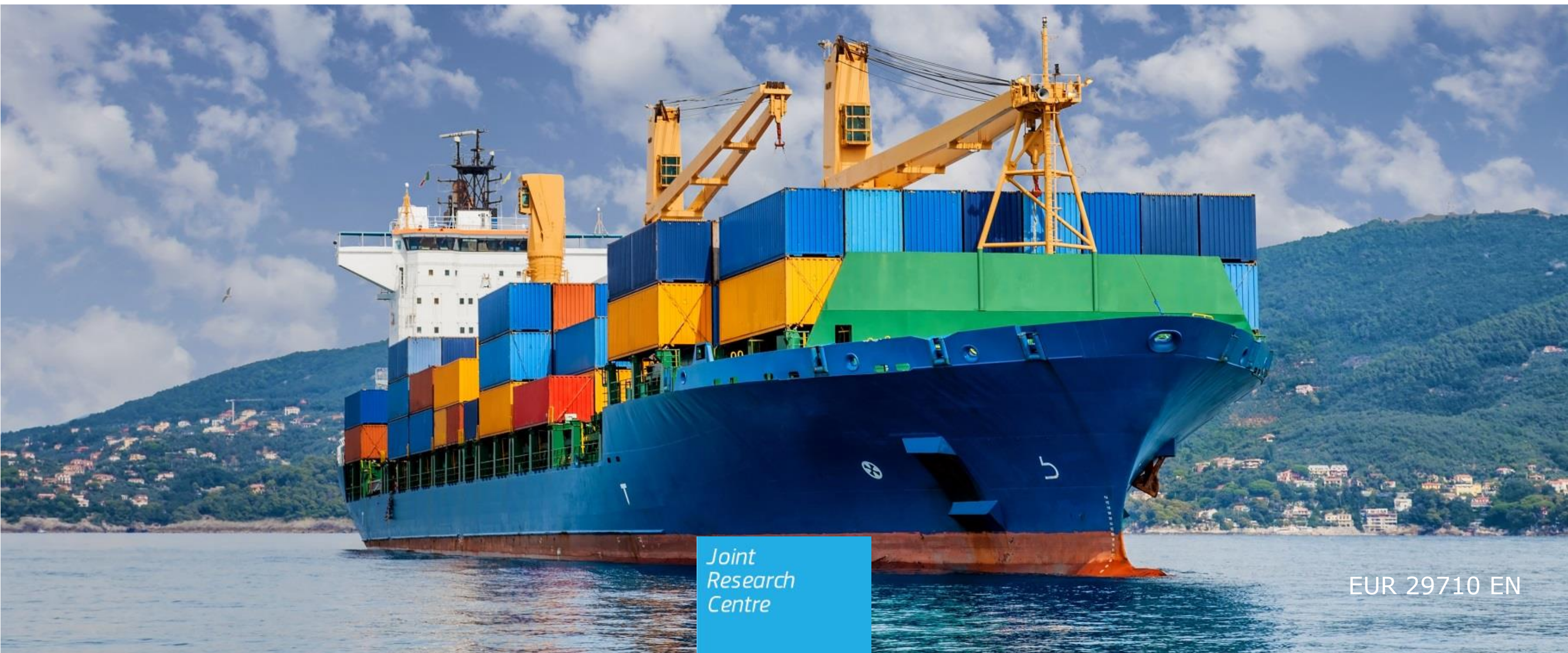

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Abstract

The Consumer Footprint aims at assessing the potential environmental impacts due to consumption. The calculation of the Consumer Footprint of the European Union (EU) is based on the Life Cycle Assessment (LCA) of representative products (or services) purchased and used in one year by an EU citizen. This report details the subset indicator of the basket of products (BoP) on household goods, which is built to assess the impact associated to household goods in the EU, from raw material extraction to end of life. The reference flow is the amount of household goods purchased and used by an average EU citizen in a reference year (2010). It consists of a process-based life cycle inventory model for a basket of products that represents the most relevant household goods product groups, selected by a number of criteria, including importance in terms of mass, relevance in economic value, and listed in the products for which an Ecolabel has been defined. In total, 30 representative products were modelled, considering the following product groups: detergents, rinse-off cosmetics, absorbent hygiene products, furniture, bed mattresses, footwear, clothes (textile products), and paper products.

The Consumer Footprint for the BoP household goods is assessed using 15 environmental impact categories as for the ILCD impact assessment method and running a sensitivity with the Environmental Footprint method (EF 3.0). Results for the year 2010 show that the most impacting life cycle stage for the majority of products is the manufacture of components (raw materials, ingredients or intermediate products) that are used to produce the final products. The product groups that emerge as hotspots in most of the impact categories are detergents, furniture, paper products, and clothes. The role of this product groups rely not only on a high environmental impact intensity per single product but also on a large consumption intensity by EU citizen. The step of impact normalization and equal weighting of impact categories highlights that the most relevant impacts of the BoP household goods occur in human toxicity (cancer and non-cancer effects), resource depletion (and especially fossil resources), and ionising radiation. The relative share of these categories varies according to the set of normalisation factors used (EU-27 or global references). The employment of the weighting set of the EF method increases the relevance of climate change and resource use, while decreasing the importance of human toxicity. When considering the EF3.0 impact method, freshwater ecotoxicity becomes the most relevant impact category, followed by ionising radiation and fossil resources use. An assessment of the year 2015 unveils an increasing trend of the environmental impact due to a larger consumption, partially associated to an increased population from EU-27 to EU-28 (inclusion of Croatia).

The Consumer Footprint BoP household goods baseline has been assessed against 10 eco-innovation scenarios, referring to improvement options related to the main drivers of impact (e.g. components manufacture) and acting on the most relevant product groups. Among the scenarios assessed, the options that allow for a higher reduction of impacts are the ones related to the use of less impacting electricity mixes in the production phase and to the reuse of products (clothes and furniture). Six scenarios were specifically aimed at assessing the impact of substituting some average products (namely liquid soap, shampoo, dishwasher detergent, laundry detergent, and upholstered seat) with products that are compliant with the EU Ecolabel criteria. Results show that the environmental profile of EU Ecolabelled products is generally better than the one of the average products in the market and reduces the environmental impact of their product group (e.g. laundry and dishwasher detergent for the detergents product group). However, the effect that the choice of EU Ecolabelled products had on the overall impact coming from purchase and use of household goods resulted to be relatively limited mainly due to the relative share of the tested products over the entire environmental impacts of the BoP (from 0.4% to 7.0% of the overall normalized impact for the entire baseline BoP). Moreover, each EU Ecolabel scenario was assuming a 100% replacement of the product on the market with an EU Ecolabel option. This means that under more realistic market shares, the contribution to impact reduction is even lower as the replacement share of each assessed product would be smaller. However, the scenarios assess specific products rather than all the variety of

household goods under the EU Ecolabel scheme and, thereby, the overall effect of the EU Ecolabel scheme was not the goal of this assessment. Furthermore, the results of LCA focused on the specific impact categories which are currently part of the Environmental Footprint method. This means that certain aspects covered by Ecolabel criteria (such as biodegradability) are not accounted for.

Regarding the role of consumers, the study showed that users' behaviour could have a relevant effect on the impact of household goods consumption. For instance, for detergents and personal care products, a relevant share of the improvement potential is related to a proper use by consumers (e.g. by saving water and energy and avoiding overdosing during the use phase). For this reason, promoting purchase of more sustainable products may not be sufficient to reduce the environmental impacts of consumption, but it has to be accompanied with complementary actions. In the case of household goods, awareness campaigns towards a more responsible consumption behaviour showed a large potential in improving the environmental impacts related to the use (e.g. dosage, energy use) and end of life cycle stages (e.g. reuse of products).

1 The European Union (EU) Consumer Footprint

Assessing the environmental impact due to consumption of goods and services is a crucial step towards achieving the sustainable development goal related to responsible production and consumption (SDG 12). The evaluation of the impacts is an essential step towards designing better solutions and policy options in the context of the European Green Deal of the political guidelines of the President-elect of the European Commission (von der Leyen, 2019). Since 2010, as part of its commitment towards more sustainable production and consumption, the European Commission has developed an assessment framework to monitor the evolution of environmental impacts associated to EU consumption adopting LCA as reference methodology (EC-JRC, 2012a; EC-JRC, 2012b). The present study is expanding the initial assessment framework to ensure a more complete and robust evaluation of the impacts, addressing SDG 12, partially SDG11 (on sustainable cities and communities), SDG 9 (on industry, innovation and infrastructure), and SDG 8 (on sustainable economic growth), and assessing impact on a number of environmental impact categories related to other SDGs, mainly the ones addressing ecosystems quality and human health (Box 1).

Box 1 Overview of the link between SDGs, the assessment of the environmental impact of consumption and the impact quantification with Life Cycle Assessment (Environmental Footprint method).

The assessment framework aims to support a wide array of policies, such as those related to circular economy, resource efficiency, and eco-innovation. The environmental impact of EU consumption is assessed adopting two sets of life cycle-based indicators: the Consumer Footprint and the Consumption Footprint, which have a complementary role in assessing impacts (Box 2).

The Consumer Footprint adopts a bottom-up approach, aiming at assessing the potential environmental impact of the consumption of an average EU citizen in relation to the impacts of representative products. In fact, the Consumer Footprint is based on the results of the Life Cycle Assessment (LCA) of more than 100 representative products purchased and used in one year by an EU citizen. The Consumer Footprint allows assessing environmental impacts along each step of the products life cycle (raw material extraction, production, use phase, re-use/recycling, and disposal), and accounts for both imported goods and those produced in EU.

For the calculation of the Consumer Footprint, the consumption of EU citizens is split into five key areas (food, housing, mobility, household goods, and appliances). For each area, a respective Basket of representative Products (BoP) has been built based on statistics on consumption and stock of products. For each of the five BoPs, a baseline scenario has been calculated, taking as reference the consumption of an average EU citizen in 2010. To assess the trends in consumption, an additional baseline is calculated for the year 2015.

This report focuses on the BoP household goods, which is one of the 5 key areas of consumption identified for calculating the Consumer Footprint.

The developed LCAs are in line with the International Life Cycle Data system (ILCD) guidelines and follow, to the extent it is possible and relevant, the Environmental Footprint methods as published in the Communication "Building the Single Market for Green Products" (EC, 2013). The quality of the models has been ensured by periodical model refinements. In order to allow for periodical updates, the models has been built with a parametric approach. Hence, for example, the amount and structure of consumption could be updated to more recent reference years using data on apparent consumption (i.e. BoP composition and relative relevance of representative products) taken from Eurostat.

The baseline models allow the identification of the environmental hotspots along the products life cycle and within the consumption area of each specific BoP. Then, results of the hotspot analysis are used as a basis for the selection of actions towards environmental burden reduction, covering interventions such as: shifts in consumption patterns, behavioural changes, implementation of eco-solutions, or a combination of the previous ones. For each of the actions, a scenario has been developed, by acting on the baseline model and simulating the changes associated to the specific intervention. The LCA results of each scenario are then compared to the results of the baseline, to identify potential benefits or impacts coming from the implementation of the solution tested, as well as to unveil possible trade-offs.

Complementary to the Consumer Footprint, also the Consumption Footprint indicator was developed by the European Commission Joint Research Centre (EC-JRC). The Consumption Footprint is basically a top-down approach, aiming at assessing the potential environmental impact of EU apparent consumption, accounting for both domestic impacts (production and consumption at country level with a territorial approach) and trade-related impacts. The impacts are assigned to the country where the final consumer is located. As mentioned above, this report focuses on the Consumer Footprint indicator and in particular to the Consumer Footprint Basket of Product (BoP) indicator for household goods.

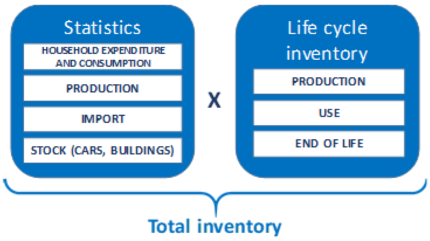
Box 2 Overview of the two life cycle-based indicators for assessing the environmental impact of EU consumption.

The life cycle-based indicators for assessing the impact of EU consumption

The Consumer Footprint (BOTTOM UP)

LCA of products representative of the consumption of an average EU citizen

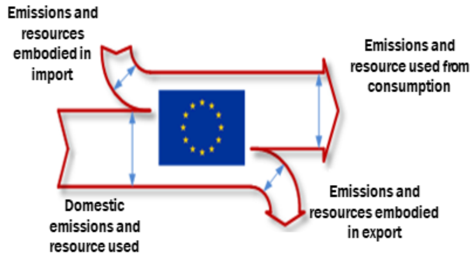
- Focusing on resources used and emissions due to production and consumption during the entire life cycle of a product in selected areas of consumption (food, mobility, housing, household goods, appliances)
- Combining life cycle data (environmental profiles of products) with consumption statistics



The Consumption Footprint (TOP DOWN)

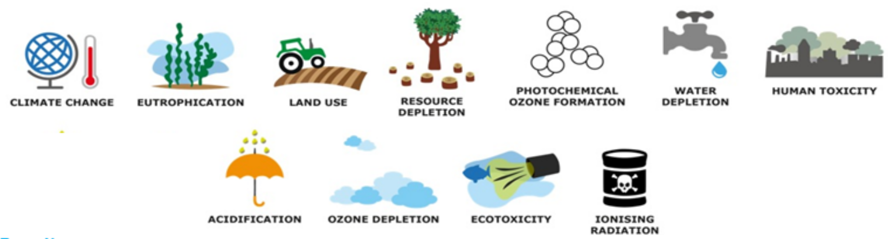
Economy-wide assessment of apparent consumption in the EU

- Focusing on resources used and emissions due to production and consumption in one year in all sectors
- Combination of environmental statistics and life cycle inventories of representative products according to trade statistics
- Alternatively through the use of the Environmentally Extended Input-Output Approach for assessing the trade



Life Cycle Impact Assessment

Each emission in the environment and resource used are then characterized in terms of potential environmental impacts in the life cycle impact assessment phase, covering the impact categories recommended for the ILCD and the Product Environmental Footprint, including:



Results

Environmental impacts associated to households in the EU. Identification of hotspots in the life cycle of the consumed products considering five product categories: Food, Mobility, Housing, Household goods, and Appliances. Results could be analysed for different types of consumer behaviours –e.g. average vs pro-environmental.

Each BoP represents a baseline for assessing eco-innovations scenarios at all life cycle stages, from raw material, production, up to use phase, and end of life. This help assessing benefits of sustainable lifestyles.

Environmental impacts of consumption in the EU and for each Member State, including the distinction of impacts in three categories:

- Direct impacts, which occur because of the use of products and services.
- Indirect exported impacts, which occur because of the life cycle impacts of products that are produced in the country and exported elsewhere.
- Indirect imported impacts, which occur because of the life cycle impacts of products that are produced in different countries where they are consumed.

2 Environmental impacts of consumer goods

As highlighted by the European Environmental Agency (EEA, 2012), current EU consumption patterns generate relevant environmental pressures, which are not limited to greenhouse gas emissions, but include also the use of natural resources, acidifying emissions, etc. Some of these pressures originate directly from the use of products and services, whereas some others are generated along the production chains of consumer goods.

In addition, an increasing share of products consumed in the EU is imported from other parts of the world. Therefore, also part of the environmental impacts of the production of goods that occur outside the EU is due to EU consumption patterns. Consequently, the focus of EU environmental policies on sustainable consumption and production has gradually evolved over recent decades from a focus mainly on cleaner production, through sustainable products, to a more holistic approach to sustainable consumption and production. This entails, for instance, the choice of raw materials and ingredients that are less impacting both in their production chain and at their end of life.

Specific hotspots and related improvement options can be identified for different types of household products, as illustrated below. Cosmetics and pharmaceutical products have a relevant impact on the aquatic environment after their use, when their components are released into municipal wastewater (Ternes et al., 2004). UV filters, preservatives and surfactants used in the formulation of cosmetics and detergents can have toxic effects on aquatic organisms (Vita et al., 2018; Liu and Wong, 2013) and the efficacy of removal of these substances by conventional wastewater treatment is limited (Liu and Wong, 2013; Barbosa et al., 2016). Ultraviolet (UV) filters can also bioaccumulate and scientific studies indicated their potential for estrogenic activity (Brausch and Rand, 2011).

Due to those known issues, several Research and Development (R&D) activities in the field of cosmetics and detergents have been focused on the choice of ingredients that can help to reduce the environmental impact associated to their production chain and to their disposal at the end of life (Philippe et al., 2012; Ramli, 2017). The use of ingredients from renewable feedstock is one of the most studied options. Trujillo-Cayado et al. (2018) discussed emulsions formulated with renewable components as a sustainable alternative to products containing traditional organic solvents in surfactants. Secchi et al. (2016) assessed, through Life Cycle Assessment (LCA), the use of a C16–18 triglycerides mixture derived from olive oil industry by-products as an ingredient for a cosmetic cream. Martinez et al. (2017) performed a LCA of a bio-based cosmetic cream containing refined palm kernel oil. In parallel, attention is given to innovative wastewater treatment systems, able to improve the removal rate for pharmaceuticals and personal care products (Luo et al., 2014; Zhang et al., 2014, Ferreira et al., 2016).

Another hotspot is the presence of chemicals in consumer products. Many of these products may be sources of chemicals that have a diverse spectrum of health effects, including endocrine disruption and associations with asthma (Dodson et al., 2012, Kabir et al., 2015). Previous research suggests that consumer products are a source of phthalates, alkylphenols, parabens, polychlorinated biphenyls (PCBs), and polybrominated diphenyl ether (PBDE) flame retardants at household level (e.g. Rudel et al. 2003). However, research in this field is still needed, especially because of the large range of products and of compounds potentially released.

Phillips and colleagues (2018) characterized chemicals in 100 consumer products – which included formulations (e.g., shampoos, paints), articles (e.g., upholsteries, shower curtains), and foods (cereals) with the aim to support prioritization of chemicals based on potential human health risks. Vojta et al. (2017) analysed 137 individual samples of various consumer products, building materials and waste, to identify and characterize potential sources of halogenated flame-retardants (e.g. upholstered furniture) in indoor environment. Pourzahedi et al. (2016) conducted a LCA for 15 nanosilver-enabled consumer products, investigating hotspots and patterns of contribution.

Absorbent products have been largely identified as a relevant source of impact, especially because they contribute to the volume of municipal solid waste (Arena et al., 2016; Cordella et al., 2015). Options to reduce their impact include the reduction of the average weight of products (mainly due to the introduction of superabsorbent polymers – SAP) (Edana, 2015), the use of alternative materials - such as bio-based plastic, hemp, and bamboo, in order to improve compostability (e.g. Mirabella et al., 2013), and the substitution of disposable products (e.g. baby diapers) with reusable ones (DEFRA, 2008; O'Brien et al., 2009). Potential recycling options has been studied as well (Torrijos et al., 2014; Arena et al., 2016).

A growing number of studies that quantify the environmental impacts coming from overall consumption and use of household goods in a life cycle perspective has been published in the scientific literature. Some of them are based on process-based LCA (e.g. Kalbar et al., 2016), whereas others make use of input-output data (e.g. Duarte et al., 2010; Zhu et al., 2010; 2010; Ivanova et al., 2016; Wood et al., 2017).

Ivanova et al. (2016) assessed the contribution of several household consumption categories (namely food, mobility, housing, clothing & footwear, manufactured products, and services) to the direct and embodied environmental impacts generated by household consumption. According to their results, manufactured products and clothing & footwear together account for 21% of the carbon footprint of EU households, 17% of their land footprint, 25% of material footprint, and 16% of water footprint. Consumption of manufactured products is particularly relevant for the material footprint of EU households. Clothing is the second most land-intensive consumption category (after food, which is the main contributor), and the second most water-intensive (again after food), with a requirement of 0.05 m^3 of blue water per euro spent.

The environmental impact associated to household consumption of goods depends, on the one hand, on the intensity of the impacts coming from the production and trade of goods and, on the other hand, on the lifestyle of people, i.e. on their consumption habits and choices. Therefore, solutions to reduce the impact of household consumption should entail both eco-innovation of the production processes and a change in lifestyles and consumption habits.

According to Druckman and Jackson (2016), one of the main determinants of households' carbon footprint is income, with carbon footprints increasing with increasing incomes. However, other drivers, such as household size and composition, rural or urban location and type of energy supply, also play a part. The link between the available income and the intensity of environmental impact of household consumption is underlined by several authors (e.g. Ivanova et al, 2016; Kalbar et al., 2016; Tukker et al., 2010; Büchs and Schnepf, 2013; Duarte et al., 2012). This is a relevant issue to be considered when analysing options for improvement, because at higher income levels, the reduction of consumption in one area can generate a rebound effect, i.e. can liberate money that may be spent in other consumption area, which could be even more intense in terms of environmental impact per unit of product consumed (Font Vivanco et al., 2018).

Due to the environmental relevance of household goods, the present study aims at assessing the environmental impact of household consumption in the EU with a life cycle perspective. The use of LCA as approach for assessing the impact allows for considering a wide range of impacts, going beyond carbon footprint (which, for some product categories, may not be sufficient to highlight potential hotspots).

The BoP household goods assesses the impact of household goods consumption in the EU using a bottom-up approach, based on the selection of representative products and related life cycle inventories. The aim is to define a baseline scenario, modelled considering the statistics about household goods consumption by an average EU citizen, as a reference for evaluating the potential improvements coming from eco-innovation and behavioural changes in this area of consumption.

3 Basket model for household goods

The main goal of the BoP household goods is to assess the average environmental impact per EU citizen associated with the consumption of products that relate to daily life of a household (e.g. detergents, personal care products, furniture, etc.), and to provide recommendations for the way forward by including the analysis of existing eco-innovation strategies and targets for improving the environmental performance of products in the household goods sector. This section describes the scope and the structure of the Basket of Product (BoP) on household goods, including the Life Cycle Inventory (LCI). The aim is to enable illustrate how the BoP is modelled, in order to help the interpretation of the results and, if needed, to replicate the exercise. This section describes the scope and the structure of the Consumer Footprint of the BoP on household goods. The LCI covered under the BoP household goods is included in this report.

3.1 Description of the BoP household goods

In order to comprehensively assess the impact of consumption at EU level, in 2012 the European Commission's Joint Research Centre developed a life cycle-based method that focuses on specific representative products which were then upscaled to overall EU consumption figures, named the Basket of Products (BoP) indicators (EC-JRC, 2012). The project (called LC-IND) focused on indicators to measure the environmental impact of the consumption of goods and services by the average EU citizen, focusing on housing, food and transport, via the identification and environmental assessment of the most representative products of each category (the so-called BoP). This report covers an additional BoP called "household goods", added to the previous ones, to complement them and to enlarge the scope of the assessment.

The definition and characterization of the household goods sector was performed for EU-27 countries in order to assess the environmental impacts of the EU-27 household goods representative basket of products (BoP household goods) for the reference year 2010.

The BoP household goods consists of a process-based LCI model for a BoP that represents the most relevant household goods product groups. The selection of the product groups to be included in the basket was based mainly on the list of product groups already covered by the EU Ecolabel and Green Public Procurement (GPP) criteria, complemented with the product groups for which a Product Environmental Footprint (PEF) (EC, 2013) pilot was ongoing at the time of the study (2018). The reason of this choice was twofold: on the one hand, the products groups that are covered by EU Ecolabel or GPP criteria are selected based on their market significance in terms of stock volume and sales and importance of the environmental impact generated. This is in line with the rationale for the selection of the representative products for the other BoPs (e.g. for BoP food). On the other hand, one of the aim of the BoP household goods is to support the analysis of the environmental savings potential related to the implementation of non-energy requirements coming from the Ecodesign, EU Ecolabel, and GPP policies. Therefore, it is important that the BoP has a scope that is similar to the ones of the abovementioned policies.

The selected product groups (and related representative products) that form the BoP are:

— detergents (all-purpose cleaners and sanitary cleaners, detergents for dishwashers, detergents for hand dishwashing, liquid laundry detergents, and powder laundry detergents),

— sanitary products (absorbent hygiene products: baby diapers, sanitary pads, tampons, and breast pads),

— personal care products (rinse-off cosmetics: bar soaps, liquid soaps, shampoos, and hair conditioner),

— furniture (bedroom wooden furniture, kitchen furniture, upholstered seats, non-upholstered seats, and wooden tables),

— bed mattresses,

— footwear (work and waterproof (WW), sport, leisure, and fashion footwear),
— clothes (textile products) (t-shirt, blouse, trousers, and jeans),
— paper products (newspapers, books, and toilet paper).

For each product group in the basket, an inventory model based on representative products has been developed. Data about representative products have been taken mainly from background reports compiled for the definition of EU Ecolabel criteria and from the screening reports of the PEF pilots (see chapter 3.2). The impact of each representative product is then multiplied by the mass of the total product group, as consumed in one year by an average EU citizen (Table 1).

3.1.1 Product groups in the BoP household goods and related quantities

A quantitative and qualitative analysis of the structure of EU-27 household consumption was performed for the selected product groups, including an analysis of international trade. Data on apparent consumption (defined as Production - Exports + Imports) of the representative products were taken from the Eurostat database (Eurostat, 2015). These data are reported in Table 1 as "per capita apparent consumption". An additional analysis was performed to check to which extent the apparent consumption of the representative products could represent the overall consumption of the related product groups selected for the basket. The coverage of the product groups (i.e. % of quantity or value of the representative products compared to the whole quantity or value of the product group that they represent) was calculated based on the quantity (in mass, pieces or pairs) and on the value (in euros).

As illustrated in Table 2, the representativeness of the products included in the basket ranges from full representation to relatively low (in some cases, below 50% of the entire product group). Therefore, it was decided to upscale the apparent consumption of each product (i.e. the amount included in the basket) to represent the 100% of the apparent consumption of the product groups selected. This is a relevant approximation by which it is assumed that, for instance, a t-shirt, may be representative for the impact of other kind of clothes (textile products) that are not included in the basket. However, it was deemed more useful to have this approximation instead of underrepresenting the actual consumption of the considered product groups. For this purpose, an upscale of the annual consumed quantities of each representative product per EU citizen was performed, based on data regarding the coverage of the single representative products within the corresponding product group (Table 2). The coverage by quantity was considered as the first option for the calculation of upscaled quantities of apparent consumption. However, for some of the product groups the coverage calculated by quantity and by value is quite different (Table 2). This is generally due to a lack of data about quantities (and especially about import and export) for most of the products in the product group considered. For this reason, the coverage by economic value was used as a basis for the upscale of the product groups for which data on coverage by quantity were considered not robust enough (see comments in Table 2).

Table 1 summarises the values of per capita apparent consumption of the representative products, the coverage of the product group (either by quantity or mass) used as a basis for upscaling the apparent consumption and, finally, the values of the apparent consumption (upscaled) used in the baseline model of the BoP household goods.

Finally, it has to be considered that the product groups selected for the BoP do not represent all the household goods that EU citizens purchase and use in their everyday life. There are some product groups, such as pharmaceuticals, which can generate significant environmental impacts both in the production and in the use stage and that are not taken into account in the present analysis. Therefore, their potential additional contribution should be taken into account when interpreting the results of the BoP household goods and of the sum of the impact of all the BoPs. As well, several products of the daily life that can have a role in the overall environmental impacts due to their consumption intensity are not included in the BoP, such as, for example, plates, glasses, and household textiles.

Table 1. Composition of the BoP household goods in terms of product groups, representative products and related quantities (referred to the reference flow, i.e. household goods consumption of an average EU-27 citizen in the reference year 2010) (Source: Eurostat, 2015).

Product group	Representative product	Total apparent consumption (unit/year 2010)	Per capita apparent consumption (unit/ citizen*year^{-1})	Coverage by representative products (%)	Per capita apparent consumption upscaled (unit/ citizen*year^{-1})	Unit
Detergents	All-Purpose Cleaners and Sanitary Cleaners (500mL)	5,020,703,455	9.99	100	9.99	kg
	Detergents for Dishwashers (tablet)	1,220,288,309	2.43		2.43	kg
	Hand Dishwashing Detergents (650mL)	878,530,349	1.75		1.75	kg
	Laundry Detergents liquid (650mL)	5,040,246,743	10.03		10.03	kg
	Laundry Detergents powder (dose)	1,558,000,147	3.10		3.10	kg
Sanitary products (absorbent hygiene products)	Baby diapers	786,735,433	1.57	49	3.22	kg
	Sanitary pads	991,362,870	1.97		4.05	kg
	Tampons	22,536,286	0.04		0.09	kg
	Breast pads	135,840,184	0.27		0.56	kg
Personal care (Rinse-off cosmetics)	Bar soap	718,676,400	1.43	31	4.59	kg
	Liquid soap (255mL)	285,135,500	0.57		1.82	kg
	Shampoo (255mL)	490,190,553	0.98		3.13	kg
	Hair conditioner (255mL)	324,550,414	0.65		2.07	kg
Furniture	Bedroom wooden furniture	65,991,756	0.131	66	0.20	p
	Kitchen furniture	99,635,746	0.198		0.30	p
	Upholstered seat	62,131,672	0.124		0.19	p
	Non-Upholstered seat (wooden seat)	89,872,496	0.179		0.27	p
	Dining room furniture (wooden table)	54,735,761	0.109		0.17	p
Bed mattresses	Mattress (Latex, polyurethane and spring mattresses)	39,946,072	0.079	89	0.09	p
Footwear	Work and Waterproof (WW)	120,544,539	0.24	50	0.48	pa
	Sport	152,705,002	0.30		0.61	pa
	Leisure	575,848,245	1.15		2.29	pa
	Fashion	575,848,245	1.15		2.29	pa
Clothes (textile products)	T-shirt	3,533,705,142	7.03	22	31.80	p
	Women blouse	949,656,480	1.89		8.55	p
	Men trousers	415,925,233	0.83		3.74	p
	Jeans	532,586,108	1.06		4.79	p
Paper products	Newspaper	13,958,343,439	45.99	31	90.50	kg
	Book	2,969,875,678	5.91		19.26	kg
	Toilet paper	3,631,492,140	7.23		23.55	kg

p = pieces; pa = pair

Table 2. Coverage of the quantity and value of the product groups by the representative products modelled in the BoP. The % highlighted in green were used to upscale the quantity of the apparent consumption used in the functional unit (F.U.) of the BoP household goods.

Product group	**Total value (€)**	**Value covered by the BoP (€)**	**Value covered by the BoP (%)**	**Total quantity (unit)**	**Quantity covered by the BoP (unit)**	**Quantity covered by the BoP (%)**	**Comment**
Detergents	1.29E+10	1.29E+10	100	1.37E+10 (kg)	1.37E+10 (kg)	100	No direct correspondence between the products in the BoP and the product categories in Prodcom. Therefore, the whole value of the category was allocated to BoP products. This is the reason for 100% coverage.
Sanitary products (absorbent hygiene products)	7.33E+09	4.58E+09	63	3.98E+09 (kg)	1.94E+09 (kg)	49	Results of coverage by value and by mass are equally robust, because data on mass and value are available for all the products considered. Data on coverage by mass are considered for the study.
Personal care (Rinse-off cosmetics)	1.63E+10	5.08E+09	31	1.12E+09 (kg)	1.00E+09 (kg)	89	Results on coverage by value are more robust, because availability of data on mass is very low (data are available only for some of the products in the product group)
Furniture	5.20E+10	3.42E+10	66	6.75E+08 (p)	3.25E+08 (p)	48	Results on coverage by value are more robust, because availability of data on mass is very low (data - especially for import and exports - are available only for some of the products in the product group)
Bed mattresses	3.78E+09	3.34E+09	89	4.95E+07 (p)	4.08E+07 (p)	82	No data for import and export quantities.
Footwear	2.08E+10	7.63E+09	37	2.85E+09 (pa)	1.42E+09 (pa)	50	Results of coverage by value and by mass are equally robust, because data on mass and value are available for all the products considered. Data on coverage by mass are considered for the study.
Clothes (textile products)	8.10E+10	1.90E+10	23	2.46E+10 (p)	5.43E+09 (p)	22	Results of coverage by value and by mass are equally robust, because data on mass and value are available for most of the products considered. Data on coverage by mass are considered for the study.
Paper products	8.57E+10	2.16E+10	25	6.70E+10 (kg)	2.06E+10 (kg)	31	Results of coverage by value and by mass are equally robust, because data on mass and value are available for most of the products considered. Data on coverage by mass are considered for the study.

3.2 Life Cycle Inventory of the BoP

The reference system is the EU-27 per capita consumption in 2010 for the products listed in Table 1. The functional unit (F.U.) is defined as the consumption of household goods by an average EU citizen in one year (reference year 2010).

Life cycle stages considered in the life cycle of the representative products are reported in Table 3.

Table 3. Summary of life cycle stages and related activities included in the BoP household goods.

Life cycle stage	Activities included
Components manufacture	Manufacture of raw materials
	Transport of raw materials to the production site
Production	Energy and water consumption for product manufacture
	Direct emissions from product manufacturing process
	Waste generation and treatment at the production
Packaging	Manufacture of packaging
	Final disposal of packaging
Logistics	International transport (import of finished products)
	Transport to retailer
Use	Transport of the products from retailer to consumer's home
	Energy and water for product use (when relevant)[1]
End of life (EoL)	Final disposal of the product at end of life
	Wastewater treatment (for detergents, personal care products, and toilet paper)

To model the process-based life cycle inventories of the selected representative products, the following approach was followed:

1. Priority was given to the inventories already defined in the EU Ecolabel background reports published by the EU Ecolabel Product Bureau[2] and in the screening studies of the PEF pilots[3] available in March-May 2017, since they are based on a market analysis and on stakeholders' feedback.
2. When a complete life cycle inventory was not available in one of these sources, data were complemented with information coming from previous studies published in the scientific literature, technical reports, or Environmental Product Declarations (EPDs).

Table 4 reports an overview of the data sources used for each of the representative products modelled in the BoP.

Table 4. Overview of LCI data sources used to model the representative products.

Product Group	Representative product	Data source	Type
Detergents	All-Purpose Cleaners and Sanitary Cleaners	Arendorf et al., 2014a	EU Ecolabel background report
	Detergents for Dishwashers	Arendorf et al., 2014b	EU Ecolabel background report
	Hand Dishwashing Detergents	Arendorf et al., 2014c	EU Ecolabel background report

(1) Use phase of clothes (i.e. washing cycles) is not included in the model, to avoid double counting with the use phase of detergents

(2) http://susproc.jrc.ec.europa.eu/product_bureau/projects.html

(3) https://webgate.ec.europa.eu/fpfis/wikis/spaces/viewspace.action?key=EUENVFP

Product Group	Representative product	Data source	Type
	Laundry Detergents liquid	Screening report of the PEF pilot on Household Heavy Duty Liquid Laundry Detergents (HDLLD) for machine wash	PEF screening report
	Laundry Detergents powder	Arendorf et al., 2014d	EU Ecolabel background report
Sanitary products (absorbent hygiene products)	Baby diapers Sanitary pads Tampons Breast pads	EC-JRC, 2013a	EU Ecolabel background report
Personal care (rinse-off cosmetics)	Bar soap Liquid soap Shampoo Hair conditioner	Escamilla et al., 2012	EU Ecolabel background report
Furniture	Bedroom wooden furniture	Iritani et al., 2015	Scientific paper
	Kitchen furniture	González-García et al., 2011	Scientific paper
	Upholstered seat	Castellani et al., 2015	Scientific paper
	Non-Upholstered seat (wooden seat)	Interviews with a furniture company	Data from industry
	Dining room furniture (wooden table)	Interviews with a furniture company	Data from industry
Bed mattresses	3 types: Latex, polyurethane (PUR) and spring	EC-JRC, 2013b	EU Ecolabel background report
Footwear	Work and waterproof (WW) Sport Leisure Fashion	Screening report of the PEF pilot on footwear	PEF screening report
Clothes (textile products)	T-shirt	Screening report of the PEF pilot on T-shirts (Bill of Materials, packaging and transports); van der Velden et al., 2014 (electricity for spinning of fibres); Zhang et al., 2015 (electricity for cutting and sewing the textile)	PEF screening report; Scientific papers
	Women blouse	Ellebæk Larsen et al., 2007 - EDIPTEX project report (BoM); van der Velden et al., 2014 (electricity for spinning of fibres); Zhang et al., 2015 (electricity for cutting and sewing the textile)	Technical report; Scientific papers
	Men trousers	Marks & Spencer plc, 2002 (BoM); van der Velden et al., 2014 (electricity for spinning of fibres); Zhang et al., 2015 (electricity for cutting and sewing the textile)	Industry report; Scientific papers
	Jeans	ADEME, (2006); van der Velden et al., 2014 (electricity for spinning of fibres); Zhang et al., 2015 (electricity for cutting and sewing the textile)	Industry report; Scientific papers
Paper products	Newsprint	Screening report of the PEF pilot on intermediate paper (pulp and paper production); Rafenberg and Eric, 1998	PEF screening report; Scientific paper
	Book	Screening report of the PEF pilot on intermediate paper (pulp and paper production); Castellani et al., 2015 (book production)	PEF screening report; Scientific paper
	Toilet paper	Screening report of the PEF pilot on intermediate paper (pulp and paper production); EPD, 2016	PEF screening report; EPD

3.2.1 General assumptions adopted in the life cycle inventory of products

In order to ensure consistency within the whole BoP, some cross-cutting assumptions have been adopted for all the representative products. These assumptions refer mainly to the following life cycle stages of the products: transport, use, and imports.

Transport of raw materials is included in the stage "Components manufacture". Transport of finished products occurs from the production site to the site of retailing stage and from retailing to the home of the final consumers. When specific data about transport distances and modes were available in the sources used to model the representative products, these data were used in the BoP model. When specific data were not available, transport was modelled according to Product Environmental Footprint Category Rules (PEFCRs) (EC, 2017a).

Regarding the **use** phase, for transport from retail to home of big products (furniture and bed mattresses), a transport by van was estimated. For the transport of small products, the assumption applied is that 30 products are bought in a single purchase by the final consumer. Therefore, the impact of transport is allocated between the purchased products considering that each product is one thirty of the items purchased (3.33% of the transport burden), for a transport distance of 4 km (Vanderheyden and Aerts, 2014), by passenger car. This transport is included in the life cycle of the product.

Towards considering the **imports** of products (i.e. the share of products that are produced outside the EU and then imported as finished products), the following approach was considered:

- Country-specific import data for the BoP household goods were taken from the Eurostat international trade database for the year 2010 (Eurostat, 2015). A selection of the most relevant countries in terms of quantity of product imported was considered, with the aim to cover at least 90% of the quantity imported for each representative product considered.
- For the share of production known to occur outside the EU, a specific electricity mix was created, to represent the real conditions of the production sites (according to the share of imports from extra-EU countries, calculated before). Details are provided in section 3.2.4.

For the share of products imported to the EU an international transport was modelled, based on distances and means of transport used for each product (with the exception of newspapers, for which data on imports per country were not available). Details are provided in section 3.2.6.

3.2.2 Lifespan of products

The products included in the BoP household goods have different lifespans. For the environmental assessment, the following assumptions were considered:

- liquid and powder detergents (all-purpose cleaners and sanitary cleaners, detergents for dishwashers, hand dishwashing detergents, laundry detergents liquid, and laundry detergents powder) have a lifespan under a year;
- sanitary products (absorbent hygiene products: baby diapers, sanitary pads, tampons, and breast pads) have a lifespan under a year;
- personal care (rinse-off cosmetic products: bar soap, liquid soap, shampoo, and hair conditioner) have a lifespan under a year;
- furniture (bedroom wooden furniture, kitchen furniture, upholstered seat, non-upholstered seat (wooden seat), and wooden table) have a lifespan of 15 years, according to the EU Ecolabel background reports;
- bed mattresses (latex, PUR, and spring) have a lifespan of 10 years, according to the EU Ecolabel background report;

— footwear (work and waterproof, sport, leisure, and fashion) have a lifespan of a year, according to the PEFCR;

— clothes (textile products) (t-shirt, women blouse, men trousers, and jeans) have a lifespan of a year, according to the PEFCR;

— paper products have a lifespan under a year (newsprint and toilet paper) and of 10 years (book).

3.2.3 LCI of components manufacture

The Bill of Materials (BoM) for each of the representative products was taken from the reference sources reported in Table 4. Details of the BoM modelled for each product are provided in Annex 1. Transport of raw materials to the production site is also included in this stage.

3.2.4 LCI of production

The inventory of the production stage was built for each activity included in the production chain of each product by collecting literature or database data. The main sources of data are reported in Table 4. The definition of the energy mixes used in the production stage was based on the results of the analysis done about the international transport of imported products by country. For each product, the European electricity mix was used for the share of production that is known to happen in Europe. The dataset for the European electricity mix "Electricity, low voltage {Europe without Switzerland}| market group" (from ecoinvent 3.2 library) was used to represent the EU electricity profile.

For the share of production known to occur outside the EU, a specific electricity mix was created, to represent the real conditions of the production sites (according to the share of imports from extra-EU countries).

Finally, the PEF screening reports of footwear and clothes detail a specific electricity mix based on the most relevant production sites for those products. In this case, priority was given to these data, because they were agreed within a group of stakeholders that includes some of the most important companies producing those products.

Table 5 reports the electricity mixes created for the imported share of each representative product in the BoP household goods. Regarding clothes, the PEF screening report on T-shirts reports detailed electricity mixes (based on production countries) for each of the production phases from yarn spinning to cutting and sewing of the finished product. Table 6 reports the different electricity mixes modelled for each of those phases, based on data reported in the PEF screening report.

Table 5. Electricity mixes used to model the share of production that occurs outside the EU (based on the ratio of finished products that are imported to EU-27 and on the ratio of countries from which they are imported – source: Eurostat, 2015).

Household goods products	Electricity mix share (%)																						
	China	Turkey	United States	Switzerland	Indonesia	Malaysia	Vietnam	Israel	Croatia	Mexico	Thailand	Brazil	Serbia	Ukraine	Canada	Norway	Bosnia and Herzegovina	United Arab Emirates	Russian Federation	South Africa	Australia	India	Egypt	Lebanon
Sanitary products	13.0	17.3	32.8	22.2				4.6		5.2				4.9										
Bar soap	7.4	32.9	9.0	11.1				41.5		1.8	9.2													
Liquid soap	29.4	6.5	6.7	31.8		3.0			11.3	2.7	11.3													
Shampoo	14.1	20.3	39.0	14.2				4.2	4.0						1.6			2.0	2.0					
Hair conditioner	4.0	2.5	67.1	6.0				1.7				2.9			4.8					3.4	2.2			
Detergents	6.7	9.6	30.9	4.1		11.7		4.3					7.1			13.2						2.3		
Kitchen furniture	63.6	3.9			2.7	3.6						3.2	3.3	8.0			3.4							
Bedroom furniture	50.3	5.5			3.9	13.2	6.9					16.0												
Upholstered seat	86.1	4.2				4.7	2.7				2.3													
Non-upholstered seat	76.0				5.9	2.6	15.5																	
Wooden table	99.1																							
Bed mattresses	49.5	34.4		4.3					3.6							8.2								
Book	59.5	3.4			27.8	6.2																		
Toilet paper	9.8	3.6	4.2	50.7				3.6	3.0				7.9				3.6						11.8	4.8
Work and waterproof footwear*	70.0		2.6		9.5		16.7																	
Sport footwear*	56.0				22.0		22.0																	
Fashion footwear*	33.9				33.0		33.0																	
Leisure footwear*	58.5				8.3		33.3																	

*Source: PEF screening report

Table 6. Electricity mixes used to model the production phases of clothes (spinning, texturizing of synthetic yarns, knitting and dyeing, and cutting and sewing of the final product).

Production process	**Electricity mix share (%)**									
	China	Turkey	India	Bandlagesh	Pakistan	Indonesia	Japan	Thailand	Europe	Morocco
Spinning	63.0	4.0	23.0		5.0	4.0				
Texturizing	81.0	2.0	13.0				2.0	2.0		
Knitting and dyeing	44.0	17.0		28.0					11.0	
Cutting and sewing	22.0	18.0	8.0	46.0						5.0

3.2.5 LCI of packaging

The LCI of the packaging of products in the BoP household goods has been modelled consistently with what was done in the main sources of data considered for modelling the representative products (Table 4). It includes primary packaging and secondary packaging (only for products for which data were available in the original sources). It is assumed that rinse-off cosmetics (personal care), footwear, and toilet paper do not require secondary packaging; and that furniture and bed mattresses are sold without primary packaging, while newspapers and books are sold without any packaging. Table 7 illustrates the assumptions made about packaging of the products in the BoP.

Table 7. Modelling of packaging for the products in the BoP.

	Description of packaging		Packaging materials [g] per unit of product								
Product	**Primary**	**Secondary**	**PET (bottle grade)**	**PET (amorp hous)**	**PP**	**HDPE**	**LDPE**	**PS**	**Paper**	**Card board**	**Reference flow of the product**
All-Purpose Cleaners (APC)	500 mL bottle (LDPE) with trigger (LDPE + PP)	Cardboard box (10 bottles/per box)	34	11	10	-	11	-	-	20	500 mL (1 bottle)
Detergents for Dishwashers	Flow rap film (PP)	Cardboard box + shrinkwrap (LDPE)	-	-	0.35	-	0.18	-	-	3	20 g of detergent used for one washing cycle
Hand Dishwashing Detergents	650 mL bottle (PET) with cap (PP)	Cardboard box (16 bottles per box)	36.5	-	3.8	-	-	-	-	21	1 bottle (0.65mL) of manual dishwasher detergent
Laundry Detergents liquid	650 mL bottle (High density polyethylene - HDPE) with cap (PP)	Cardboard box (6 bottles per box)	-	-	0.8	3.7	-	-	-	15	75 mL of detergent (1 laundry cycle)
Laundry Detergents powder	Cardboard box	Cardboard case (20 boxes per case)	-	-	-	-	-	-	-	5	85 grams of a powder laundry detergent (1 laundry cycle)
Baby diapers	Plastic bag (LDPE)	Cardboard box	-	-	-	-	0.45	-	-	3.5	1 diaper
Sanitary pads	Plastic bag (LDPE)	Cardboard box	-	-	-	-	0.1	-	-	0.8	1 sanitary pad
Tampons	PE wrap (LDPE)	Cardboard box	-	-	-	-	0.1	-	-	0.8	1 tampon
Breast pads	Plastic bag (LDPE)	Cardboard box	-	-	-	-	0.05	-	-	0.4	1 breast pad
Bar soap	Paper wrapping	n.a.	-	-	-	-	-	-	15	-	1 bar soap (100g)
Liquid soap	255 mL bottle (HDPE)	n.a.	-	-	-	39	-	-	-	-	255 mL (1 bottle)
Shampoo	255 mL bottle (HDPE)	n.a.	-	-	-	39	-	-	-	-	255 mL (1 bottle)
Hair conditioner	255 mL bottle (HDPE)	n.a.	-	-	-	39	-	-	-	-	255 mL (1 bottle)
Bedroom wooden furniture	No packaging	Cardboard box + polystyrene (PS)	-	-	-	-	-	3080	-	22600	1 furniture piece
Kitchen furniture	No packaging	Cardboard box + polystyrene (PS) + plastic film (LDPE)	-	-	-	-	24	45	-	2400	1 furniture piece

	Description of packaging		Packaging materials [g] per unit of product								
Product	**Primary**	**Secondary**	**PET (bottle grade)**	**PET (amorp hous)**	**PP**	**HDPE**	**LDPE**	**PS**	**Paper**	**Card board**	**Reference flow of the product**
Upholstered seat	No packaging	Cardboard + plastic film (LDPE)	-	-	-	-	540	-	-	60	1 furniture piece
Non-upholstered seat	No packaging	Cardboard box + polystyrene (PS)	-	-	-	-	-	50	-	292	1 furniture piece
Dining room furniture	No packaging	Cardboard box	-	-	-	-	-	-	-	525	1 furniture piece
Bed mattresses	No packaging	Cardboard box + polystyrene (PS)	-	-	-	-	-	534	-	56	1 mattress
WW shoes	Cardboard box + wrapping paper	n.a.	-	-	-	-	-	-	171	69	1 pair of shoes
Sport shoes	Cardboard box + wrapping paper	n.a.	-	-	-	-	-	-	18	185	1 pair of shoes
Leisure shoes	Cardboard box + wrapping paper	n.a.	-	-	-	-	-	-	6	30	1 pair of shoes
Fashion shoes	Cardboard box + wrapping paper	n.a.	-	-	-	-	-	-	13	85	1 pair of shoes
T-shirt	Plastic bag (LDPE)	Cardboard box	-	-	-	-	10	-	-	43.3	1 T-shirt
Women blouse	Plastic bag (LDPE)	Cardboard box	-	-	-	-	10	-	-	43.3	1 blouse
Men trousers	Plastic bag (LDPE)	Cardboard box	-	-	-	-	16	-	-	55	1 pair of trousers
Jeans	Plastic bag (LDPE)	Cardboard box	-	-	-	-	16	-	-	55	1 pair of jeans
Newspaper	No packaging	No packaging	-	-	-	-	-	-	-	-	1 newspaper
Book	No packaging	No packaging	-	-	-	-	-	-	-	-	1 book
Toilet paper	Paper wrapping + Plastic bag (LDPE)	n.a.	-	-	-	-	20	-	-	29	1 pack (4 rolls)

3.2.6 LCI of logistics

Logistics consists of international transportation from outside the EU and transport of processed goods from industry to retailing. As mentioned before, for the inventory of the international transport of imported finished products, the share of imported goods over the total amount of apparent consumption (production minus export plus import) was calculated. Results are reported in Table 8.

Table 8. Summary of the share of imported goods, the sea transport distance, and the road transport distance for each representative product.

Product Group	Representative product	Import (% of apparent consumption)	Sea transport (km/unit)	Road transport (km/unit)
Detergents	All-Purpose Cleaners (APC)	3.3	7,543	857
	Detergents for Dishwashers			
	Hand-Dishwashing Detergents			
	Laundry Detergents liquid			
	Laundry Detergents powder			
Sanitary products (absorbent hygiene products)	Baby diapers	6.7	4,924	915
	Sanitary pads	1.9		
	Tampons	20.7		
	Breast pads	12.8		
Personal care (rinse-off cosmetics)	Bar soap	18.1	4,318	1,247
	Liquid soap	13.1	7,374	876
	Shampoo	6.5	5,428	978
	Hair conditioner	12.4	6,554	793
Furniture	Bedroom wooden furniture	11.8	12,836	1,430
	Kitchen furniture	0.6	12,259	1,184
	Upholstered seat	25.4	16,047	1,195
	Non-Upholstered seat	58.4	16,185	1,341
	Dining room furniture	23.6	17,049	1,131
Bed mattresses	3 types: Latex, PUR and spring	2.7	10,230	1,244
Footwear	Work and waterproof (WW)	66.5	13,153	1,233
	Sport	93.7	15,819	1,439
	Leisure	99.2	16,853	1,268
	Fashion			
Clothes (textile products)	T-shirt	94.7	9,964	1,380
	Women blouse	85.4	9,897	1,535
	Men trousers	93.5	12,062	1,299
	Jeans	94.7	12,062	1,299
Paper products	Newspaper	0	0	0
	Book	0.9	14,466	1,118
	Toilet paper	1.2	2,504	760

For each unit (kg, pair or piece) of imported goods, the inventory of transport for each mode (road or sea transport) is also calculated. The transport of finished products is assumed to occur from the capital of the exporting country to the city of Frankfurt, which is considered a central destination for the arrival of imports in the EU. For exporting countries directly connected to the EU by land, such as Switzerland or Belarus, only a transport by lorry is considered from the capital of the exporting country to the city of Frankfurt. For the others, the transport is considered to be composed by: a transport by lorry between the capital of the exporting country and the country's main port; a transport by ship from the port of the exporting country to the main EU ports and, finally, a transport by lorry between the port of destination and the city of Frankfurt. Rotterdam and Marseille are considered as the EU ports of arrival of the goods.

The distances are calculated by using www.sea-distances.org and Google maps. This transport is allocated to a percentage of the final product in the LCI model, corresponding to the share of imported goods out of the total apparent consumption of that kind of product.

3.2.7 LCI of use phase

The use phase consists of the transport to the consumers' home (by private car or van, as described before), and of the use of the product at home. For most of the products in the BoP (namely absorbent hygiene products, furniture, bed mattresses, and paper products), the impact of the use was considered null or negligible. In these cases, only the transport from retailer to home is included in the use stage. For some other type of products, the use of the product at home constitutes a relevant stage in the whole life cycle, hence it has been modelled in detail (Table 9).

The use of laundry detergents implies the use of water (and the use of electricity to warm it). The same water (and related electricity), plus the detergent itself, may be part of the use stage of clothes (that are part of the items washed). Therefore, to avoid double counting within the same basket, the amount of water and electricity used for laundry is allocated only to the detergent life cycle. This assumption leads, of course, to a lower impact of clothes compared to studies where the life cycle of clothes is assessed alone, and should be taken into account when analysing results of the contribution of product categories to the overall impact of the whole BoP.

A possible double counting may also occur in the case of the use of shampoo and hair conditioner (both used in the washing of the hair). In this case, a 50-50 allocation of the water used was implemented, i.e. 50% to the shampoo and 50% to the hair conditioner. Coherently with the assumptions made in the original source (EU Ecolabel background report), the heating of the water used for the shower and the energy needed for drying the hair are not included in the system boundaries, as they are optional and not directly related to the products.

Table 9. Inventory data for the use of product at home.

Product	**Reference quantity (for washing cycle)**	**Electricity (kWh)**	**Water (L)**	**Notes**
All purpose cleaner	4.7 g[4]	0.04	0.55	Water temperature: 40°C. Use scenario as described in the EU Ecolabel report (Arendorf et al., 2014a), based on Koheler and Wildbolz (2009)
Dishwasher detergent	20 g[5]	1.42	18.5	Water temperature: 60°C. Use scenario as described in the EU Ecolabel report (Arendorf et al., 2014b), based on Stamminger et al. (2007) and EC (2007)
Hand dishwashing detergent	8-12 mL[6]	0.05-0.11	7.5-15	Water temperature: 40°C. Use scenario as described in the EU Ecolabel report (Arendorf et al., 2014c), based on Stamminger et al. (2007) and Koheler and Wildbolz (2009)
Laundry detergent (liquid)	75mL	50	0.6	Water temperature: 40°C. Use scenario as described in the PEF screening report

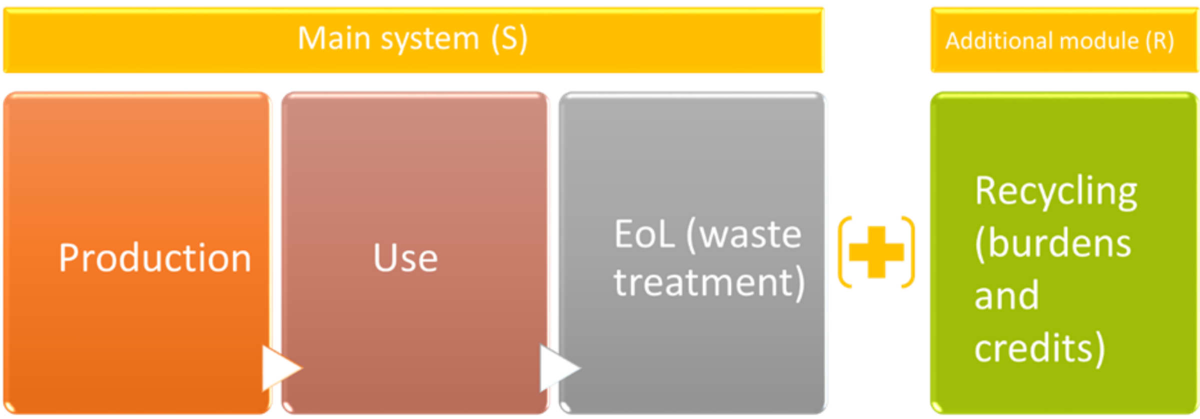
(4) Corresponding to 5 spraying cycles, needed to clean an area of 0.24 m^2.
(5) Quantity used for washing of four place settings in the dishwasher.
(6) Quantity used for manual washing of four place settings: 8 ml in case of "full sink", 12 ml in case of "direct application". The ratio between "full sink" and "direct application" assumed in the BoP model is 50-50.

Product	Reference quantity (for washing cycle)	Electricity (kWh)	Water (L)	Notes
Laundry detergent (powder)	85g	0.53	49	Water temperature: 40°C. Use scenario as described in the EU Ecolabel report (Arendorf et al., 2014d), based on EC (2007) and Koheler and Wildbolz (2009)
Bar soap	2g[7]	(not included)	3	Use scenario as described in the EU Ecolabel report (Escamilla et al., 2012)
Liquid soap (hand)[8]	2g[9]	(not included)	3	Use scenario as described in the EU Ecolabel report (Escamilla et al., 2012)
Liquid soap (shower)	13g	(not included)	22	Use scenario as described in the EU Ecolabel report (Escamilla et al., 2012)
Shampoo	10.5g[10]	(not included)	22	Use scenario as described in the EU Ecolabel report (Escamilla et al., 2012)
Hair conditioner	14g[11]	(not included)	22	Use scenario as described in the EU Ecolabel report (Escamilla et al., 2012)

3.2.8 LCI of End of Life

The end of life (EoL) stage in the BoP is modelled in a way that allows separating the burdens and benefits of recycling from the rest of the system, in order to provide a clearer picture of their contributions to the total impact. Two systems are identified: "S", referring to the system excluding recycling activities, and "R", referring to the burdens and benefits of recycling and reuse activities. Figure 1 illustrates the approach followed for all the BoPs' models used to calculate the Consumer Footprint in the EU.

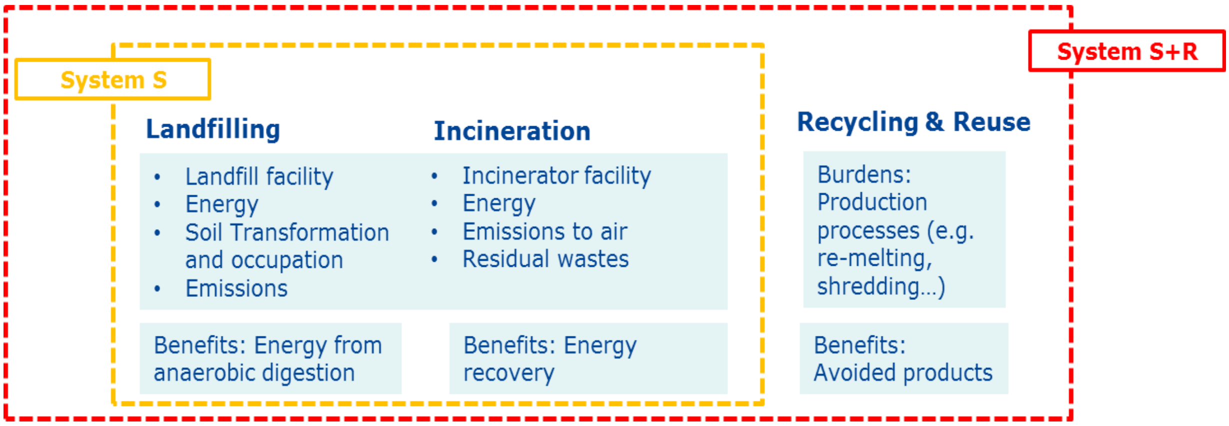
Figure 1. Illustration of the approach adopted to model EoL as waste treatment and recycling, as systems "S" and "R".



The sum of the two, named System "S+R", is the one which allows evaluating in a more comprehensive way those aspects which are of interest also in the context of circular economy: the additional module "R" quantifies burdens and benefits of activities such as recycling and reuse. Details on activities included in each system are provided in Figure 2.

(7) Dose product for 1 washing action: 2g, reference flow 100g (one bar soap), number of washing per reference flow: 50.
(8) It is assumed that half of the liquid soap is used to wash the hands and half is used for the shower.
(9) Dose product for 1 washing action: 2g, reference flow 255g (one bottle), number of washing per reference flow: 128.
(10) Dose product for 1 washing action: 10.5g, reference flow 255g, number of washing per reference flow: 24.
(11) Dose product for 1 washing action: 14g, reference flow 255g, number of washing per reference flow: 18.

Figure 2. EoL activities included in System S, R and S+R.



In the BoP household goods, when specific information about the rate of recycling was available in the data sources used (Table 4), this was applied in the models. When specific information was not available, or when no (or negligible) recycling is done for a specific type of product, it is assumed that the product goes into the unsorted municipal waste stream. A scenario based on the values of proportion of the material in the product that is used for energy recovery at EoL (R3) according to PEFCR rules, i.e. 55% of unsorted municipal solid wastes to landfill and 45% to incineration, was applied. Assumptions on EoL scenario for the products in the BoP household goods are summarised in Table 10.

The end of life of packaging materials was modelled following the distinction of the systems S and R, then summed in the system S+R, used for the hotspot analysis. EoL of packaging is included in the packaging life cycle phase. Details of the datasets used to model the two systems are provided in Annex 2.

Therefore, the "R" system includes the burdens and benefits of recycling of (a) the product itself at the end of life stage according to the rates provided by data sources (i.e., 11% of clothes (textile products) and 62% of newspaper and books) and (b) the packaging of the products.

Table 10. Summary of assumption on EoL scenario for the products in the BoP household goods.

Product Group	Representative product	EoL scenario
Detergents	All-Purpose Cleaners (APC)	100% to wastewater treatment (together with the water used in the use phase)
	Detergents for Dishwashers	
	Hand Dishwashing Detergents	
	Laundry Detergents liquid	
	Laundry Detergents powder	
Sanitary products (absorbent hygiene products)	Baby diapers	0% recycling 45% incineration 55% landfill
	Sanitary pads	
	Tampons	
	Breast pads	
Personal care (rinse-off cosmetics)	Bar soap	100% to wastewater treatment (together with the water used in the use phase)
	Liquid soap	
	Shampoo	
	Hair conditioner	
Furniture	Bedroom wooden furniture	0% recycling 45% incineration 55% landfill
	Kitchen furniture	
	Upholstered seat	
	Non-Upholstered seat (wooden seat)	
	Dining room furniture (wooden table)	
Bed mattresses	3 types: Latex, PUR and spring	0% recycling 45% incineration 55% landfill

Footwear	Work and waterproof	0% recycling 45% incineration 55% landfill
	Sport	
	Leisure	
	Fashion	
Clothes (textile products)	T-shirt	11% recycling (of which, 87% as rags, avoided product: textile[12]; 13% as insulation material, avoided product: rock wool[13]) 37.4 % incineration 51.6% landfill
	Women blouse	
	Men trousers	
	Jeans	
Paper products	Newspaper	62% recycling (avoided product: pulp production for graphic paper[14]) 17% incineration 20% landfill
	Book	
	Toilet paper	100% to wastewater treatment (together with the water used in the use phase)

[12] Mixed: cotton, polyester and viscose.
[13] 0.89 kg of avoided rock wool per kg of textile recycled.
[14] 0.8 kg of avoided pulp per kg of paper recycled.

4 Results of baseline's hotspot analysis

The upscaled inventory of the BoP household goods (reference flow: consumption of household goods by an average EU citizen in the reference year 2010[15]) has been characterized using ILCD v. 1.08 (EC-JRC, 2011) (Table 11) and normalized using ILCD EU-27 normalisation factors (Benini et al., 2014) (Table 14), including also the comparison with country-specific normalisation factors addressing water scarcity in the different countries, and ILCD Global normalization factors (Sala et al., 2016) (Table 15). Normalized results have been weighting using the equal weighting of ILCD and the weighting set developed for the EF as sensitivity (Sala et al., 2018). Impacts of long-term emissions have been excluded.

Overall BoP households and per capita results shown in Table 11 and Table 13, respectively, refer to the systems S, R and S+R, for comparison. Results of the hotspot analysis refer only to the System S+R, which includes burdens and credits associated to recycling activities.

Table 11. Characterized results (ILCD) for the whole BoP household goods baseline (overall impacts of household goods consumption in EU in 2010).

Impact category	**Unit**	**System S+R**	**System S**	**System R**
Climate change	kg CO_2 eq	7.00E+11	7.26E+11	-2.58E+10
Ozone depletion	kg CFC-11 eq	5.67E+04	5.95E+04	-2.77E+03
Human toxicity, non-cancer	CTUh	9.40E+04	9.97E+04	-5.65E+03
Human toxicity, cancer	CTUh	2.39E+04	2.42E+04	-3.69E+02
Particulate matter	kg $PM_{2.5}$ eq	5.72E+08	6.14E+08	-4.17E+07
Ionizing radiation, effects on human health (HH)	kBq U^{235} eq	4.47E+10	4.66E+10	-1.99E+09
Photochemical ozone formation	kg NMVOC eq	2.08E+09	2.18E+09	-1.02E+08
Acidification	molc H^+ eq	4.10E+09	4.28E+09	-1.79E+08
Terrestrial eutrophication	molc N eq	8.17E+09	8.53E+09	-3.61E+08
Freshwater eutrophication	kg P eq	5.66E+07	5.89E+07	-2.27E+06
Marine eutrophication	kg N eq	1.14E+09	1.19E+09	-4.45E+07
Freshwater ecotoxicity	CTUe	8.65E+11	8.85E+11	-2.01E+10
Land use	kg C deficit	2.16E+12	2.37E+12	-2.06E+11
Water resource depletion	m^3 water eq	5.43E+10	5.68E+10	-2.47E+09
Resource depletion	kg Sb eq	7.40E+07	7.03E+07	3.65E+06

[15] The hotspot analysis presented in this chapter has been run considering the functional unit of the basket with upscaled quantities of representative products, as reported in Table 1.

Table 12. Characterized results (ILCD) for the F.U. of the BoP household goods baseline (impacts of household goods consumption by an average EU citizen in 2010).

Impact category	Unit	System S+R	System S	System R
Climate change	kg CO_2 eq	1.39E+03	1.44E+03	-5.14E+01
Ozone depletion	kg CFC-11 eq	1.13E-04	1.18E-04	-5.52E-06
Human toxicity, non-cancer	CTUh	1.87E-04	1.98E-04	-1.13E-05
Human toxicity, cancer	CTUh	4.75E-05	4.82E-05	-7.34E-07
Particulate matter	kg $PM_{2.5}$ eq	1.14E+00	1.22E+00	-8.30E-02
Ionizing radiation, effects on human health (HH)	kBq U^{235} eq	8.89E+01	9.28E+01	-3.96E+00
Photochemical ozone formation	kg NMVOC eq	4.13E+00	4.33E+00	-2.02E-01
Acidification	molc H^+ eq	8.16E+00	8.51E+00	-3.57E-01
Terrestrial eutrophication	molc N eq	1.63E+01	1.70E+01	-7.19E-01
Freshwater eutrophication	kg P eq	1.13E-01	1.17E-01	-4.52E-03
Marine eutrophication	kg N eq	2.28E+00	2.36E+00	-8.86E-02
Freshwater ecotoxicity	CTUe	1.72E+03	1.76E+03	-4.01E+01
Land use	kg C deficit	4.30E+03	4.71E+03	-4.11E+02
Water resource depletion	m^3 water eq	1.08E+02	1.13E+02	-4.91E+00
Resource depletion	kg Sb eq	1.47E-01	1.40E-01	7.27E-03

The relative relevance of some impact categories varies quite significantly depending on the set of normalisation references used (Table 13 and Table 14). The most relevant impact is resource depletion when applying the default EU-27 set (25%), while it is human toxicity, cancer effects when applying global normalisation references (39%). The contribution of toxicity-related impact categories is further checked and discussed with the improved impact assessment models for toxicity-related impacts included in the EF 3.0 package (Saouter et al., 2018) due to limitations of the current model (Saouter et al., 2017a; 2017b), which only cover 50% of the elementary flows contributing to toxicity (Zampori et al., 2016).

Resource depletion is the impact category that varies the most between the two sets, being the most relevant (25%) in the case of EU-27 normalisation and the fourth most relevant (9%) in the case of global normalisation. The variation of water resource depletion is even higher (from 23% with EU-27 references to 0% with global references). However, it is worth to consider that the default ILCD EU-27 normalization factor for water resource depletion is calculated using average EU values, whereas the characterization factors are country-specific. When applying country-specific normalization factors (ILCD EU 27 country-specific) the relevance of water depletion is reduced from 23% to 3%.

If the results of the BoP household goods per citizen are normalised referring to the average impact per person in EU-27 (Sala et al., 2015) and applying equal weighting (Figure 3), the impact category mineral, fossil and renewable resource depletion assumes the highest relevance (25%) compared to the others. The second most important impact category is water resource depletion (23%) and the third is human toxicity, cancer effects (22%).

When comparing the equal weighting used in ILCD with the weighting factors developed for the EF, the relevance of impact category change (Table 13 and Table 14). In general, resource depletion and climate change show an increased relevance for the EF method (Figure 3). On the contrary, the relevance of human toxicity, cancer decreases.

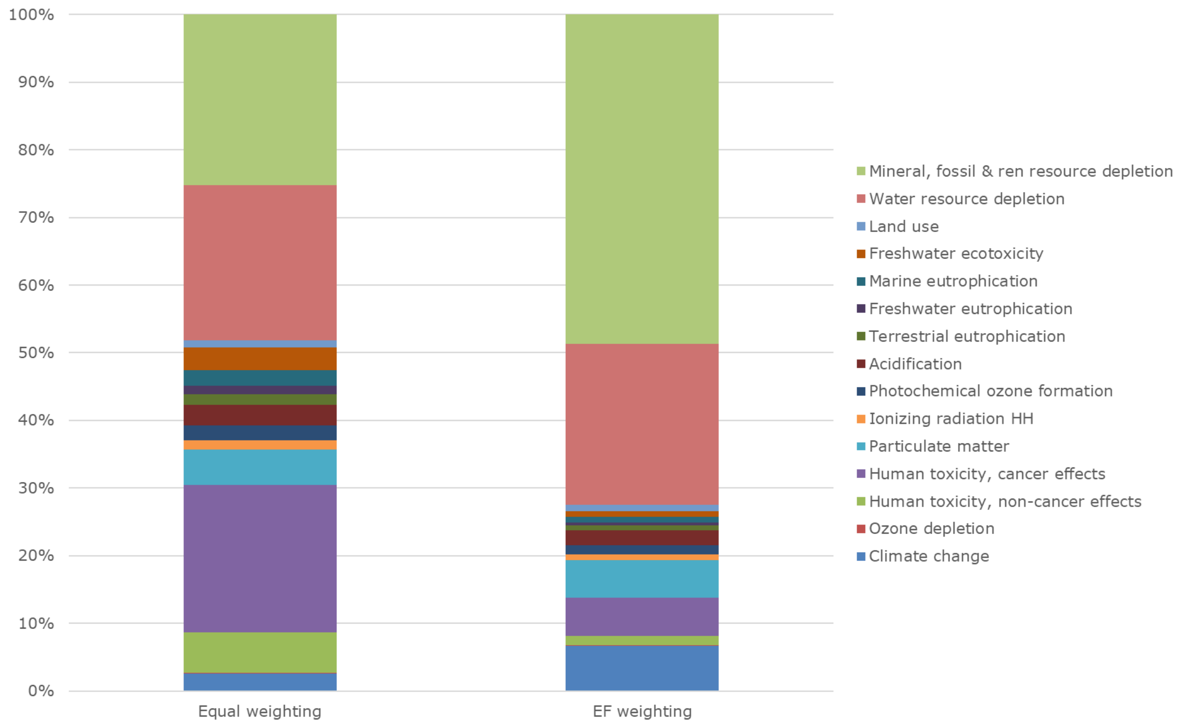
Table 13. Normalized results (ILCD EU-27) for the BoP household goods per capita baseline. Relevance of impacts after normalization with equal and EF weighting of impact categories. Country-specific normalization factors (NFs) considers the calculation of water resource depletion at the country level with specific water scarcity values.

Impact category	System S+R (ILCD EU-27)			System S+R (ILCD EU-27 country-specific)		
	Value (per person)	Relevance (%)		Value (per person)	Relevance (%)	
		Equal WFs	EF WFs		Equal WFs	EF WFs
Climate change	1.52E-01	2.6	6.7	1.52E-01	3.3	8.5
Ozone depletion	5.25E-03	0.1	0.1	5.25E-03	0.1	0.1
Human toxicity, non-cancer	3.50E-01	6.0	1.3	3.50E-01	7.6	1.7
Human toxicity, cancer	1.27E+00	21.8	5.6	1.27E+00	27.4	7.2
Particulate matter	3.01E-01	5.2	5.6	3.01E-01	6.5	7.2
Ionizing radiation, human health	7.92E-02	1.4	0.8	7.92E-02	1.7	1.1
Photochemical ozone formation	1.31E-01	2.3	1.3	1.31E-01	2.8	1.7
Acidification	1.74E-01	3.0	2.2	1.74E-01	3.8	2.9
Terrestrial eutrophication	9.33E-02	1.6	0.7	9.33E-02	2.0	0.9
Freshwater eutrophication	7.64E-02	1.3	0.4	7.64E-02	1.7	0.6
Marine eutrophication	1.35E-01	2.3	0.8	1.35E-01	2.9	1.1
Freshwater ecotoxicity	1.94E-01	3.3	0.8	1.94E-01	4.2	1.0
Land use	5.72E-02	1.0	0.9	5.72E-02	1.2	1.2
Water resource depletion	1.34E+00	23.0	23.8	1.37E-01	3.0	3.1
Resource depletion	1.47E+00	25.2	48.7	1.47E+00	31.8	61.9
TOTAL (single weighted) (Pt)	-	3.88E-01	4.79E-01	-	3.08E-01	3.77E-01

Table 14. Normalized results (ILCD Global) for the BoP household goods per capita baseline. Relevance of impacts after normalization with equal and EF weighting of impact categories.

Impact category	System S+R			
	Total BoP	Per capita		
			Relevance (%)	
	Value	Value	Equal WFs	EF WFs
Climate change	1.33E-02	1.82E-01	5.8	23.0
Ozone depletion	3.52E-04	4.84E-03	0.2	0.2
Human toxicity, non-cancer	2.87E-02	3.94E-01	12.5	4.3
Human toxicity, cancer	8.98E-02	1.23E+00	39.1	15.7
Particulate matter	6.49E-03	8.91E-02	2.8	4.8
Ionizing radiation HH	2.34E-02	3.20E-01	10.2	9.6
Photochemical ozone formation	7.40E-03	1.02E-01	3.2	2.9
Acidification	1.07E-02	1.47E-01	4.7	5.4
Terrestrial eutrophication	6.70E-03	9.20E-02	2.9	2.0
Freshwater eutrophication	3.22E-03	4.41E-02	1.4	0.7
Marine eutrophication	5.85E-03	8.03E-02	2.5	1.4
Freshwater ecotoxicity	1.06E-02	1.46E-01	4.6	1.7
Land use	2.45E-03	3.36E-02	1.1	1.6
Water resource depletion	7.08E-04	9.71E-03	0.3	0.5
Resource depletion	2.00E-02	2.75E-01	8.7	26.1
TOTAL (single weighted) (Pt)	-	-	2.10E-01	1.67E-01

Figure 3. Results of normalized results considering equal weighting and EF weighting and equal weighting of impact categories for the BoP household goods, EU normalization.



Resource depletion is highly relevant for almost all product groups (above 40% for sanitary products, furniture and paper products). The same applies to water depletion, even if with a slightly lower level of contribution. Each product group has a different distribution of the remaining impact categories in terms of relevance. Human toxicity, cancer effect is the most relevant one for personal care products, bed mattresses, and footwear (for which it contributes to more than 70% of the overall impact of the product groups). When global normalisation factors are applied, human toxicity, cancer effects becomes the most relevant impact category for almost all the product groups in the basket. On the contrary, resource depletion is less relevant than before for almost all the product groups. This is due to the fact that EU normalization factors consider only the resources extracted in EU. Therefore, global factors are more representative of the impact on resources.

As a sensitivity analysis, the BoP household goods has been analysed with the impact assessment method developed in the context of the transition phase of the Environmental Footprint (EC - JRC, 2018) (called here "EF 3.0"), where some impact categories considered in ILCD were updated with recent impact assessment models and factors[16]. Table 15 presents the updated list of impact assessment models used in the EF 3.0 method, with differences with ILCD highlighted in green. Results of characterization and normalization with the EF 3.0 method are presented in Table 16 for the whole BoP household goods baseline and in Table 17 for an average EU citizen. Global normalization factors for the EF 3.0 method have been used (updated from Crenna et al., 2019, Annex 3).

Table 15. Impact categories, models and units of EF 3.0 impact assessment method. Differences with ILCD (EC-JRC, 2011) are highlighted in green.

Impact category	**Reference model**	**Unit**
Climate change	IPCC, 2013	kg CO_2 eq
Ozone depletion	World Meteorological Organisation (WMO), 1999	kg CFC-11 eq
Human toxicity, non-cancer	based on USEtox2.1 model (Fantke et al., 2017), adapted as in Saouter et al. (2018)	CTUh
Human toxicity, cancer	based on USEtox2.1 model (Fantke et al., 2017), adapted as in Saouter et al. (2018)	CTUh
Particulate matter	Fantke et al., 2016	Disease incidence
Ionising radiation, human health	Frischknecht et al., 2000	kBq U^{235} eq
Photochemical ozone formation, human health	Van Zelm et al., 2008, as applied in ReCiPe, 2008	kg NMVOC eq
Acidification	Posch et al., 2008	molc H^+ eq
Eutrophication, terrestrial	Posch et al., 2008	molc N eq
Eutrophication, freshwater	Struijs et al., 2009[17]	kg P eq
Eutrophication, marine	Struijs et al., 2009	kg N eq
Ecotoxicity, freshwater	based on USEtox2.1 model (Fantke et al., 2017), adapted as in Saouter et al. (2018)	CTUe
Land use	Soil quality index based on an updated LANCA model (De Laurentiis et al., 2019) and on the LANCA CF version 2.5 (Horn and Meier, 2018)	Pt
Water use	AWARE 100 (based on; UNEP, 2016)	m^3 water eq
Resource use, fossils	Abiotic Depletion Potential (ADP) fossils (van Oers et al., 2002)	MJ
Resource use, minerals and metals	Abiotic ultimate reserve (van Oers et al., 2002)	kg Sb eq

[16] Main results of this report employ the original impact assessment method (ILCD) to be aligned with the method adopted in the individual reports, namely the other four basket of products. However, this sensitivity assessment displays as well the methodological advancements in the Environmental Footprint, with the newest method.

[17] CF for emissions of P to soil changed from 1 to 0.05 kg P_{eq}/kg

When the EF 3.0 method is applied, the impact on freshwater ecotoxicity is the most relevant after normalization and equal weighting of impact categories (Table 16). This result differs from the ILCD results with global normalization (Table 15) due to a different approach in the toxicity impact assessment between ILCD and EF 3.0 (Saouter et al., 2018). Ionising radiation is the second most relevant impact category due to the relevance of EU in nuclear energy at the global level (Crenna et al., 2019). When fossil resources are considered separately from mineral and metal ones (as it is in the EF 3.0 method), it is evident that the main contribution to resource depletion comes from the use of fossil resources. The impact on water resources (5.7%) is higher than the one obtained with ILCD when using global normalization references (0%), but lower than the one obtained with ILCD using EU-27 references. The relevance of the categories are equal at the EU citizen level (Table 17). When comparing ILCD and EF weighting approaches, climate change and fossils resource use gain relevance, in detriment of freshwater ecotoxicity.

Table 16. Characterized and normalized results for the whole BoP household goods baseline (impacts of consumption of household goods in EU in 2010) with EF 3.0 method, applied to the system S+R. Global normalization and equal and EF weighting.

Impact category	Unit	Characterization	Normalization	Relevance (%)	
				Equal WFs	EF WFs
Climate change	kg CO_2 eq	7.48E+11	1.34E-02	7.1	26.2
Ozone depletion	kg CFC-11 eq	5.97E+04	1.61E-04	0.1	0.1
Human toxicity, non-cancer	CTUh	1.02E+04	6.42E-03	3.4	1.1
Human toxicity, cancer	CTUh	5.85E+02	5.02E-03	2.7	1.0
Particulate matter	Disease incidence	3.90E+04	9.51E-03	*5.0*	7.9
Ionising radiation, human health	kBq U^{235} eq	4.47E+10	1.53E-03	0.8	0.7
Photochemical ozone formation, human health	kg NMVOC eq	2.13E+09	7.59E-03	4.0	3.4
Acidification	molc H^+ eq	4.10E+09	1.07E-02	5.7	6.2
Eutrophication, terrestrial	molc N eq	8.17E+09	6.70E-03	3.6	2.3
Eutrophication, freshwater	kg P eq	5.55E+07	5.01E-03	2.7	1.3
Eutrophication, marine	kg N eq	1.14E+09	8.48E-03	4.5	2.3
Ecotoxicity, freshwater	CTUe	1.99E+13	6.76E-02	35.9	12.0
Land use	Pt	1.31E+13	1.82E-03	1.0	1.3
Water use	m^3 water eq	1.06E+12	1.34E-02	7.1	10.6
Resource use, fossils	MJ	1.10E+13	2.45E-02	13.0	18.9
Resource use, minerals and metals	kg Sb eq	2.91E+06	6.63E-03	3.5	4.6
Total (single weighted)	Pt	-	-	1.18E-02	1.08E+00

Table 17. Characterized and normalized results for the F.U. of the BoP household goods baseline (impacts of consumption by an average EU citizen in 2010) with EF 3.0 method, applied to the system S+R. Global normalization and equal weighting.

Impact category	Unit	Characterization	Normalization	Relevance (%)	
				Equal WFs	EF WFs
Climate change	kg CO_2 eq	1.49E+03	2.67E-11	7.1	26.2
Ozone depletion	kg CFC-11 eq	1.19E-04	3.22E-13	0.1	0.1
Human toxicity, non-cancer	CTUh	2.02E-05	1.28E-11	3.4	1.1
Human toxicity, cancer	CTUh	1.17E-06	1.00E-11	2.7	1.0
Particulate matter	Disease incidence	7.77E-05	1.89E-11	*5.0*	7.9
Ionising radiation, human health	kBq U^{235} eq	8.89E+01	3.05E-12	0.8	0.7
Photochemical ozone formation, human health	kg NMVOC eq	4.23E+00	1.51E-11	4.0	3.4
Acidification	molc H^+ eq	8.16E+00	2.13E-11	5.7	6.2
Eutrophication, terrestrial	molc N eq	1.63E+01	1.34E-11	3.6	2.3
Eutrophication, freshwater	kg P eq	1.10E-01	9.93E-12	2.7	1.3
Eutrophication, marine	kg N eq	2.27E+00	1.68E-11	4.5	2.3
Ecotoxicity, freshwater	CTUe	3.96E+04	1.35E-10	35.9	12.0
Land use	Pt	2.61E+04	3.63E-12	1.0	1.3
Water use	m^3 water eq	2.11E+03	2.68E-11	7.1	10.6
Resource use, fossils	MJ	2.19E+04	4.89E-11	13.0	18.9
Resource use, minerals and metals	kg Sb eq	5.79E-03	1.32E-11	3.5	4.6
Total (single weighted)	Pt	-	-	2.35E-11	2.15E-09

4.1 Contribution by life cycle stages

Details on the contribution of life cycle stages to each impact category are provided in Table 18 (system S+R), Figure 4 (system S+R), and Figure 5 (only System S).

Table 18. Contribution of different life cycle stages to the impact categories (based on the characterized inventory results of System S+R before normalization and weighting).

Climate change		**Human toxicity, non-cancer effects**		**Particulate matter**	
Life cycle stage	*Contrib. (%)*	*Life cycle stage*	*Contrib. (%)*	*Life cycle stage*	*Contrib. (%)*
Components manufacture	34.1	Components manufacture	41.3	Components manufacture	45.7
Production	23.4	End of life	25.2	Production	34.5
Use	22.6	Use	15.7	Use	14.3
Packaging	10.2	Production	9.6	Logistics	3.3
End of life	5.6	Logistics	5.3	End of life	2.6
Logistics	4.2	Packaging	2.9	Packaging	-0.3
Ozone depletion		**Human toxicity, cancer effects**		**Ionizing radiation HH**	
Life cycle stage	*Contrib. (%)*	*Life cycle stage*	*Contrib. (%)*	*Life cycle stage*	*Contrib. (%)*
Components manufacture	45.3	Components manufacture	71.2	Use	41.4
Use	37.1	End of life	12.9	Components manufacture	33.2
Logistics	9.5	Use	9.9	Production	19.4
Production	6.6	Production	4.3	Logistics	4.4
Packaging	1.2	Logistics	0.8	Packaging	1.7
End of life	0.3	Packaging	0.8	End of life	-0.1
Photochemical ozone formation		**Acidification**		**Terrestrial eutrophication**	
Life cycle stage	*Contrib. (%)*	*Life cycle stage*	*Contrib. (%)*	*Life cycle stage*	*Contrib. (%)*
Components manufacture	40.9	Components manufacture	44.9	Components manufacture	49.7
Production	22.4	Production	24.6	Production	19.2
Use	21.9	Use	20.8	Use	18.3
Logistics	8.9	Logistics	5.3	Logistics	8.2
End of life	3.3	End of life	2.9	End of life	3.0
Packaging	2.5	Packaging	1.5	Packaging	1.6
Freshwater eutrophication		**Marine eutrophication**		**Freshwater ecotoxicity**	
Life cycle stage	*Contrib. (%)*	*Life cycle stage*	*Contrib. (%)*	*Life cycle stage*	*Contrib. (%)*
Components manufacture	35.3	Components manufacture	37.1	Components manufacture	54.6
Use	24.2	End of life	28.3	Use	14.5
End of life	21.9	Production	13.1	Logistics	10.6
Production	17.0	Use	11.9	End of life	9.3
Packaging	0.9	Logistics	5.3	Production	5.6
Logistics	0.7	Packaging	4.3	Packaging	5.3
Land use		**Water resource depletion**		**Resource depletion**	
Life cycle stage	*Contrib. (%)*	*Life cycle stage*	*Contrib. (%)*	*Life cycle stage*	*Contrib. (%)*
Components manufacture	78.1	Components manufacture	37.5	Components manufacture	56.4
Use	12.6	Use	29.2	Use	22.6
Production	6.6	Production	20.2	End of life	7.4
Logistics	4.9	End of life	11.8	Packaging	6.7
Packaging	0.4	Packaging	0.8	Production	4.9
End of life	-2.6	Logistics	0.5	Logistics	2.0

The life cycle stages in orange are the ones identified as "most relevant" for the impact category, as they are contributing to more than 80%.

The role of the different life cycle stages in the overall environmental impacts depends on the impact category. Considering the main contributing life cycle stages by impact category, components manufacture, production and use were the most relevant. For some impact categories, end of life and logistics contributed to some extent.

Components' manufacture (ingredients, raw materials or intermediate products) is the most impacting stage for most of the impact categories, apart from ionizing radiation. There are several reasons behind this contribution. In some cases, the largest impact is generated in the very first stage of the life cycle of the materials used. This is the case, for instance, of natural-based raw materials, such as cotton, rape oil, and wood (used, respectively, for textiles, soaps, and furniture and paper products). The agricultural phase of these components is the main contributor to some impact categories, such as land use, ecotoxicity and water use. In other cases, the impact comes from the processes needed to transform raw materials into ingredients or intermediates of the final products, which imply the use of chemical additives and energy. The production of pulp (used in absorbent hygiene products and in paper products) generates emissions to water and air that have a significant contribution to the environmental profile of the final products. The same applies to the tanning process needed to transform skins and hides into leather (to be used, e.g., in footwear), which, due to the use and emissions of chromium, generates impacts on human toxicity.

The impact of the **production** stage is generally due to the use of electricity and to the emissions to water and air. One of the production processes that is more relevant in the production stage is the production of clothes, due to the large amount of electricity needed to transform the fibres into yarn, then into textile and finally into clothes. Moreover, it has to be considered that the largest part of the production of clothes happens outside the EU, in countries that have an electricity mix that is more impacting than the EU one (e.g. China or India, where the contribution of coal to the national electricity mix is quite high).

Regarding the **use** stage, the most contributing activity is the heating of the water needed for cleaning (i.e. in the use stage of detergents), also because for many products the use stage does not imply any impact, except for the transport from the site of purchase to the home of the client.

Logistics (i.e. transport from the production site to the retail) has a lower contribution compared to the first stages of the life cycle of household goods. The same is for **packaging**, which has a contribution lower than 10% to all the impact categories considered, also due to the recycling of packaging at the end of life.

Finally, if the benefits from recycling are included (system S+R) (Figure 4), the **end of life** of some product groups helps to mitigate the impacts coming from the rest of the life cycle, thanks to the benefits coming from the recycling of products at their end of life. Within the baseline scenario of the BoP household goods, recycling is assumed to be in place only for some of the product groups (clothes and paper products), to reflect the actual situation, in which recycling is mainly applied to packaging materials. When considering the system S+R, the EoL phase generates a benefit on land use, because of the recycling of paper (especially newspapers) at the EoL, and the avoided use of virgin wood from forests. However, this benefit is offset by the impact coming from other phases, so there is no benefit for the whole BoP. In general, the difference between the impact of the BoP when considering system S+R or system S (Figure 5) alone is generally small (Table 11 and Table 13).

Figure 4. Contribution of different life cycle stages to the impact categories (based on the characterized inventory results before normalization and weighting) (System S+R).

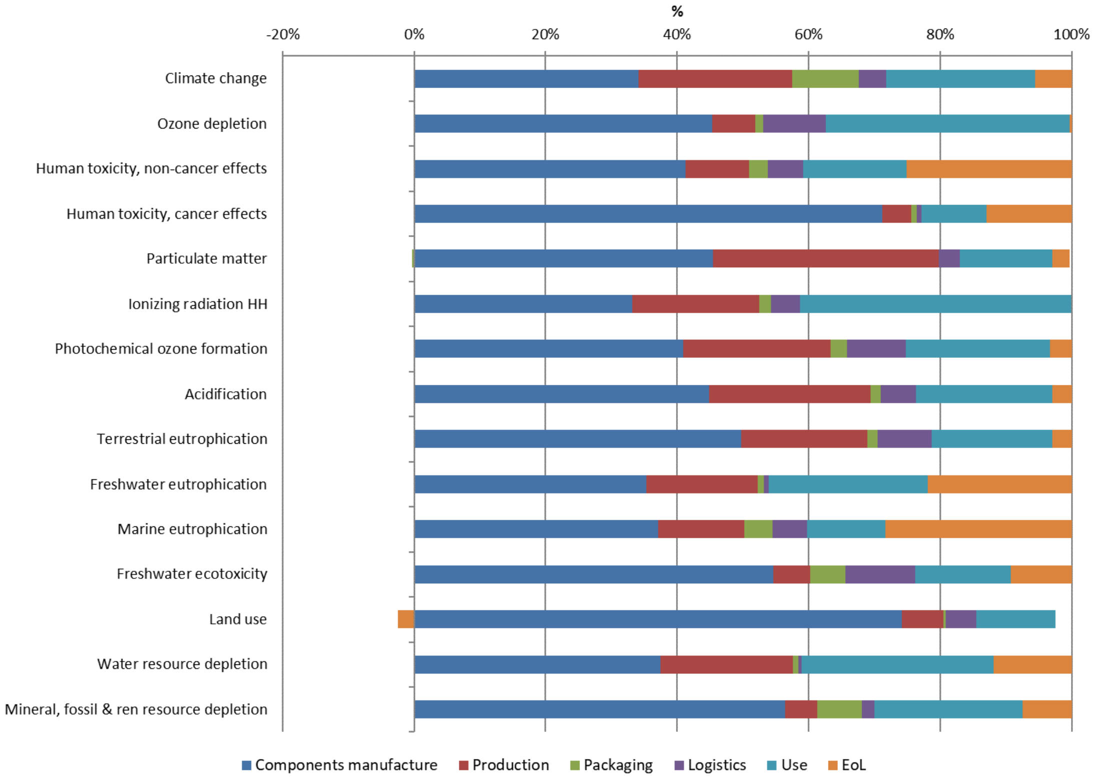
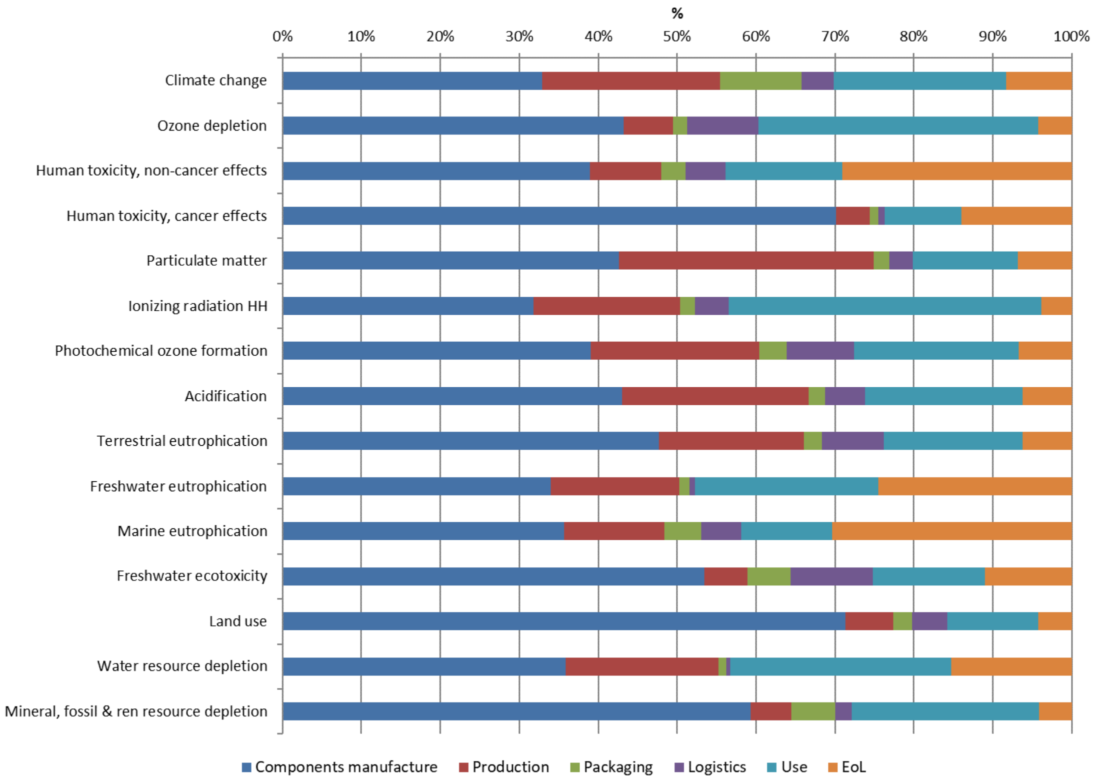


Figure 5. Contribution of different life cycle stages to the impact categories (based on the characterized inventory results before normalization and weighting) (System S).



4.2 Most relevant elementary flows

Table 19 reports the most relevant elementary flows for each impact category. Within each impact category, for the flow that contributes the most, the main process from which it originates is specified (marked with *). The inventory networks of the most important flow(s) are reported in Annex 4.

Table 19. Contribution of elementary flows to each impact category of the ILCD method.

Climate change		**Human toxicity, non-cancer effects**		**Particulate matter**	
Elementary flow	*%*	*Elementary flow*	*%*	*Elementary flow*	*%*
Carbon dioxide, fossil*	83.6	Zinc to soil*	32.2	Particulates ≤ 2.5*	74.9
Methane, biogenic	6.7	Zinc to air	23.1	sulphur dioxide	21.6
Methane, fossil	6.6	Mercury to air	20.9		
		Lead to air	5.3		
*Electricity mix EU (used for water heating)		*Tyre wear emissions (lorry)		*Electricity mix, IN	
Ozone depletion		**Human toxicity, cancer effects**		**Ionizing radiation HH**	
Elementary flow	*%*	*Elementary flow*	*%*	*Elementary flow*	*%*
Methane, bromotrifluoro-, Halon 1301*	52.7	Chromium to water*	54.3	Carbon-14 to air*	94.4
Ethane, 1,2-dichloro-1,1,2,2-tetrafluoro-, CFC-114	23.1	Chromium VI to water	30.8		
Methane, bromochlorodifluoro-, Halon 1211	15.2	Chromium to air	7.1		
Methane, tetrachloro-, CFC-10	7.1				
Methane, dichlorodifluoro-, CFC-12	2.2				
*Petroleum production (onshore)[18]		*Chrome-tanned finished leather		*Spent nuclear fuel (FR electricity mix)	
Photochemical ozone formation		**Acidification**		**Terrestrial eutrophication**	
Elementary flow	*%*	*Elementary flow*	*%*	*Elementary flow*	*%*
Nitrogen oxides*	73.8	Sulphur dioxide*	63.4	Nitrogen oxides to air*	79.9
NMVOCs	12.9	Nitrogen oxides	27.7	Ammonia to air	20.0
Sulphur dioxide	7.8	Ammonia	8.9		
*Electricity, low voltage, CN		*Electricity, medium voltage, EUR without CH		*Electricity, low voltage, CN	
Freshwater eutrophication		**Marine eutrophication**		**Resource depletion**	
Elementary flow	*(%)*	*Elementary flow*	*(%)*	*Elementary flow*	*(%)*
Phosphate to water*	91.0	Nitrogen oxides to air*	52.1	Indium*	75.2
Phosphorus to water	5.6	Nitrate to water	29.0	Cadmium	9.0
		Ammonium to water	14.6	Nickel	3.1
				Tantalum	2.2
				Lead	2.0
				Silver	1.7
				Zirconium	1.3
*Wastewater, from residence		*Electricity, low voltage, CN		*Zinc-lead extraction	

[18] Halon emissions in the petroleum production datasets are related to the equipment for fire extinguishing. In the European Union, the use of Halon 1301 has been forbidden for any new oil, gas and petrochemicals facilities since 2010, and by 2020, all fire extinguishing systems using Halon must have been replaced. However, this is not always the case for petroleum production plants in the rest of the world.

Table 19 (cont.). Contribution of elementary flows to each impact category of the ILCD method.

Land occupation		**Water resource depletion**		**Freshwater ecotoxicity**	
Elementary flow	*%*	*Elementary flow*	*%*	*Elementary flow*	*%*
Occupation, forest, intensive*	39.8	Water, cooling, DE*	11.1	Chromium to water*	14.9
Occupation, arable	34.5	Water, cooling, SA	10.0	Antimony to air	11.8
Occupation, arable, non-irrigated, intensive	4.5	Water, cooling, PL	8.3	Chlorpyrifos to soil	10.0
Occupation, traffic area, road network	4.4	Water, river, RoW	8.1	Antimony to water	9.7
Occupation, traffic area, rail/road embankment	3.5	Water, cooling, CN	5.8	Chromium VI to water	8.4
*Wood (for pulp making)		Water, cooling, FR	4.7	Zinc to water	4.7
Land transformation		Water, cooling, ES	4.6	Vanadium to air	4.6
Elementary flow	*%*	Water, cooling, IN	4.1	Zinc to soil	3.2
From forest to mineral extraction site*	32.2	Water, river, Europe	3.9	Copper to air	3.0
From pasture and meadow to industrial area	8.7	Water, well, RoW	3.7	Diflubenzuron to soil	2.8
From pasture and meadow, intensive to arable, non-irrigated, intensive	6.2	Water, cooling, UA	3.3	Zinc to air	2.4
From forest, extensive to traffic area, rail/road embankment	3.7			Profenofos to soil	2.4
*Onshore well, oil/gas production		*Electricity mix, DE		*Transport, passenger car, Europe	

As for other areas of consumption (e.g. household appliances) (Reale et al., 2019), electricity production plays a relevant role for many impact categories (either due to the use of electricity in the production or in the use of products) (e.g. particulate matter, land transformation). Transport contributes to climate change, mainly because of passenger transport (i.e. the customer transport). Freshwater ecotoxicity, human toxicity, cancer effects, and land occupation are driven by pulp production (Table 19).

When comparing the flow contribution with the ILCD and EF 3.0 methods, some differences are unveiled (Table 20). The inclusion of cooling as a contributor to water depletion is debated and represents one of the main differences between the model recommended in the ILCD method (Frischknecht, 2009) and the model included in the EF 3.0 (Boulay et al., 2016). When assessing the BoP with ILCD, the impact of cooling is excluded (not consistently with the original method) and the most contributing elementary flow is "Net water use in Europe without Switzerland".

Table 20. Most relevant elementary flows for resource depletion, water scarcity, land use and particulate matter, when applying EF 3.0 method.

Resource depletion, minerals and metals

Elementary flow	*Contr. (%)*
Cadmium*	32.4
Lead	21.8
Gold	13.9
Silver	8.7
Copper	7.7
Chromium	4.3
Zinc	3.5
*Zinc-lead mining	

Resource depletion, energy carriers

Elementary flow	*Contr. (%)*
Coal, hard*	29.6
Oil, crude	22.5
Natural gas	21.2
Uranium	16.6
Coal, brown	8.9
Gas, mine	0.5
Peat	0.2
*Hard coal mining, CN	

Climate change

Elementary flow	*Contr. (%)*
Carbon dioxide, fossil*	78.3
Methane, biogenic	9.6
Methane, fossil	9.0
Dinitrogen monoxide	1.4
Carbon dioxide, land transformation	0.8
*Transport, passenger car	

Water scarcity (country)

Elementary flow	*Contr. (%)*
Net water use in Europe without Switzerland*	61.1
Net water use, unspecified region	19.6
Net water use in CN	10.9
Net water use in US	7.2
*Tap water in the use of shampoo, soap, and laundry liquid detergents	

Land occupation

Elementary flow	*Contr. (%)*
Occupation, forest, intensive*	62.5
Occupation, arable	16.5
Occupation, traffic area, road network	4.4
Occupation, traffic area, rail/road embankment	3.3
*Wood (for pulp making)	

Land transformation

Elementary flow	*Contr. (%)*
From forest to mineral extraction site*	31.9
From pasture and meadow, to industrial area	10.8
From forest, extensive, to traffic area, rail/road embankment	8.1
From forest, extensive, to forest, intensive	4.9
*Oil and gas onshore infrastructure	

Freshwater ecotoxicity

Elementary flow	*Contr. (%)*
Aluminium to soil*	53.1
Aluminium to air	15.7
Chloride to water	9.1
Aluminium to water	6.4
Aluminium (ion) to water	2.7
*Sludge from pulp production	

Human toxicity, cancer effects

Elementary flow	*Contr. (%)*
Formaldehyde to air*	24.5
Chromium to water	23.1
Benzo(a)pyrene to air	13.8
Chromium VI to water	11.7
Chromium to air	10.5
*Sludge from pulp production	

Human toxicity, non-cancer effects

Elementary flow	*Contr. (%)*
Mercury to air*	32.7
Carbon monoxide, fossil to air	11.5
Chlorine to water	9.0
Lead to air	8.1
Chlorine to air	5.1
*Cast iron production	

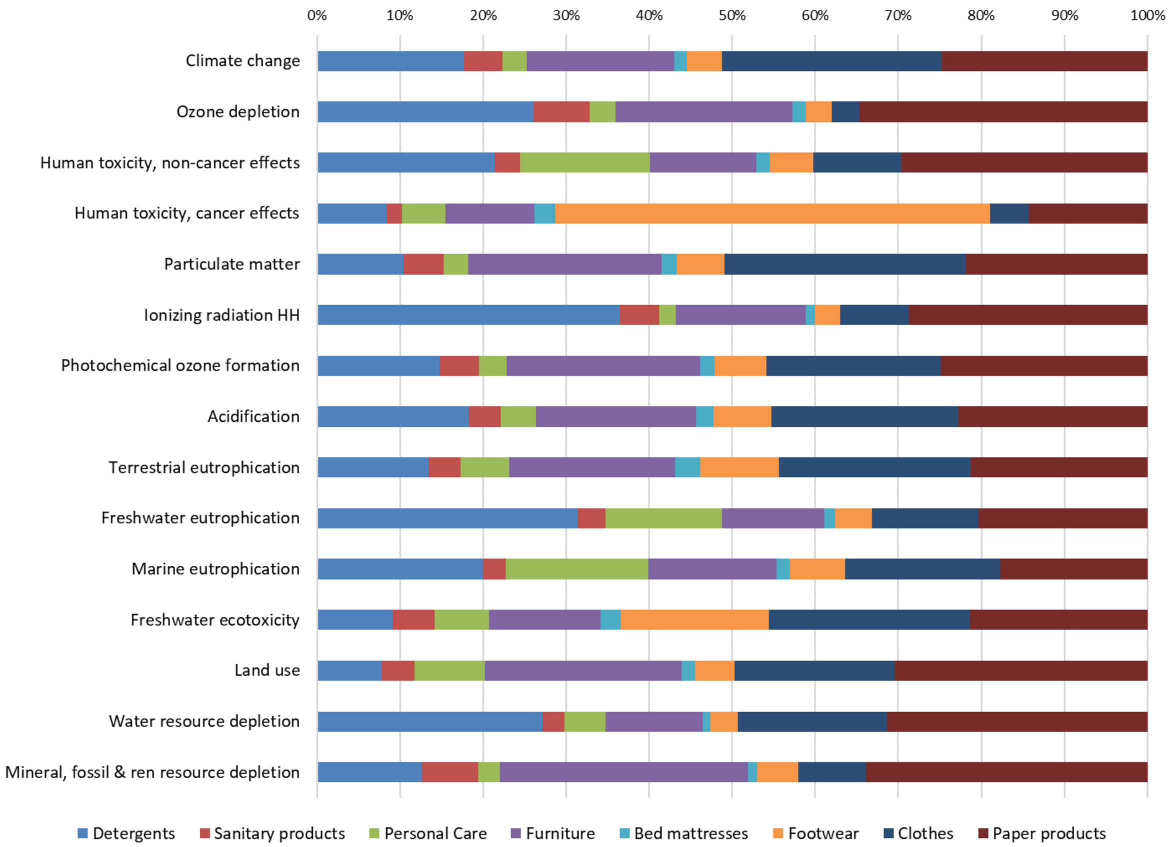
Particulate matter

Elementary flow	*Contr. (%)*
Particulates < 2.5*	74.8
Sulphur dioxide	15.7
Ammonia	6.2
Nitrogen oxides	3.3
*Electricity mix, IN	

4.3. Contribution by product groups

The larger contribution to the overall impacts generated by the BoP household goods per product groups is due to paper products, detergents, furniture and clothes, with different shares depending on the impact category considered (Figure 6 and Table 21). This contribution is partly due to inherent properties of the life cycle of the products considered and partly to the amount of each product in the BoP (Table 1). Similar results are obtained when analysing the S system, without considering the recycling (Figure 7).

Figure 6. Contribution by product groups at the characterization stage (System S+R).



As mentioned before, the main hotspots in the life cycle of **detergents** (especially dishwasher and laundry liquid detergents) are the eutrophication potential of some of the ingredients used, and the use of electricity to heat the water needed during the use stage (which generates the impact on ionising radiation and water resource depletion, due to the use of water for cooling the electricity generation plants).

Furniture products contribute the most to particulate matter, due to the use of coal in the production of the electricity used to produce the flame-retardants of the sofa. Their contribution is quite relevant also for ozone depletion, due to the emissions of Halon 1301 (as fire extinguisher), coming from the production of petroleum, as background process of the production of diesel fuel, used in freight transport.

As already discussed, an important hotspot for the **clothes** (as apparel items) is the use of electricity during the phases that transform the raw fibres into textiles (spinning, yarning, texturizing, etc.). This generates impacts on climate change, particulate matter, acidification, and water resource depletion. The most contributing product in this group is the T-shirt, mainly because of the high quantity purchased by EU citizens in one year (also as effect of the upscale of apparent consumption for this product group).

Footwear is highly relevant for human toxicity, cancer effects, because of the emissions of chromium, which is used in the chrome-tanning process in the production of leather used in fashion shoes.

Paper products contribute quite significantly to most of the impact categories, both because of the high amount of paper products consumed in one year (especially as newspapers and toilet paper) and because of the impacts coming from the pulp production process and the printing of paper.

Personal care products (rinse-off cosmetics) do not appear to be significant in most of the impact categories considered. The only exceptions are the contribution to human toxicity (non-cancer effects), freshwater eutrophication, and marine eutrophication. This contribution comes mainly from the ingredients of the soaps and shampoos and from the wastewater treatment needed after the use of the products.

Finally, **sanitary products** do not contribute significantly to any of the impact categories, except for ozone depletion and resource depletion where contributions are more relevant. This is mainly due to the very low amount of products purchased by an average EU citizen in one year, compared to the other product groups.

Figure 7. Contribution by product groups at the characterization stage (System S).

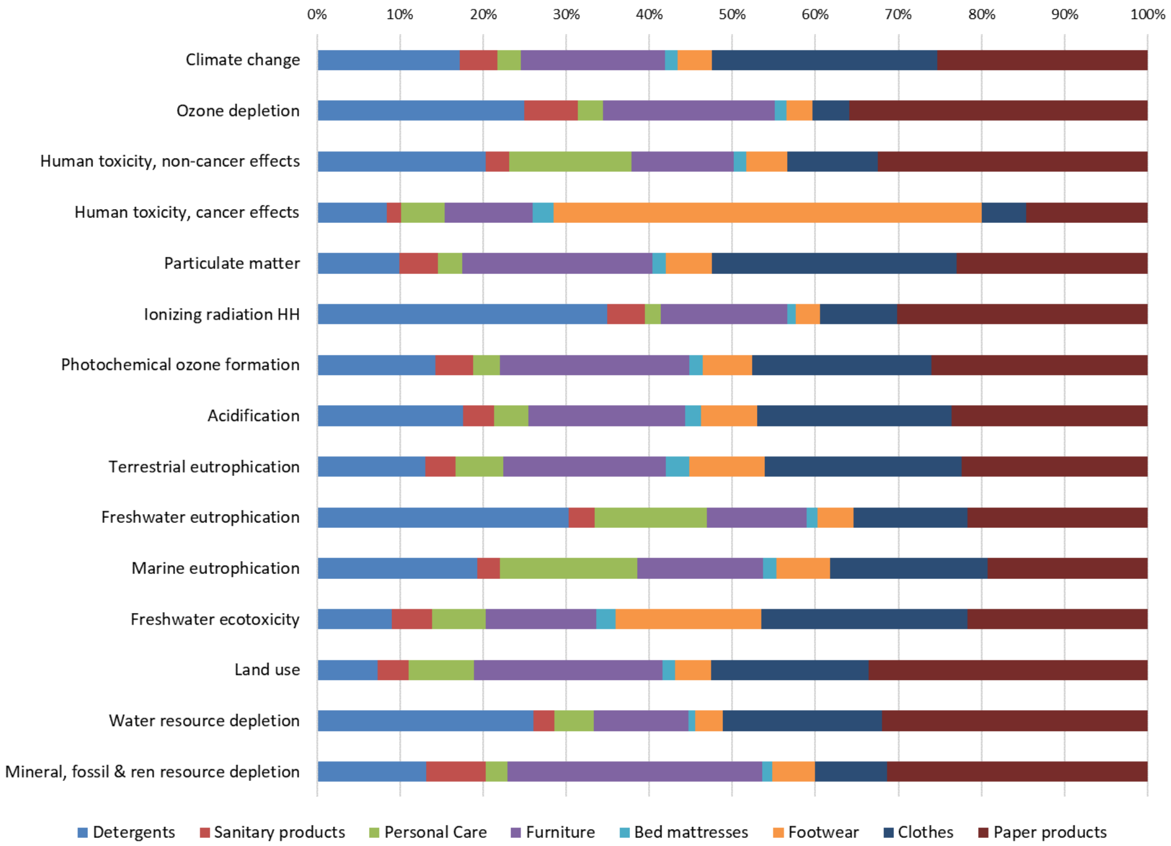


Table 21. Contribution of each representative product to the characterized results of the BoP household goods (system S+R). A colour scale is applied, from red (highest contributor) to green (lowest contributor), for each impact category.

Impact category	Detergents					Sanitary products				Personal care				Furniture	
	APC cleaner	Dishwasher detergent	Hand dishwashing detergent	Laundry liquid detergent	Laundry powder detergent	Baby diaper	Sanitary pad	Tampon	Breast pad	Bar soap	Liquid soap	Shampoo	Hair conditioner	Wardrobe	Kitchen
Climate change	4.2%	7.0%	0.7%	4.4%	1.4%	1.5%	2.6%	0.1%	0.5%	1.7%	0.4%	0.5%	0.3%	7.5%	3.4%
Ozone depletion	5.7%	10.0%	1.0%	7.2%	2.3%	1.6%	4.0%	0.1%	1.0%	1.6%	0.5%	0.6%	0.5%	9.3%	5.8%
Human toxicity, non-cancer effects	3.3%	6.0%	0.6%	8.7%	2.9%	0.8%	1.7%	0.1%	0.4%	7.9%	2.8%	3.2%	1.6%	5.0%	3.6%
Human toxicity, cancer effects	1.4%	2.6%	0.3%	3.0%	1.1%	0.5%	1.1%	0.0%	0.2%	2.9%	0.9%	1.0%	0.5%	4.0%	2.3%
Particulate matter	2.3%	3.9%	0.4%	2.8%	1.0%	1.6%	2.7%	0.1%	0.5%	1.9%	0.3%	0.4%	0.3%	9.5%	4.4%
Ionizing radiation HH	8.4%	15.3%	1.5%	8.2%	3.1%	1.6%	2.5%	0.1%	0.5%	1.1%	0.3%	0.4%	0.2%	5.8%	4.0%
Photochemical ozone formation	3.4%	5.3%	0.7%	3.9%	1.4%	1.4%	2.7%	0.1%	0.6%	2.0%	0.4%	0.6%	0.3%	10.7%	4.3%
Acidification	4.1%	7.2%	0.8%	4.7%	1.6%	1.3%	2.1%	0.1%	0.4%	2.9%	0.4%	0.5%	0.3%	7.7%	3.7%
Terrestrial eutrophication	2.9%	5.0%	0.6%	3.7%	1.3%	1.1%	2.1%	0.1%	0.4%	4.6%	0.4%	0.5%	0.3%	8.4%	3.7%
Freshwater eutrophication	6.0%	11.1%	0.9%	10.4%	3.1%	1.2%	1.7%	0.1%	0.3%	7.1%	2.6%	2.9%	1.5%	4.2%	2.8%
Marine eutrophication	3.1%	5.5%	0.4%	8.4%	2.6%	0.9%	1.5%	0.1%	0.3%	9.5%	2.8%	3.2%	1.6%	6.9%	2.7%
Freshwater ecotoxicity	1.7%	2.6%	0.3%	3.4%	1.1%	0.9%	3.1%	0.2%	0.8%	4.1%	0.9%	1.1%	0.6%	5.8%	2.1%
Land use	1.5%	2.6%	0.3%	2.7%	0.7%	0.9%	2.4%	0.1%	0.5%	7.5%	0.3%	0.4%	0.2%	8.0%	6.4%
Water resource depletion	6.0%	10.9%	1.3%	6.9%	2.0%	1.1%	1.3%	0.1%	0.2%	2.7%	0.8%	1.0%	0.5%	3.1%	2.5%
Mineral, fossil & ren resource depletion	2.1%	3.7%	0.4%	2.5%	3.9%	1.1%	4.4%	0.2%	1.1%	1.8%	0.3%	0.4%	0.2%	5.0%	22.2%

Impact category	Furniture			Bed mattress	Footwear				Clothes				Paper products		
	Sofa	Wooden seat	Wooden table	Bed mattress	WW shoes	Sport shoes	Leisure shoes	Fashion shoes	T-shirt	Blouse	Trousers	Jeans	Newspaper	Book	Toilet paper
Climate change	3.9%	1.9%	1.1%	1.5%	0.7%	0.5%	1.6%	1.4%	10.2%	10.5%	1.6%	4.1%	14.3%	2.9%	7.6%
Ozone depletion	3.7%	1.3%	1.2%	1.5%	0.5%	0.3%	1.2%	1.2%	0.7%	1.2%	0.4%	0.9%	22.0%	4.2%	8.5%
Human toxicity, non-cancer effects	2.6%	0.8%	0.7%	1.7%	1.6%	0.2%	0.8%	2.6%	5.3%	2.4%	0.7%	2.2%	14.1%	2.3%	13.3%
Human toxicity, cancer effects	3.2%	0.6%	0.6%	2.5%	19.4%	0.1%	0.4%	32.4%	2.4%	0.7%	0.3%	1.2%	4.3%	0.7%	9.4%
Particulate matter	5.1%	2.9%	1.5%	1.8%	0.9%	0.8%	2.3%	1.7%	16.0%	3.6%	2.2%	7.2%	10.4%	1.9%	9.6%
Ionizing radiation HH	3.2%	1.4%	1.4%	1.0%	0.4%	0.3%	0.9%	1.5%	5.1%	1.2%	0.6%	1.4%	18.0%	3.9%	6.8%
Photochemical ozone formation	4.8%	2.1%	1.4%	1.8%	0.9%	0.7%	2.5%	2.2%	11.4%	3.4%	1.7%	4.5%	13.5%	2.7%	8.6%
Acidification	4.6%	2.1%	1.3%	2.0%	1.5%	0.5%	2.0%	2.9%	12.4%	3.0%	1.7%	5.4%	12.5%	2.6%	7.7%
Terrestrial eutrophication	4.7%	1.9%	1.2%	3.0%	2.5%	0.5%	2.0%	4.5%	13.4%	2.6%	1.4%	5.8%	11.5%	2.4%	7.4%
Freshwater eutrophication	3.4%	1.1%	0.8%	1.3%	1.2%	0.3%	1.2%	1.7%	7.3%	1.4%	0.8%	3.3%	11.8%	2.4%	6.2%
Marine eutrophication	3.6%	1.3%	0.9%	1.6%	1.8%	0.4%	1.4%	3.1%	8.8%	5.0%	1.0%	3.9%	10.2%	2.1%	5.5%
Freshwater ecotoxicity	3.9%	0.8%	0.8%	2.4%	5.8%	0.2%	1.7%	10.2%	12.4%	4.6%	0.5%	6.7%	12.8%	2.2%	6.4%
Land use	3.8%	2.6%	2.9%	1.6%	1.1%	0.1%	1.4%	2.0%	11.7%	1.1%	0.3%	6.1%	16.5%	2.6%	11.4%
Water resource depletion	3.9%	1.2%	0.9%	0.9%	0.4%	0.3%	1.6%	1.1%	10.3%	1.4%	0.8%	5.4%	11.1%	2.5%	17.7%
Mineral, fossil & ren resource depletion	1.3%	0.6%	0.6%	1.2%	0.4%	0.2%	0.9%	3.4%	4.3%	1.2%	0.8%	1.8%	22.6%	3.4%	7.9%

4.4. Trends: consumption and environmental impacts between 2010 and 2015

The aim of this section is to update the baseline to the closest year for which data are available in order to have an updated overview of the impacts coming from the consumption of household goods in EU households. The consumption of each representative product in the BoP has been updated to the selected year (2015).

Table 22 details the consumption of each representative product per EU citizen in 2015. Consistently, the number of EU citizens has been updated. The amount consumed per person is reported considering that the number of citizens grew from 502,489,100 to 508,401,408, according to Eurostat. Technologies are assumed to be the same of the baseline 2010.

Between 2010 and 2015, the consumption per average EU citizen increased for most of the representative products, apart from most of the personal care products (rinse-off cosmetics: bar soap, shampoo, and hair conditioner), most of the furniture (with the exception of dining room furniture), most of the footwear (with the exception of sport footwear), and newspaper. Liquid soap was the product with the highest increase in consumption (+130%). Contrarily, the consumption of hair conditioner showed the largest reduction (-39%).

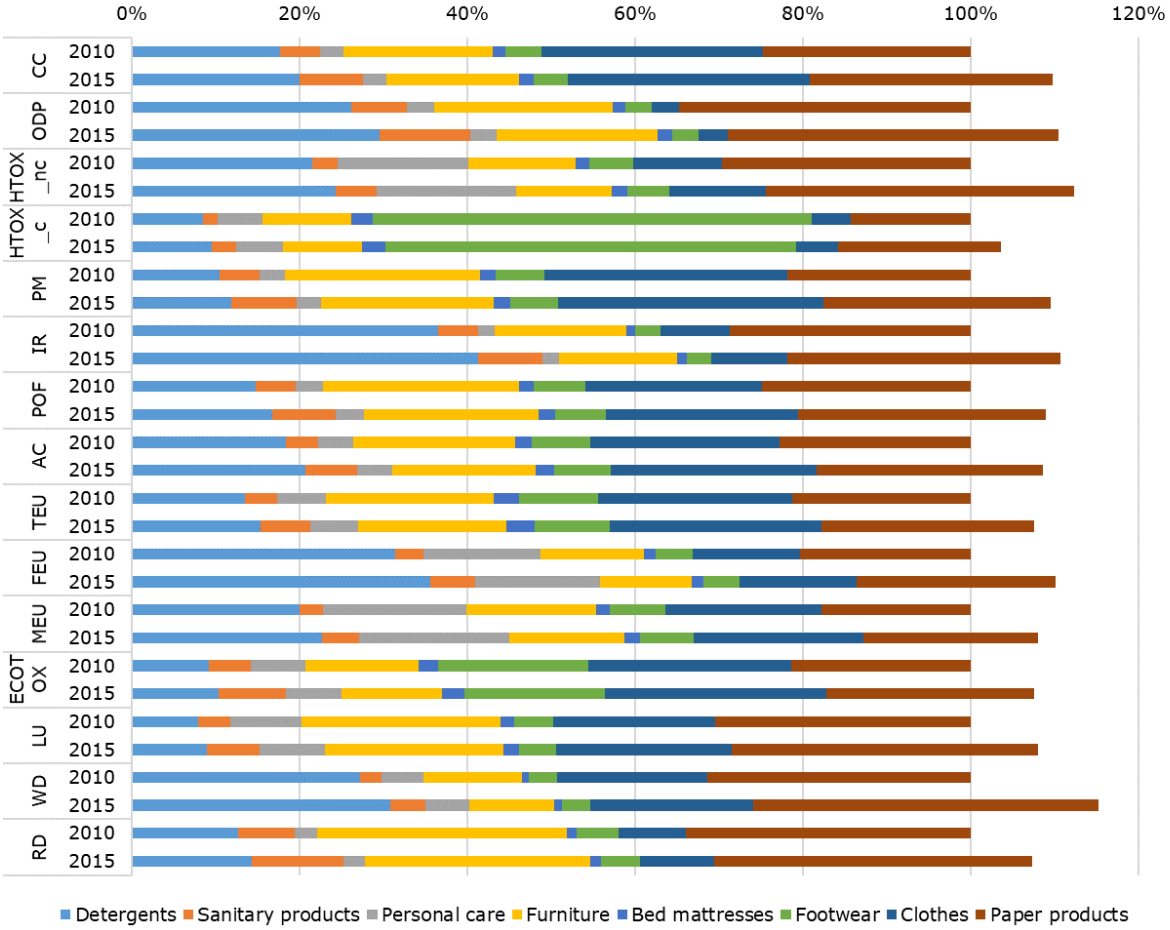
In terms of environmental impacts, Figure 8 shows the evolution of the impact related to household goods consumption between 2010 and 2015. The largest increases are observed for the impact categories water resource depletion (+15.2%) and human toxicity, non-cancer (12.3%). The increase in ionizing radiation (+10.7%), ozone depletion (10.4%), and freshwater eutrophication (+10.1%) slightly surpasses the 10%. The rest of the categories show an increase under 10%, being human toxicity, cancer, the one with the lowest variation (+3.6%).

In general, the environmental impacts related to the household goods consumed by EU citizens show an increasing trend between 2010 and 2015, mainly related to an increased consumption per capita of most of the representative products included in the BoP household goods (Table 22). These results are in line with an increased impact of the overall household consumption (including also food, mobility, housing, and appliances) (Sala et al., 2019).

Table 22. Composition of the BoP household goods in terms of product groups, representative products, upscaled consumption of an average EU-27 citizen in years 2010 and 2015, and variation between the two assessed years (Source: Eurostat, 2015).

Product group	Representative product	Per capita apparent consumption upscaled (unit/ citizen*year^{-1})		Unit	Variation
		2010	2015		(%)
Detergents	All-Purpose Cleaners and Sanitary Cleaners (500mL)	9.99	11.32	kg	+13
	Detergents for Dishwashers (tablet)	2.43	2.75	kg	+13
	Hand Dishwashing Detergents (650mL)	1.75	1.98	kg	+13
	Laundry Detergents liquid (650mL)	10.03	11.36	kg	+13
	Laundry Detergents powder (dose)	3.10	3.51	kg	+13
Sanitary products (absorbent hygiene products)	Baby diapers	4.05	5.24	kg	+29
	Sanitary pads	4.05	6.44	kg	+59
	Tampons	0.09	0.14	kg	+56
	Breast pads	0.56	0.91	kg	+63
Personal care (rinse-off cosmetics)	Bar soap	4.59	4.06	kg	-12
	Liquid soap (255mL)	1.82	4.18	kg	+130
	Shampoo (255mL)	3.13	2.04	kg	-35
	Hair conditioner (255mL)	2.07	1.26	kg	-39
Furniture	Bedroom wooden furniture	0.199	0.19	p	-5
	Kitchen furniture	0.301	0.27	p	-10
	Upholstered seat	0.188	0.15	p	-20
	Non-Upholstered seat (wooden seat)	0.271	0.18	p	-34
	Dining room furniture (wooden table)	0.165	0.18	p	+9
Bed mattresses	Mattress (Latex, PUR and spring mattresses)	0.090	0.10	p	+11
Footwear	Work and Waterproof (WW)	0.48	0.45	pa	-6
	Sport	0.61	0.82	pa	+34
	Leisure	2.29	2.13	pa	-7
	Fashion	2.29	2.13	pa	-7
Clothes (textile products)	T-shirt	31.80	34.7	p	+9
	Women blouse	8.55	9.32	p	+9
	Men trousers	3.74	4.08	p	+9
	Jeans	4.79	5.22	p	+9
Paper products	Newspaper	90.50	85.05	kg	-6
	Book	19.26	25.07	kg	+30
	Toilet paper	23.55	36.39	kg	+55

Figure 8. Contribution by product groups at the characterization stage (System S+R) for 2010 and 2015. Values for 2010 are set as 100%.



The following acronyms are employed for the impact categories: Climate change (CC), Ozone depletion (OD), (Human toxicity, non-cancer effects (HTOX_nc), Human toxicity, cancer effects (HTOX_c), Particulate matter (PM), Ionizing radiation (IR), Photochemical ozone formation (POF), Acidification (AC), Terrestrial eutrophication (TEU), Freshwater eutrophication (FEU), Marine eutrophication (MEU), Freshwater ecotoxicity (ECOTOX), Land use (LU), Water resource depletion (WD), Mineral, fossil & renewable resource depletion (RD).

5. Main hotspots

In summary, the main hotspots identified for the BoP household goods are the following:

- Toxicity impact categories appear to be relevant in the different method employed. While human toxicity, cancer effects, is the most relevant in ILCD, freshwater ecotoxicity results in the largest contributor when using EF 3.0. Other relevant impacts are on resource depletion (and especially on fossil resources, when depletion of fossil and mineral resources is assessed separately) and on ionising radiation.
- For almost all the product groups, the life cycle stage that contributes the most to the overall impact is the manufacture of components (raw materials, ingredients or intermediate products) that are used to produce the final product.
- Among the product groups included in the BoP, the ones that contribute the most to the overall impact are detergents, furniture, paper products, and clothes. This contribution is the result of two combined factors: the environmental profiles of the representative products analysed and the amount of products included in the functional unit (i.e. amount of products purchased by an average EU citizen in one year, as in the case of T-shirts). Each product group has different hotspots in terms of the type of impacts and the life cycle stage in which the impacts are generated.
- The differences between System S+R and System S are generally small. In the baseline scenario, there is no recycling at end of life for most of the product groups, mainly because their recyclability potential at the moment is low and because they cannot be easily separated from the unsorted urban waste stream. Furthermore, benefits from recycling and reuse are mainly offset at the whole BoP level due to the impacts generated in other life cycle phases.
- The assessment of year 2015 shows an increasing trend in the environmental impact of the consumption of household goods, mainly due to a growth in the consumption of most of the products.

Regarding methodological aspects, the relative importance of impact categories after normalization and weighting of results varies according to the LCIA method and the set of normalisation factors used (EU-27 or global references).

However, it is important to highlight that the BoP does not cover all the product groups that are part of the household consumption of goods. For instance, pharmaceuticals are not included in the BoP, but are known hotspots for some environmental impacts (e.g. emissions to water after use). Therefore, when interpreting the results of the BoP household goods, the potential additional impact coming from these product groups should be considered. It is important to notice that also other approaches, based on environmental extended input output tables, miss products groups that could be of relevance (see the study of Castellani et al. 2019). Hence, it is not possible to estimate their potential contribution to overall consumption.

The results of the hotspot analysis on the baseline of the BoP household goods are generally in line with the hotspot addressed by the EU Ecolabel and GPP criteria for the product groups included in the basket. Possible synergies among eco-innovation strategies and the feasibility of developing scenarios on these topics are discussed in the following section.

6. Eco-innovations relevant for the BoP household goods

Towards assessing different scenarios considering eco-innovations in the life cycle of the products included in the BoP household goods, this section illustrates the main findings of a literature review on eco-innovation for the area of consumption covered by the BoP household goods. It is summarized as a list of areas of improvement, some of them specifically related to one BoP, others cross-cutting among BoPs, and the related information needed to drive the further selection. These areas of improvements and related eco-innovation constitute a long list of possible scenarios that may be tested on the BoP baseline.

Based on the areas of concern identified by the hotspot analysis, and focusing on product categories that emerged as more critical, possible improvements and eco-innovation needed in the household goods supply chain to make these strategies operational were identified. The main areas of eco-innovation are the ones listed in Table 23.

For detergents and personal care products, the main efforts of manufacturers to reduce the environmental impact of the products are concentrated on the formulation. Most of the innovations proposed refer to the use of less impacting surfactants (generally focusing on natural-based and renewable ingredients) and, in the case of detergents, to the development of formulations that allow for proper washing with lower temperatures (i.e. allowing for energy savings). The reduction of packaging is also taken into consideration. In the case of detergents this is achieved through the compaction of the detergent, whereas in the case of personal care products, through the reduction of unnecessary packaging (e.g. packaging that has no functional purpose but has the function of making the product more appealing). An important effort of detergent manufacturers is devoted also to the development of consumers' information campaigns on the correct dosage of detergents (e.g. the "cleanright" campaign by the International Association for Soaps, Detergents and Maintenance Products - A.I.S.E.).

For pulp-based products, i.e. paper products and hygiene products containing cellulose, possible solutions to reduce the environmental impact of the supply chain refer to the use of pulp obtained from certified wood (i.e. wood coming from forests that are sustainably managed), to the use of pulp from recycled paper, and to the reduction of potentially harmful chemical additives in pulp making. The use of totally chlorine-free (TCF) pulp, i.e. pulp bleached without chlorine, is an example.

The same principle applies in the choice of leather (e.g. used in footwear) that is tanned with a chrome-free process.

The choice of more environmentally friendly chemicals and related processing of the raw materials is relevant also for textiles. Some of the innovations proposed refer to the use of more environmentally friendly dyes or the implementation of solutions for a more efficient wastewater treatment. Energy-efficiency and water-efficiency measures in the production process (e.g. the transformation of fibres into textile) are also suggested. For natural fibres such as cotton, the agricultural stage (cultivation of raw fibres) is an important environmental hotspot, like any other agricultural activity. Therefore, the use of cotton coming from organic agriculture is proposed, especially in the apparel sector.

Finally, there are some cross-cutting measures that could be applied to several product groups and that might generate important benefits. They are generally linked to the extension of the service life of products (e.g. through a better maintenance or by promoting the reuse at the end of the first life) and to the recycling, in closed or open loops, of the materials that compose the products.

Table 23. Overview of eco-innovation options relevant for the BoP household goods.

Product group	Areas of eco-innovation	Proposed solutions and eco-innovation	References
Detergents and personal care products	Product formulation	Choice of less impacting surfactants, builders and solvents (e.g., by using natural-based/renewable ingredients)	Grbavčić et al. (2015) Siwayanan et al. (2014) Keshwani et al. (2015) Dreja et al. (2014) Sahota (2014) Barve and Dighe (2016).
		Improved formulation to allow for a proper washing at lower temperature	AISE (2017) Honisch et al. (2016) Khan et al. (2013)
	Dosage of product in the use phase	Consumers education on correct dose of detergents	AISE and Cefic (2017)
	Packaging	Reduced packaging (by avoiding packaging that is not necessary or by compacting the detergent)	Nessi et al. (2014) García-Arca et al. (2017) Saouter et al. (2002)
Wood-based and pulp-based products (furniture, paper products and sanitary products)	Fibres sourcing	Use of wood from sustainable managed forests	Sikkema et al. (2016) Dieterich and Auld (2015).
		Use of pulp from recycled paper	Sikkema et al. (2016) Ghose and Chinga-Carrasco (2013). Pèlach Serra et al. (2016)
	Chemical additives	Reduction/substitution of chemical additives in pulp making	Ghose & Chinga-Carrasco (2013). Pèlach Serra et al. (2016)
	Bleaching	Totally chlorine-free (TCF) pulp bleaching	Popp et al. (2011), González-García et al. (2009), EC-JRC (2015)
Textiles (in clothes, mattresses and furniture)	Water and energy use in textile manufacture	Energy-efficiency and water-efficiency measures in the production process	Alkaya and Demirer (2014), Ozturk et al. (2016)
	Organic cotton	Use of cotton from organic agriculture	Rieple and Singh (2010)
	Chemicals/wastewater	Use of more environmentally friendly dyes, improvement of water treatment	Kant (2012) Ozturk et al. (2016) Agnhage (2017)
Leather (in footwear)	Tanning	Chrome-free tanning	Krishnamoorthy et al. (2013) Zuriaga-Agustí et al. (2015) Mutlu et al. (2014)
Cross-cutting	Extension of the service life of products	Longer life/reuse of products	Alkaya and Demirer (2014) Laitala and Boks (2012) Armstrong et al. (2015) Niinimäki and Hassi (2011) Castellani et al. (2015)
	Recycling of product components	Closed-loop or open-loop recycling of materials (e.g. textiles)	WRAP (2011) Björquist (2017) Leonas (2017) Vadicherla & Saravanan (2014)
	Fluorine-free repellent coatings	Use of fluorine-free repellent coating (e.g. for furniture and textiles)	Rabnawaz et al. (2015) Lei et al. (2017) Hill et al. (2016)

7. EU Ecolabel and GPP criteria on household goods and eco-innovation scenarios on the BoP household goods

The EU Ecolabel is a key element of the EU Sustainable Product policy. It is in line with the objectives of such policies and of the wider objectives within the EU2020 and the 7th European Environmental Action Programme (EAP) as well as the Roadmap to a Resource Efficient Europe. Thus, the EU Ecolabel Regulation should be considered in the context of these wider policy initiatives of resource efficiency and the single market for green products. EU Ecolabel is especially relevant since it is the only policy approach that explores the total environmental impact of a product, identifying the key life cycle stages to be addressed through the criteria and thereby also addressing the increasing global impact as a result of EU production and, in particular, consumption. The life cycle approach is becoming a cornerstone of environmental decision making, and the EU Ecolabel has led the way in this respect. Other policy approaches, and evidence gathering, are moving to a closer alignment with the EU Ecolabel's approach.

The study on the Evaluation of the Implementation of the EU Ecolabel Regulation (EC, 2017b) stated the situation of EU Ecolabel and its relation with EU Policies and with respect to market and consumption patterns.

It is recognised that continued pressure from consumption and production in the EU, as noted in the latest State of the Environment Report from the EEA (EEA, 2015), means there is a continuous need to improve the sustainability of that consumption and production. The study also finds that the EU Ecolabel remains relevant as a tool that fulfils the role of promoting goods and services at the top end of the market, an area that is covered by other policy tools to a limited extent – although there is some overlap with the Energy Label in some cases. For this reason, the EU Ecolabel should still be considered as relevant in its objectives and in the issues it seeks to address. The EU Ecolabel supports companies and consumers in their own efforts to produce and consume with less environmental impact. The study on the Evaluation of the Implementation of the EU Ecolabel Regulation confirms that there is still a need to further focus on sustainable consumption and production, supporting the role of the EU Ecolabel and the issues addressed (such as water, material consumption, hazardous materials, end of life, etc.).

The same study reported increasing trends from 2009 to 2015 in the number of products and licenses for the product groups studied. Licenses were 1,015 in 2009 and 2,010 in 2015. The number of products, i.e. items on the market, has increased from 19,000 in 2011 to 44,000 in 2015 (it should be noted that one license could correspond to more than one product, for instance, when there are different models of the same range of products).

Regarding the degree of awareness of the EU Ecolabel, a Eurobarometer survey in 2017 (Eurobarometer, 2017) recorded that more than half of EU citizens have seen or heard about at least one EU Ecolabel. More than a quarter of respondents (27%) said that they have seen or heard about the EU Ecolabel, while other country-specific labels presented a high level of awareness in their countries of origin (the Nordic Swan, Bra Miljöval, the Blue Angel, etc.). There is considerable variation between Member States in levels of awareness of the EU Ecolabel. This is highest in Luxembourg (62%), France (61%), and Denmark (51%), and lowest in Romania (13%), Bulgaria (14%), and the Czech Republic (16%). Among those who are aware of at least one EU Ecolabel, 30% say they have bought a product carrying the EU Ecolabel. Around one third of respondents (32%) say that EU Ecolabels play an important role in their purchasing decisions, while a quarter (25%) say that they do not. Among those respondents who have seen or heard about the EU Ecolabel (27%), more than three-quarters (78%) trust that products carrying this label are environmentally-friendly.

The evaluation study also found that consumers have a higher awareness of the EU Ecolabel for beauty care and for cleaning products. This suggests that awareness is product-specific, since these particular product groups have a direct impact on individual human health and wellbeing, leading consumers to show a higher degree of interest in their environmental impact as well as their health impact, which influences their purchasing choices. This evaluation also identifies these products as typically everyday products that can be bought in supermarkets or in a similar purchasing situation.

Green Public Procurement (GPP) or green purchasing is a voluntary instrument towards a more resource-efficient EU economy. GPP focuses on Europe's public authorities as consumers and the employment of their purchasing power to prioritize environmentally friendly options. As major consumers, choosing goods, services and tenders with a lower impact to the environment can make a relevant contribution to a sustainable EU consumption and production. A key aspect of GPP is that enhancing green purchasing by EU institutions can enhance the demand of sustainable goods and services thereby stimulating eco-innovation.

The current EU Ecolabel and GPP criteria for the product groups that compose the BoP household goods refer to the main issues identified as hotspot for each product group and are based on the most important areas of improvements identified through literature review and a workshop with relevant stakeholders. Even if identified with a different approach, they form a good starting point for the selection of the areas of improvements to be developed as scenarios of eco-innovation for the BoP household goods. Both EU schemes (EU Ecolabel and GPP) are used to identify the areas of improvement for household goods (Table 24). However, only EU Ecolabel is quantitatively evaluated in this report with specific scenarios (see Chapter 8).

Among the sets of criteria currently available for the product groups in the basket, there are some cross-cutting themes that are common to several types of products.

For detergents and personal care product, the main issue identified is the formulation of the product itself, leading to requirements such as avoiding the use of fragrances, reducing the use of antimicrobials (or substitution with pine oil) and biocides, reducing or avoiding the use of phosphorus and phosphate and the choice of biodegradable surfactants, to reduce the eutrophication potential. When bio-based ingredients are used, sustainable sourcing of palm oil, palm kernel oil, and their derivatives shall be ensured. Other criteria for detergents refer to the information and education of consumers, in order to avoid over dosage (e.g. in case of concentrated products) and to reduce the amount of energy used for heating the water during washing. Another issue considered is the type and size of packaging.

For products that use cellulose as raw material (absorbent hygiene products and paper products) the criteria focus on the pulp production process. Some of them refer to the emissions to water and to air coming from chlorine bleaching (Adsorbable Organic Halogens – AOX –, Chemical Oxygen Demand – COD –, phosphorus, sulphur and nitrogen oxides), and suggest the use of Elemental Chlorine Free (ECF) pulp. Others are related to the emissions coming from the use of additives, such as optical brighteners or wet strength agents. The type and the amount of additives for paper making and de-inking of paper (for recycling) are considered as well. For printed paper, the type of inks and solvents used for printing becomes relevant, as well as the emissions of VOCs during the printing process. Finally, due to the large impacts generated during the production of paper products, their recycling is an important issue to be considered (even if the rate of recycling of paper at the end of life is, on average, already quite high in the EU, i.e. around 60-70%).

Regarding the sustainable sourcing of materials, for all products that are wood-based (i.e. products using cellulose, paper products, and furniture), the choice of wood coming from sustainable managed forests is to be preferred. However, it has to be noted that the certification of sustainable management of forests include criteria about issues that cannot be captured by LCA (e.g. working conditions, illegal logging, employment of local workers, effects on biodiversity and ecosystem services).

For furniture, other criteria about the materials used are more focused on the use of hazardous substances for coating of metals, manufacturing of plastics (e.g. vinyl chloride monomer), the heavy metal content in paints, primers and varnishes, and the use of flame retardants for upholstered furniture (and mattresses). Emissions of formaldehyde and VOCs during the use stage are also taken into account.

The use of organic cotton is suggested for products that include cotton textile as the main or one of the raw materials, such as clothes, upholstered furniture, bed mattresses, absorbent hygiene products, and footwear. The substitution of conventional cotton with organic cotton might have relevant impact on the environmental profile of these products, because the impact coming from agricultural activities are usually quite relevant in the whole life cycle. The same could apply for products with leather components, because the tanning process can be quite impacting, due to the use of chromium. Chrome-free tanning can be an option to reduce the impacts due to the use of leather (e.g. in footwear). In addition, the reduction of the amount of water used in the tanning process is mentioned as a criterion for EU Ecolabel products.

Other criteria for footwear refer to the emissions to water from the production of leather, textiles, and rubber, the use of hazardous substances in the manufacturing process (e.g. adhesives), on the solutions to reduce the amount of raw materials used for a pair of shoes and on the durability of the products.

Durability and life extension is a matter of concern also for textiles, together with the energy use during the manufacturing of fibres and textiles, both natural and man-made (e.g. scouring of wool, spinning and weaving of nylon and other fibres).

Table 24 reports the criteria mentioned before, the product groups and life cycle stage to which they could be applied and discuss the feasibility of developing scenarios based on these criteria.

Starting from the feasibility analysis reported in Table 24 and considering also the relevance of some aspects that emerged as hotspot in the baseline analysis, a set of scenarios testing EU Ecolabel criteria on some of the product groups included in the basket has been developed. The selection of scenarios related to EU Ecolabel criteria is discussed in chapter 8.

Table 24. Summary of EU Ecolabel and GPP criteria for the product groups included in the BoP, with specification of products and life cycle stage to which the different criteria could be applied as well as the feasibility of implementation in the BoP model. The scenarios where the area of improvement has been applied are reported.

Area of improvement[a]	Product groups	Life cycle stage	Comment	Scenarios
Emissions to water	Detergents/soap and shampoos	Components manufacture/ Use/EoL	Applicable. The topic can be addressed by one or more scenarios, acting on the composition of the products, the dosage in the use stage, the type of waste water treatment.	5-8
Avoiding the use of fragrances	Detergents/soap and shampoos	Components manufacture	Not applicable. Fragrances are not included in the LCI model of the BoP, because there are no available datasets for LCI of fragrances.	-
Reducing the use of antimicrobials (or substitution with pine oil) and biocides	Detergents/soap and shampoos	Components manufacture	Applicable. Possible scenario on improved formulation of products.	5-8
Reducing or avoiding the use of phosphorus and phosphate	Detergents/soap and shampoos	Components manufacture	Applicable. Possible scenario on improved formulation of products.	5-8
Choice of biodegradable surfactants	Detergents	Components manufacture	Applicable. Possible scenario on improved formulation of products.	7, 8
Sustainable sourcing of palm oil, palm kernel oil and their derivatives	Detergents/soap and shampoos	Components manufacture	Not applicable. Issue that cannot be fully captured by LCA as sustainable sourcing entails aspects beyond the environmental dimension.	-
Education of consumers	Detergents/soap and shampoos	Use	Applicable. The topic can be addressed by scenarios on consumers' behaviour (e.g. reduction of product dose per use).	5-8
Packaging	Detergents/soap and shampoos/footwear	Packaging	Applicable. Possible scenario on concentrated formulation of products.	5-8
No chlorine bleaching	Absorbent hygiene products/paper products	Components manufacture	Applicable. Possible scenario assuming 100% TCF pulp as input.	1
Emissions to water from pulp production	Absorbent hygiene products/paper products	Components manufacture	Applicable to some extent. Some of the datasets used for modelling pulp production contain aggregated emissions, so that it is not easy to identify correctly the ones to be modified in a possible scenario. In addition, ILCD method does not provide a CF for the aggregated flow "AOX", so it would be difficult to account for the differences between processes with high AOX emissions and lower AOX emission. A sensitivity analysis could be done, by using a proxy CF for AOX.	1

[a] Criteria with grey background present limitation or are not applicable in the current BoP model.

Table 24 (cont.). Summary of EU Ecolabel and GPP criteria for the product groups included in the BoP, with specification of products and life cycle stage to which the different criteria could be applied as well as the feasibility of implementation in the BoP model. The scenarios where the area of improvement has been applied are reported.

Area of improvement[a]	Product groups	Life cycle stage	Comment	Scenarios
Use of additives (optical brighteners or wet strength agents)	Absorbent hygiene products/paper products	Production	Not applicable. No optical brighteners are so far included in the model of Absorbent Hygiene Products or paper products. Wet strength agents are included only in the model of toilet paper. A scenario on toilet paper without wet strength agents would not make sense, because the criterion is about avoiding wet strength agents to improve recyclability (that is not an issue for toilet paper).	-
Excluding additives that are classified as hazardous substances and mixtures	Absorbent hygiene products/paper products	Production	To be analysed further, to see if the way in which the LCI of the BoP is modelled can match the way in which the criteria are formulated.	-
Inks and solvents used for printing	Printed paper products	Production	Applicable to some extent (e.g. for some of the solvents used for printing).	-
VOCs emissions during manufacturing	Printed paper products/Footwear	Production	To be analysed further, to see if the way in which the LCI of the BoP is modelled can match the way in which the criteria are formulated.	-
Recycling of paper	Printed paper products	EoL	Applicable. Possible scenario assuming higher share of de-inked paper as input.	-
Wood/cellulose from sustainable managed forests	Absorbent Hygiene products/Furniture/ Paper products	Components manufacture	Not applicable. Issue that cannot be fully captured by LCA.	-
Heavy metal content in paints, primers and varnishes	Furniture	Components manufacture	Applicable to some extent. Paints and varnishes in furniture products within the BoP household goods have been modelled relying on background data (from ecoinvent database). Therefore, it is not straightforward to understand which input and emissions should be modified in a possible scenario.	-
Flame retardants	Furniture/Bed mattresses	Production	Applicable. However, it has to be noted that flame retardants are included only in the BoM of the sofa (upholstered seat) and that the ones included are compliant with the EU Ecolabel criteria.	-
Emissions of VOCs and formaldehyde during the use stage	Furniture	Use	Not applicable. The model of the BoP so far does not include any emissions in the use stage.	-

[a] Criteria with grey background present limitation or are not applicable in the current BoP model.

Table 24 (cont.). Summary of EU Ecolabel and GPP criteria for the product groups included in the BoP, with specification of products and life cycle stage to which the different criteria could be applied as well as the feasibility of implementation in the BoP model. The scenarios where the area of improvement has been applied are reported.

Area of improvement[a]	Product groups	Life cycle stage	Comment	Scenarios
Use of hazardous substances for coating of metals, manufacturing of plastics (e.g. vinyl chloride monomer)	Furniture	Production	Applicable to some extent. Metals and plastics in furniture products within the BoP household goods have been modelled relying on background data (from ecoinvent database). Therefore, it is not straightforward to understand which inputs and emissions should be modified in a possible scenario.	-
Use of organic cotton instead of conventional one	Clothes, upholstered furniture, bed mattresses, absorbent hygiene products and footwear	Components manufacture	Applicable. Possible scenario with organic cotton replacing conventional one.	-
Chrome-free tanning process	Footwear	Components manufacture	Applicable to some extent. Possible scenario modelling the use of chrome-free tanning (e.g. vegetable tanning) instead of chrome tanning. However, a full LCI of vegetable tanning process is not available in commercial databases, neither in publicly available sources (e.g. scientific literature or technical reports).	-
Reduction of water use in the tanning process	Footwear	Components manufacture	Applicable. Possible scenario on water saving measures in tanning process.	-
Lower material intensity	Footwear	Production	Applicable to some extent. To model a scenario, specific expertise in the field is needed, to understand how dematerialization can be achieved while ensuring the same performance of the product.	-
Durability/ Reparability/Reusability	Clothes/Footwear	Use/EoL	Applicable. One or more scenarios on extended product life, second hand markets, etc.	3
Improve the share of products that are recycled at the EoL	All products	EoL	Applicable. Possible cross-cutting scenario.	-
Reduce the impact of electricity used for manufacturing of fibres, textiles and clothes	Clothes	Production	Applicable. Possible scenario testing different energy mixes or electricity from renewable sources.	2
Use of recycled materials	Clothes	Components manufacture	Applicable. Possible scenario testing textiles with recycled input materials for clothes.	4

[a] Criteria with grey background present limitation or are not applicable in the current BoP model.

8. Scenarios of eco-innovation for the area of consumption household goods

The selection of the scenarios for the BoP Household goods is based on the long list coming from the literature review (Table 23) and the analysis of EU Ecolabel and GPP criteria (Table 24). Scenarios are selected only for products included in the BoP household goods. Priority is given to:

— scenarios that are expected to address the most relevant hotspots identified in the baseline (e.g. changing the electricity mix for the production phase of textile products or using recycled fibres to produce textiles);

— scenarios able to simulate the effect of EU policies, especially if in relation to the hotspots of the consumption sector, as emerged from the assessment of the BoP baseline (e.g. for BoP household goods, a group of scenarios is related to the choice of EU Ecolabel products with improved formulations, such as soaps, shampoos, and detergents);

— scenarios related to changes in consumer behaviour, such as the reuse of products, e.g. by reselling them in second hand shops.

8.1. Selection of scenarios on EU Ecolabel criteria

Starting from the analysis of the EU Ecolabel criteria presented in Table 24, a further analysis of the potential improvement areas for three product groups (soaps and shampoos, dishwasher and laundry detergents, and upholstered seats) has been done. The analysis considered the results of the hotspot analysis done on the baseline scenario (reference year 2010) of the BoP household goods and the results of the LCA studies done for the base case scenarios considered in the background studies done for the selection of the EU Ecolabel criteria[19].

After the identification of the hotspots of each product group, different actions have been detected in order to improve the environmental performance of the scenarios. The following life cycle stages have been considered, in line with the baseline scenario: components manufacture, production, logistics, packaging, use, and EoL. The proposed actions and their potential application are summarised in Table 25.

The improvement potential has been defined taking as a basis the level of enhancement (*high, medium, or low)* of each eco-innovation action identified for the different products. This level has been defined by the authors, based on the following criteria:

— the relative relevance of that parameter in terms of environmental impacts and potential savings, according to the LCA results for the base case scenario

— the feasibility of incorporating this eco-innovation measure in the product category, due to technical, market and usability limitations related to each product typology

— the possibility of including this measure in the LCA modelling

The eco-design actions included in the EU Ecolabel as mandatory or optional requirement have been selected to be analysed as improvement action of the baseline scenario. For the improvement actions included in Table 25 which are not covered by EU Ecolabel criteria, but which have been identified as having a medium and high improvement potential, some sensitivity analyses have been performed. Based on the analysis presented before, it has been decided to run scenarios that include the implementation of mandatory EU Ecolabel criteria (for the actions that can be modelled in LCA and with the current life cycle inventory of the baseline scenario). Sensitivity analyses have been run for those actions that are not mandatory according to the EU Ecolabel criteria, but could still have an improvement potential. Table 26 reports a summary of the scenarios and sensitivity analyses developed.

[19] The full documentation of the preparatory work done for the selection of EU Ecolabel criteria can be found at: http://susproc.jrc.ec.europa.eu/product_bureau/projects.html. Reference to specific documents used for the analysis are provided in the description of each scenario, presented in the following chapters.

Table 25. Potential innovation actions for the product groups considered.

		Liquid soaps and shampoos		Dishwasher and laundry detergents		Upholstered Seat	
Life cycle stage	**Eco-innovation actions**	**Included in EU Ecolabel**	**Improvement potential**	**Included in EU Ecolabel**	**Improvement potential**	**Included in EU Ecolabel**	**Improvement potential**
Components manufacture	Selection of more sustainable ingredients/materials	Yes. Mandatory	Medium	Yes. Mandatory	Medium	Yes. Mandatory	High
	Restriction of substances classified under hazard statements	Yes. Mandatory	Medium	Yes. Mandatory	Medium	Yes. Mandatory	Medium
	Selection of local providers / ingredients / materials	No	Low	No	Low	No	Low
Production	Reduction of energy and water consumption	No	Medium	No	Medium	No	Medium
	Reduction of emissions	No	Medium	No	Medium	No	Low
	Intensification and improvement of efficiency of processes	No	Low	No	Low	No	Low
	Waste prevention /waste management	No	Medium	No	Medium	No	Medium
	Clean manufacturing and environmental management	No	Low	No	Low	No	Low
Packaging	Ecodesign on the packaging	No	Low	No	Low	No	Low
	Elimination of packaging components	Yes. Mandatory	Low	Yes. Optional	High	No	Low
	Reduction of weight	Yes. Mandatory	High	Yes. Mandatory	High	No	Low
	Refilling systems	Yes. Optional	High	No	Low	No	-
	Recycled content (increase % of cardboard packaging)	Yes. Optional	Medium	Yes. Optional	High	No	Medium
	Improvement of capacity / volume of the product	Yes. Optional	Medium	Yes. Optional	High	No	-
	Selection of sustainable materials	No	Low	Yes. Optional	High	No	Medium
	Restriction of substances classified under hazard statements	Yes. Mandatory	High	Yes. Mandatory	High	No	Low
Logistics	Reduction of weight transported (packaging)	No	High	No	High	No	Medium
	Local consumption (km0)	No	Low	No	Low	No	Low
	Optimization of logistics and tertiary packaging	No	Low	No	Low	No	Medium

		Liquid soaps and shampoos		Dishwasher and laundry detergents		Upholstered Seat	
Life cycle stage	**Eco-innovation actions**	**Included in EU Ecolabel**	**Improvement potential**	**Included in EU Ecolabel**	**Improvement potential**	**Included in EU Ecolabel**	**Improvement potential**
	Use of less pollutant means of transport	No	Low	No	Low	No	Low
Use phase	Reduction of water consumption	No	Medium	No	High	No	Medium
	Reduction of dosage: packaging ecodesign, awareness and fitness for use	No	Medium	Yes. Mandatory	High	No	Medium
	Reduction of energy consumption	No	Low	Yes. Mandatory	High	No	Low
	Maintenance and cleaning activities	No	-	No	-	No	Low
	Extension of lifespan of the product	No	-	No	-	Yes. Mandatory	Medium
End of life	Wastewater treatment - hazardous substances in water	No	Low	No	Low	No	Low
	Recyclability of packaging - EU rates	Yes. Mandatory	High	Yes. Mandatory	High	No	High
	Reduction of product losses- Design of packaging dosage system	Yes. Mandatory	Medium	No	Low	No	-
	Design for disassembly	No	-	No	-	Yes. Mandatory	High

*Mandatory means that the product has to consider the action to be certified by EU Ecolabel.
**Optional means that EU Ecolabel includes a criterion referring to this topic, however a product does not need to include the requirement to be certified by EU Ecolabel.
(For references, see the section "rationale for building the scenario", in the following chapters)

Legend:
- Action covered by EU Ecolabel criteria
- Action not covered by EU Ecolabel criteria
- High Improvement potential
- Medium Improvement potential
- Low Improvement potential

Table 26. Summary of scenarios and sensitivity analyses performed on the BoP household goods.

	Liquid soaps	Shampoos	Dishwasher detergents	Laundry detergents	Upholstered Seat
Components manufacture	Formulation according to criteria requirements included in EU Ecolabel	Formulation according to criteria requirements included in EU Ecolabel	Formulation according to criteria requirements included in EU Ecolabel	Formulation according to criteria requirements included in EU Ecolabel	Design according to EU Ecolabel criteria: design for a better recyclability
Production	Reduction of energy consumed during manufacturing process: 5%, 10% and 20% compared to the base-case	Reduction of energy consumed during manufacturing process: 5%, 10% and 20% compared to the base-case	Reduction of energy consumed during manufacturing process: 5%, 10% and 20% compared to the base-case	Reduction of energy consumed during manufacturing process: 5%, 10% and 20% compared to the base-case	Reduction of energy consumed during manufacturing process: 5%, 10% and 20% compared to the base-case
Packaging	Increase of the packaging capacity, reduction of material, and use of 20% of HDPE from recycled material	Increase of the packaging capacity, reduction of material, and use of 20% of HDPE from recycled material	Substitution of primary packaging with water-soluble plastic, 100% of cardboard from recycled material in secondary packaging	Increase of packaging capacity	Substitution of the plastic film packaging by a cardboard box
Packaging end of life	Improve recycling rates: for plastic packaging (60% and 100%) and for cardboard packaging (90% and 100%)	Improve recycling rates: for plastic packaging (60% and 100%) and for cardboard packaging (90% and 100%)	Improve recycling rates: for plastic packaging (60% and 100%) and for cardboard packaging (90% and 100%)	Improve recycling rates: for plastic packaging (60% and 100%) and for cardboard packaging (90% and 100%)	Improve recycling rates: for plastic packaging (60% and 100%) and for cardboard packaging (90% and 100%)
Logistics	Use of Euro 6 lorries for transport	Use of Euro 6 lorries for transport	Use of Euro 6 lorries for transport	Use of Euro 6 lorries for transport	Use of Euro 6 lorries for transport
Use phase	10% dosage reduction Reduction of water use (5% and 10%)	10% dosage reduction Reduction of water use (5% and 10%)	Reduction of dosage (5%), electricity (37%) and water (46%)	Reduction of dosage (7%) and electricity consumed (24%)	Lifespan extension: giving a second life of 2.1 years to the product
End of life	Improvement related with the water reduction during use and considering direct emissions to water	Improvement related with the water reduction during use	Improvement related to reduction of water use		Recycling rates improvement according to a better design for disassembly

Legend:	(green)	Considered in eco-innovation action	(white) Considered in sensitivity analysis

8.2. List of the scenarios tested in the BoP household goods

Following the criteria presented before, a total of 10 scenarios have been selected and modelled in the context of the BoP household goods. These scenarios include four scenarios of eco-innovation strategies implemented to different life cycle stages of representative products (see Table 24 in section 7):

- Scenario 1 – Larger use of Totally Chlorine Free (TCF) pulp in paper products and sanitary products
- Scenario 2 – Reducing the impact of electricity use in the textile sector
- Scenario 3 – Improving reuse (second-hand products)
- Scenario 4 – Using textiles with recycled input materials for clothes manufacturing

Six of the scenarios focus on the eco-innovations supported by the EU Ecolabel criteria (as described in Table 26 in section 8.1). While five of them evaluate the implementation of these criteria to a specific product, a scenario including all the EU Ecolabel scenarios is also assessed:

- Scenario 5 – EU Ecolabel scenario on liquid soap
- Scenario 6 – EU Ecolabel scenario on shampoo
- Scenario 7 – EU Ecolabel scenario on dishwasher detergent (DD)
- Scenario 8 – EU Ecolabel scenario on laundry detergent (LD)
- Scenario 9 – EU Ecolabel scenario on upholstered seat
- Scenario 10 – Overall potential from the analysed EU Ecolabel scenarios

Regarding the scenarios on the EU Ecolabel, these scenarios evaluate the effect of the EU Ecolabel at the single product level and the potential effect to the environmental impacts of the whole BoP household goods. It is not in scope of this assessment to evaluate the overall effect of the EU Ecolabel scheme.

8.3. Scenario 1 – Larger use of Totally Chlorine Free (TCF) pulp in paper products and sanitary products

<u>Description and aim:</u>

This scenario aims at testing the influence of replacing elemental chlorine free (ECF) with totally chlorine free (TCF) pulp in paper products and in sanitary products that contain pulp.

<u>Area of intervention:</u>

— Hotspot addressed: emissions coming from the use of chlorine in pulp bleaching.

— Product groups: Paper products and sanitary products

— Life cycle stage: component manufacture

<u>Policy relevance:</u> EU Water Framework Directive (EC, 2000).

<u>Rationale for building the scenario:</u>

The use of chlorine as an additive for sulphate (or kraft) pulp bleaching, and the related emission of chlorinated organic compounds to water is one of the environmental hotspots of the pulp and paper industry (see Section 4.3). It may affect the environmental profile of paper products and, more generally, of products that contain pulp as raw material of the product. For the BoP household goods, this is the case of sanitary and paper products.

In the EU, chlorine (Cl_2) and hypochlorite (e.g. NaOCl) have been phased out as primary bleaching chemicals in recent years. According to EC-JRC (2015), the two main types of bleaching methods in use in the EU are elemental chlorine free (ECF), i.e. when no molecular or gaseous chlorine is used in the bleaching, and totally chlorine free (TCF) bleaching. All ECF mills use chlorine dioxide in the bleaching sequences and in a few cases also ozone, alkali for the extraction of the dissolved lignin, and peroxide and oxygen for the reinforcement of the extraction stages. TCF bleaching uses oxygen, ozone or peracetic acid and peroxide with alkali for lignin extraction. Both methods are predominant in EU pulp production. Since the beginning of the 1990s, TCF bleaching has become the predominantly used bleaching method in EU sulphite pulp mills (EC-JRC, 2015). On the contrary, ECF is by far the most common bleaching method (around 90% of the market) used for sulphate pulp production in the EU.

The TCF scenario aims at modelling the effects of a complete substitution of ECF sulphate (kraft) pulp with TCF sulphate (kraft) pulp in the representative products of the BoP household goods (namely in paper products and in sanitary products).

<u>Parameters modified in the model:</u>

To model the assumption of 100% substitution of ECF kraft pulp with TCF kraft pulp, the ecoinvent dataset "Sulfate pulp {*country or region*}| production, elementary chlorine free bleached" used in the baseline model was substituted with the correspondent ecoinvent dataset for TCF pulp, "Sulfate pulp {*country or region*}| production, totally chlorine free bleached". The quantity of the pulp input has not been modified.

The substitution has been applied to:

— Kraft pulp used to produce graphic paper (in the LCI of the book and of the newspaper)

— Kraft pulp used to produce tissue paper (in the LCI of toilet paper)

— The share of bleached kraft pulp included in the dataset for the global market average of kraft pulp ("Sulfate pulp {GLO}| market for") used in the LCIs of sanitary products.

The different environmental profiles of the datasets employed in the baseline (Sulfate pulp, ECF bleached) and in this scenario (Sulfate pulp, TCF bleached) are further discussed in the results (Figure 10).

Results:

The comparison between the baseline and the scenario TCF applied to the whole BoP (i.e. applying the substitution to all the products that contain bleached kraft pulp) shows a slight reduction of impact (less than 1%) in most of the impact categories and an increase of the impact due to particulate matter emissions (+3.6%) and due to land use (+0.3%) (Table 27). The reason of this difference is that the two bleaching methods (ECF and TCF) do not differ only for the type and amount of the bleaching agent, but also for other parameters of the process such as the energy use and the related emissions, which are higher for TCF than for ECF.

Table 27. Comparison between the baseline scenario (consumption and use of household goods in the baseline year 2010 by an average EU citizen) and the scenario TCF.

Impact category	Unit	Baseline	Scenario TCF	Variation (%)
Climate change	kg CO_2 eq	1.39E+03	1.39E+03	-0.4
Ozone depletion	kg CFC-11 eq	1.13E-04	1.13E-04	-0.1
Human toxicity, non-cancer	CTUh	1.87E-04	1.87E-04	0.1
Human toxicity, cancer	CTUh	4.75E-05	4.71E-05	-0.7
Particulate matter	kg $PM_{2.5}$ eq	1.14E+00	1.18E+00	3.6
Ionizing radiation, effects on human health (HH)	kBq U^{235} eq	8.89E+01	8.87E+01	-0.2
Photochemical ozone formation	kg NMVOC eq	4.13E+00	4.11E+00	-0.6
Acidification	molc H^+ eq	8.16E+00	8.14E+00	-0.2
Terrestrial eutrophication	molc N eq	1.63E+01	1.62E+01	-0.6
Freshwater eutrophication	kg P eq	1.13E-01	1.13E-01	-0.1
Marine eutrophication	kg N eq	2.28E+00	2.27E+00	-0.4
Freshwater ecotoxicity	CTUe	1.72E+03	1.72E+03	-0.3
Land use	kg C deficit	4.30E+03	4.31E+03	0.3
Water resource depletion	m^3 water eq	1.08E+02	1.08E+02	-0.1
Resource depletion	kg Sb eq	1.47E-01	1.47E-01	-0.2

It is worthy to note that the major improvement from the TCF process compared to a chlorine based bleaching or an ECF bleaching is expected on the freshwater ecotoxicity impact category, thanks to the reduction of emissions of AOX to water. However, the ILCD method does not include a CF for the generic elementary flow "Adsorbable Organic Halogens (AOX)", but only for specific substances that are included in this group. On the contrary, the datasets representing the inventory of resources and emissions of the pulp production process usually include the generic flow for AOX, because a specific breakdown of substances is not available from the production plants. Therefore, the emission of AOX (and the related reduction in the TCF scenario) is not taken into account in the results presented in Table 27.

To overcome this limitation of the method, a CF was calculated for AOX. The proposed CF is a weighted average of CFs for single AOX compounds already included in ILCD, weighted according to the composition of AOX emissions from the pulp and paper industry, as provided by INFRAS (1998). Details of the calculation are summarized in Table 28.

Table 28. Input data used for the calculation of a freshwater ecotoxicity CF for AOX emissions to water from pulp and paper production.

Main compounds in AOX from pulp and paper production (INRAS, 1998)	Amount of compound (kg) in 1 kg of AOX emitted (INRAS, 1998)	CF in ILCD (CTUe/kg)	Calculated weighted CF (CTUe/kg)
4-chlorobenzenamine	0.850	5.42E+03	4.65E+03
1,2-dichlorobenzene	0.075	4.40E+01	
1,2,3-trichlorobenzene	0.075	5.59E+02	

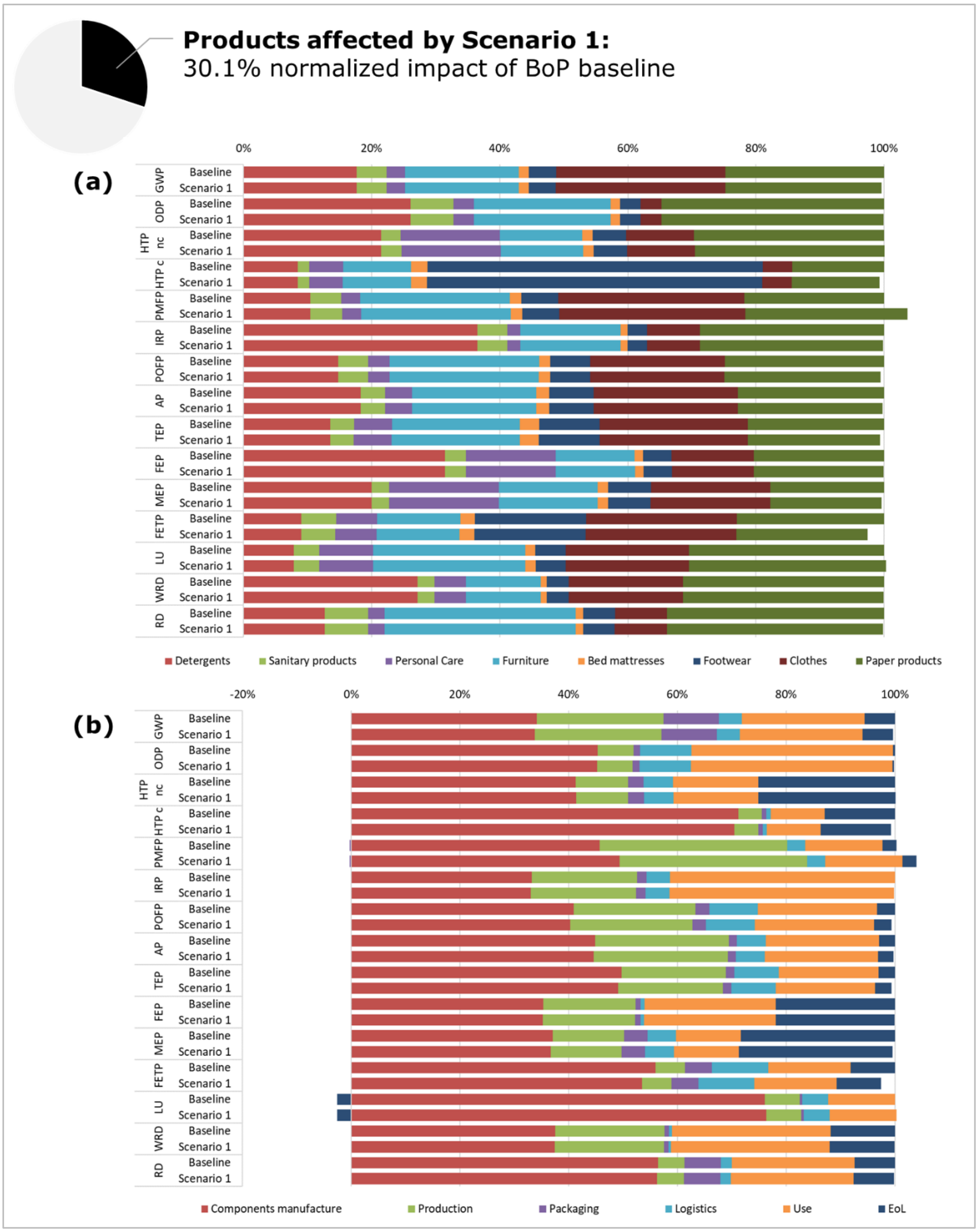
Table 29 reports the results of the TCF scenario compared to the baseline assessed using the ILCD method with the additional CF for AOX. When the emission of AOX is taken into account at the impact assessment phase, the reduction of freshwater ecotoxicity impact increases from -0.3% to -2.5%. However, the improvement in the environmental profile of the whole BoP is still limited and the increase in the impact of particulate matter emission remains larger than the reduction of ecotoxicity.

Table 29. Results of the comparison between the baseline and the scenario TCF assessed using ILCD with the additional CF for AOX.

Impact category	Unit	Baseline	Scenario TCF	Variation (%)
Climate change	kg CO_2 eq	1.39E+03	1.39E+03	-0.4
Ozone depletion	kg CFC-11 eq	1.13E-04	1.13E-04	-0.1
Human toxicity, non-cancer	CTUh	1.87E-04	1.87E-04	0.1
Human toxicity, cancer	CTUh	4.75E-05	4.71E-05	-0.7
Particulate matter	kg $PM_{2.5}$ eq	1.14E+00	1.18E+00	3.6
Ionizing radiation	kBq U^{235} eq	8.89E+01	8.87E+01	-0.2
Photochemical ozone formation	kg NMVOC eq	4.13E+00	4.11E+00	-0.6
Acidification	molc H^+ eq	8.16E+00	8.14E+00	-0.2
Terrestrial eutrophication	molc N eq	1.63E+01	1.62E+01	-0.6
Freshwater eutrophication	kg P eq	1.13E-01	1.13E-01	-0.1
Marine eutrophication	kg N eq	2.28E+00	2.27E+00	-0.4
Freshwater ecotoxicity	CTUe	1.77E+03	1.73E+03	-2.5
Land use	kg C deficit	4.30E+03	4.31E+03	0.3
Water resource depletion	m^3 water eq	1.08E+02	1.08E+02	-0.1
Resource depletion	kg Sb eq	1.47E-01	1.47E-01	-0.2

Figure 9 shows the same results of Table 29, highlighting the contribution per product group and per life cycle stage. As shown in the figure, the scenario has a limited effect, as only the production phase of paper products (where the substitution takes place) is affected. The Scenario 1 affects sanitary and paper products, which contribute to 30.1% of the normalized impact of the baseline BoP household goods.

Figure 9. Scenario 1 in comparison with the baseline scenario (with total from the baseline set as 100%): split into the contributions of (a) the various product groups and (b) the life cycle stages. Method: ILCD with the additional CF for AOX.



Abbreviations: GWP (Climate change), ODP (Ozone depletion), HTP nc (Human toxicity, non-cancer effects), HTP c (Human toxicity, cancer effects), PMFP (Particulate matter), IRP (Ionizing Radiation HH), POFP (Photochemical ozone formation), AP (Acidification), TEP (Terrestrial eutrophication), FEP (Freshwater eutrophication), MEP (Marine eutrophication), FETP (Freshwater ecotoxicity), LU (Land use), WRD (Water resource depletion), RD (Mineral, fossil & renewable resource depletion), all from the ILCD v1.08 method (EC-JRC, 2011).

The results for the whole BoP household goods are influenced also by the amount of paper products and sanitary products bought by an average citizen in one year, compared to the quantity of other representative products in the BoP. Therefore, the same comparison is run considering a single unit of two products affected by the scenario, namely baby diaper and newspaper. Results are presented in Table 30 and Table 31.

Table 30. Results of the comparison between 1 baby diaper as it is in the baseline and 1 baby diaper in the scenario TCF (using ILCD with the additional CF for AOX).

Impact category	Unit	Diaper in baseline	Diaper in scenario TCF	Variation (%)
Climate change	kg CO_2 eq	6.68E+00	6.66E+00	-0.2
Ozone depletion	kg CFC-11 eq	5.55E-07	5.55E-07	-0.1
Human toxicity, non-cancer	CTUh	4.77E-07	5.00E-07	4.8
Human toxicity, cancer	CTUh	6.68E-08	6.56E-08	-1.8
Particulate matter	kg $PM_{2.5}$ eq	5.55E-03	5.72E-03	3.1
Ionizing radiation, effects on human health (HH)	kBq U^{235} eq	4.48E-01	4.47E-01	-0.2
Photochemical ozone formation	kg NMVOC eq	1.76E-02	1.75E-02	-0.5
Acidification	molc H^+ eq	3.30E-02	3.29E-02	-0.2
Terrestrial eutrophication	molc N eq	5.68E-02	5.65E-02	-0.6
Freshwater eutrophication	kg P eq	4.14E-04	4.16E-04	0.6
Marine eutrophication	kg N eq	6.12E-03	6.09E-03	-0.6
Freshwater ecotoxicity	CTUe	4.64E+00	4.63E+00	-0.2
Land use	kg C deficit	1.15E+01	1.16E+01	0.4
Water resource depletion	m^3 water eq	3.79E-01	3.79E-01	-0.1
Resource depletion	kg Sb eq	5.04E-04	5.03E-04	-0.2

Most of the impact categories show a decrease, although some trade-offs are present. In the case of baby diaper, human toxicity, non-cancer shows the largest increase (4.8%) due higher emissions of zinc to soil in the TCF scenario (Table 30). Regarding the newspaper, the largest increase is found in particulate matter, where the TCF shows a large foreground emission of PM<2.5μm to air (Table 31).

Table 31. Results of the comparison between 1 newspaper as it is in the baseline and 1 newspaper in the scenario TCF (using ILCD with the additional CF for AOX).

Impact category	Unit	Newspaper in baseline	Newspaper in scenario TCF	Variation (%)
Climate change	kg CO_2 eq	2.19E+00	2.16E+00	-1.4
Ozone depletion	kg CFC-11 eq	2.74E-07	2.74E-07	-0.3
Human toxicity, non-cancer	CTUh	2.91E-07	2.91E-07	-0.2
Human toxicity, cancer	CTUh	2.24E-08	2.03E-08	-9.2
Particulate matter	kg $PM_{2.5}$ eq	1.31E-03	1.56E-03	18.9
Ionizing radiation, effects on human health (HH)	kBq U^{235} eq	1.76E-01	1.76E-01	-0.5
Photochemical ozone formation	kg NMVOC eq	6.19E-03	6.04E-03	-2.3
Acidification	molc H^+ eq	1.13E-02	1.12E-02	-1.0
Terrestrial eutrophication	molc N eq	2.06E-02	2.00E-02	-2.9
Freshwater eutrophication	kg P eq	1.46E-04	1.46E-04	-0.4
Marine eutrophication	kg N eq	2.56E-03	2.50E-03	-2.3
Freshwater ecotoxicity	CTUe	2.68E+00	2.41E+00	-10.1
Land use	kg C deficit	7.83E+00	7.91E+00	1.0
Water resource depletion	m^3 water eq	1.33E-01	1.32E-01	-0.5
Resource depletion	kg Sb eq	3.68E-04	3.66E-04	-0.4

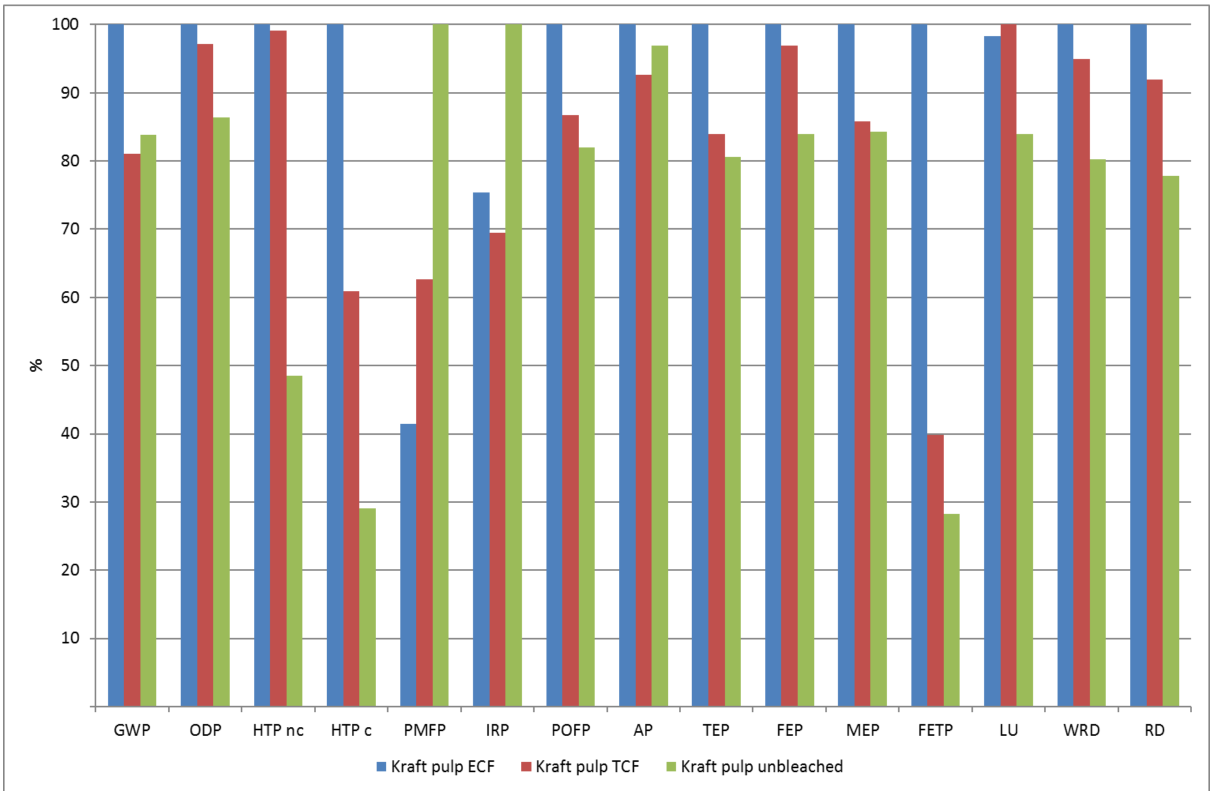
The reduction of impacts on freshwater ecotoxicity and other impact categories and the increase of the impact from particulate matter emissions are larger for the newspaper than for the baby diaper. This is due to the higher share of EFC pulp over the total amount of kraft pulp contained in the newspaper compared to the one in the diaper.

In fact, 99.7% of the kraft pulp contained in the newspaper is ECF bleached (the remaining is either TCF bleached or unbleached), whereas only 25.3% of the kraft pulp in the diaper is ECF bleached (and the remaining, and larger, part is either TCF or unbleached). Consequently, the substitution of ECF with TCF pulp in the newspaper has a larger effect on the environmental profile of the newspaper compared to the effect on the diaper.

As a further analysis, Figure 10 reports the results of the assessment of 1 kg of pulp produced with the two bleaching methods (ECF and TCF) and without any bleaching. The results confirm the trends already emerged from the previous analyses: avoiding the use of chlorine for bleaching significantly reduces the impacts on freshwater ecotoxicity. On the contrary, the emissions of particulate matter (PM) are higher if the bleaching is reduced or excluded from the production process. This could be because the bleaching process is generally coupled with the recovery of lignin and chemicals as black liquor, which is burned in a closed loop in the pulp mill and contributes to reduce the need of heat and electricity provided by external sources and to reduce the emissions of PM of the overall process.

In conclusion, the use of TCF bleaching in substitution to ECF bleaching allows for reducing the impact in most of the impact categories considered (and especially on freshwater ecotoxicity). However, it also generates additional impacts on other impact categories (mainly particulate matter, but also ionizing radiation and acidification), which are more influenced by the effect of the increased energy need coming from this type of bleaching process. Therefore, the use of a more sustainable energy mix, e.g. with a higher share of renewable energy sources and a reduced intensity in emission of particulate matter, could help to improve the environmental profile of the TCF pulp production process.

Figure 10. Results of the comparison between 1 kg of pulp not bleached, 1 kg of ECF pulp, and 1 kg of TCF pulp (using ILCD with the additional CF for AOX).



(For the abbreviations of the names of impact categories see note to Figure 9)

It is worthy to mention that the current set of criteria for the EU Ecolabel of paper products include a mandatory requirement of avoiding the use of chlorine gas as a bleaching agent (i.e. to use ECF pulp), but no mandatory requirement for TCF pulp.

Other options for chlorine free bleaching have been analysed in the scientific literature. An example is the use of enzymes. The use of laccase or xylanases in the bleaching process could help to reduce the environmental impacts coming from this stage of the pulp process (Fu et al., 2005; Monje et al., 2010) and it has already been incorporated in the bleaching sequences of some pulp mills (Bajpai, 2004). However, this technology is not widespread among pulp mills and ECF pulp bleaching is still the most used process for chemical pulping (AkzoNobel, 2017). In fact, there could be some critical challenges before this enzyme can be fully implemented for pulp bleaching at the industrial scale, such as the costs of production of those enzymes at large scale, the current low production efficiency and the cost of mediators used in the process (Singh et al., 2015; Fillat et al., 2017).

8.4. Scenario 2 – Reducing the impact of electricity use in the textile sector

Description and aim:

These two scenarios (2a/2b) aim at testing some options to reduce the impact of the electricity used in manufacturing textiles and clothes, by using more environmentally sustainable energy mixes, including a higher share of electricity from renewable sources.

Area of intervention:

- Hotspot addressed: impacts from electricity use in the manufacturing of textiles and clothes
- Product group: Clothes (Textile products)
- Life cycle stage: production

Policy relevance: Energy efficiency directive (EC 2012) and resource efficiency directive (EC 2011).

Rationale for building the scenario:

The assessment of the baseline highlighted the use of electricity during the phases that transform the raw fibres into textiles (spinning, yarning, texturizing, etc.) as one of the hotspots of the BoP household goods (especially for t-shirts). This affects especially the impact categories climate change, particulate matter, acidification, and water resource depletion and it is partly because most of the clothes that are bought by EU citizens are produced outside the EU, in countries where the electricity mix has larger shares of coal and oil and, hence, generate larger environmental impacts.

The scenario tests the effects of using the EU electricity mix, i.e. assuming that textiles and clothes are produced in the EU rather than imported from abroad, and of using an electricity mix with a larger share of electricity coming from renewable sources. In the present scenario, this assumption was applied only to the production of textiles, because the use of electricity mixes that are more impacting than the EU one emerged as a hotspot in the assessment of the baseline scenario. However, the effect of the same change applied to all the product groups in the BoP could be analysed as well.

Parameters modified in the model:

In the BoP model, the production phase of representative textile products (t-shirt, blouse, trousers, and jeans) includes the following uses of electricity: electricity for spinning; electricity for texturizing of synthetic yarns; electricity for knitting and dyeing of textiles; and electricity for cutting and sewing of final product. The electricity mixes included in the baseline model for these activities represent the real conditions of the production sites, as reported in section 3.2.4. (Table 6).

In the scenario on the EU electricity mix (scenario 2a), all the electricity used in the production phases mentioned before is modelled with the ecoinvent dataset for the average European electricity mix, i.e. "Electricity, low voltage {Europe without Switzerland}| market group for". In the scenario on a larger share of electricity produced from renewable sources (scenario 2b), the expected mix for the gross electricity generation by source in the year 2030, based on the EC's report "EU Reference Scenario 2016 – Energy, transport and GHG emissions Trends to 2050" (EC, 2016), is used. The electricity mix EU 2030 has been modelled in the context of the scenario modelling for the BoP appliances (Reale et al., 2019), as described below. The same dataset is substituted to the electricity mixes used for textile production in the model of the BoP household goods, as described before for the scenario "EU mix".

Based on the general modelling structure of the electricity sector within ecoinvent version 3 (described in Treyer and Bauer 2016), market datasets for the various voltage levels (i.e. high, medium, and low) have been established. With the exception of "solar" and "waste" sources, all other production activities are linked to the high voltage market. For “waste”, this is done on the medium voltage level, while “solar” production is modelled as electricity, low voltage, from various types of photovoltaics installations. For the subsequent transformation from high to medium and then to low voltage, the parameters from the current German electricity mix datasets in ecoinvent are used. In total, this leads to the following five new datasets for such a future electricity mix in the EU, the first dataset of which will be the linking element to the examined scenarios in this study:

- market for electricity 2030, low voltage/EU-28
- electricity 2030 voltage transformation, from medium to low voltage/EU-28
- market for electricity 2030, medium voltage/EU-28
- electricity 2030 voltage transformation, from high to medium voltage/EU-28
- market for electricity 2030, high voltage/EU-28

The resulting electricity mix EU 2030 and related datasets used for modelling are reported in Table 32.

Table 32. Electricity mix of the European electricity market dataset and the expected 2030 EU electricity mix based on the EU Reference Scenario 2016 (EC, 2016).

Energy source	**European electricity market**(1)	**2030 expected gross electricity generation**(2)		**Used dataset for 2030 mix** (3)
	%	**GWh_e**	**%**	
Nuclear energy	31.3	777,743	22.0	Electricity production, nuclear, pressure water reactor/FR
Solids	26.7	562,741	16.0	Electricity production, hard coal/DE *and* Electricity production, lignite/DE (4)
Oil (incl. refinery gas)	2.4	19,341	0.5	Electricity production, oil/DE
Gas (incl. derived gas)	18.8	654,930	18.6	Electricity production, natural gas, combined cycle power plant/DE
Biomass-waste	3.0	283,469	8.0	Electricity out of heat and power co-generation, biogas, gas engine/DE *and* Electricity out of heat *and* power co-generation, wood chips, 6667 kW, state-of-the-art 2014/DE *and* Electricity, from municipal waste incineration to generic market/DE (5)
Hydro (pumping)	0.9	-	-	
Hydro (no pumping)	6.6	378,979	10.7	Electricity production, hydro, reservoir, alpine region/ CH *and* Electricity production, hydro, river-of-river/CH (6)
Wind	6.7	608,460	17.3	Electricity production, wind, >3MW turbine, onshore/ DE *and* Electricity production, wind, 1-3MW turbine, offshore/DE (7)
Solar	3.4	232,129	6.6	Electricity production, photovoltaic, 3kWp slanted-roof installation, multi-Si, panel mounted/DE *and* Electricity production, photovoltaic, 3kWp slanted-roof installation, single-Si, panel mounted/DE *and* Electricity production, photovoltaic, 570kWp open ground installation, multi-Si/DE (8)
Geothermal (& others)	0.2	9,736	0.3	Electricity production, deep geothermal/DE

(1) Calculated considering the 60% of the share of the European without Switzerland dataset (Germany, France, United Kingdom, Italy, Spain, and Ukraine).
(2) Values for EU28 for the year 2030. *Source:* European Commission 2016.
(3) Data from the background database ecoinvent v3.2. Due to a lack of respective average data for Europe, the here mentioned "national" datasets have been chosen as respective proxy for an "average" European dataset.
(4) Based on the EU Power Statistics 2015 spreadsheet, 49% Hard Coal and 51% Lignite are expected in 2030 (Source: http://www.eurelectric.org/factsdb/).
(5) Based on the EU Power Statistics 2015 spreadsheet, 49% Biomass (here represented by the "wood" dataset), 36% Biogas & Bioliquids ("biogas" dataset) and 15% from Waste incineration ("waste" dataset) are expected in 2030 (Source: http://www.eurelectric.org/factsdb/).
(6) Based on the EU Power Statistics 2015 spreadsheet, 65% Reservoir and 35% Run-of-River are expected in 2030 (Source: http://www.eurelectric.org/factsdb/).
(7) Based on the EU Power Statistics 2015 spreadsheet, 73% Onshore and 27% Offshore Production of Wind electricity are expected in 2030 (Source: http://www.eurelectric.org/factsdb/).
(8) According to the EU Power Statistics 2015 spreadsheet, also 2030 less than 0.5% of solar-based electricity is expected to be produced in concentrated solar plants (CSP); hence, here 100% PV-based production is assumed – split (based on the outlook for 2030 in IEA 2010 and the modelling of PV in this study here) in 34% open ground, 31% Mono-Si and 35% Multi-Si (Source: http://www.eurelectric.org/factsdb/).

Results:

When the two alternative electricity mixes are used for textile production (assuming that textile production would happen in the EU), the impact on most of the impact categories considered is reduced compared to the baseline scenario (Table 33, Figure 11). The effect of this substitution on the impact of the whole BoP household goods is proportional to the contribution of textile production activities to the overall impact of the BoP, as illustrated in section 4.

Table 33. Results of the comparison between the baseline and scenarios 2a and 2b.

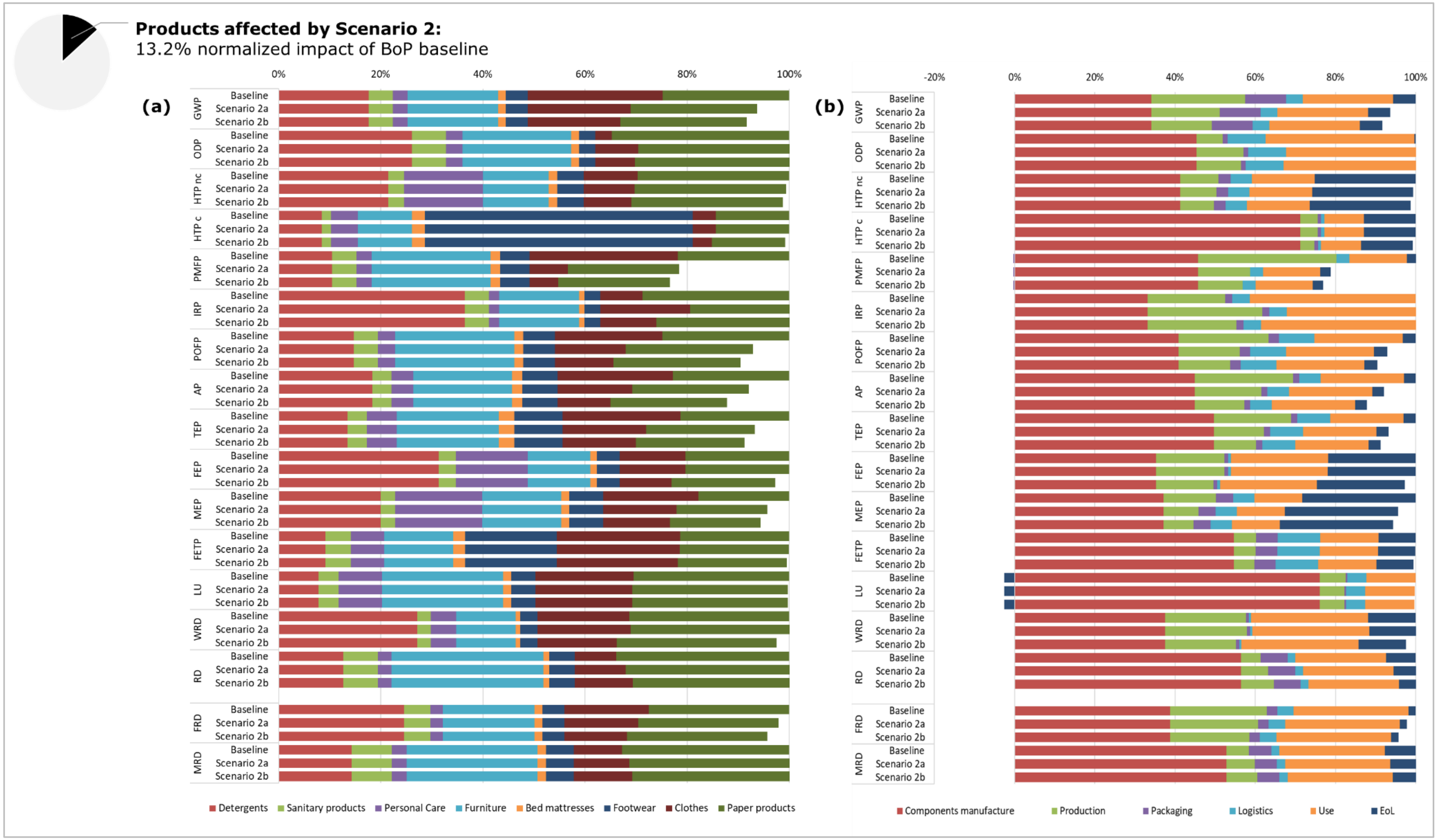
Impact category	Unit	Baseline	Scenario 2a	Variation (%)	Scenario 2b	Variation (%)
Climate change	kg CO_2 eq	1.39E+03	1.31E+03	-6.3	1.28E+03	-8.3
Ozone depletion	kg CFC-11 eq	1.13E-04	1.19E-04	5.1	1.18E-04	4.5
Human toxicity, non-cancer	CTUh	1.87E-04	1.86E-04	-0.6	1.85E-04	-1.2
Human toxicity, cancer	CTUh	4.75E-05	4.75E-05	0.0	4.71E-05	-0.8
Particulate matter	kg $PM_{2.5}$ eq	1.14E+00	8.93E-01	-21.5	8.72E-01	-23.4
Ionizing radiation, effects on human health (HH)	kBq U^{235} eq	8.89E+01	9.71E+01	9.3	9.13E+01	2.8
Photochemical ozone formation	kg NMVOC eq	4.13E+00	3.84E+00	-7.1	3.74E+00	-9.5
Acidification	molc H^+ eq	8.16E+00	7.51E+00	-7.9	7.16E+00	-12.2
Terrestrial eutrophication	molc N eq	1.63E+01	1.52E+01	-6.8	1.48E+01	-8.8
Freshwater eutrophication	kg P eq	1.13E-01	1.13E-01	0.0	1.10E-01	-2.7
Marine eutrophication	kg N eq	2.28E+00	2.18E+00	-4.3	2.15E+00	-5.6
Freshwater ecotoxicity	CTUe	1.72E+03	1.72E+03	-0.1	1.71E+03	-0.5
Land use	kg C deficit	4.30E+03	4.29E+03	-0.3	4.29E+03	-0.3
Water resource depletion	m^3 water eq	1.08E+02	1.08E+02	0.3	1.05E+02	-2.4
Resource depletion	kg Sb eq	1.47E-01	1.50E-01	1.9	1.52E-01	3.3

The highest reduction (about 23%) is obtained for particulate matter impact, due to the substitution of the Chinese and Indian electricity mixes, which include a high share of electricity from coal. The use of EU mix and EU mix 2030 for textile production leads also to a reduction of climate change impact, up to 8% in the case of EU mix 2030. Impacts on human toxicity (non-cancer effects), photochemical ozone formation, acidification, eutrophication (terrestrial, marine, and freshwater) and freshwater ecotoxicity are reduced as well. The lowest reduction happens for land use (less than 1%), whereas acidification is reduced by 8% in the case of the EU mix and by 12% in the case of EU mix 2030. Scenario 2a (EU mix) shows no decrease in human toxicity, cancer, and freshwater eutrophication. On the contrary, the two scenarios show a slight increase of the impact on ozone depletion, ionizing radiation, and resource depletion; and employing the EU mix is also related to a slight increase in water resource depletion. The increase in ionising radiation is due to the higher share of nuclear energy compared to the energy mix used in the baseline.

Additional impacts are generated also for resource depletion (greater for the EU mix 2030 than for the EU mix). In order to better analyse the effect of the scenarios on fossil and mineral resources, the same inventory was characterized also using CML-IA method v. 4.8 as implemented in the EF 3.0 method presented before (Figure 11). This method applies the abiotic depletion (ADP) concept, as it is in the version recommended in the ILCD method, but considering the contribution of energy carriers and mineral and metal resources separately. In addition, it takes the crustal content as reference for the calculation of the ADP, instead of the reserve base, as it is in the version recommended in the ILCD method.

Results of this sensitivity analysis (included in Figure 11 as FRD and MRD) show that the two alternative electricity mixes contribute to reduce the impact on fossil resources, but cause an increased impact on mineral and metal resources. A contribution analysis highlighted that this is mainly due to the use of zinc in the infrastructure of German heat and power co-generation from biogas, which is part of the EU electricity mix (with different shares in the EU mix and in the EU mix 2030).

Figure 11. Scenario 2a (EU mix) and scenario 2b (EU mix 2030) in comparison with the baseline scenario (with total from the baseline set as 100%) - split into the contributions of (a) the various product groups and (b) the life cycle stages.



(For the abbreviations of the names of ILCD impact categories see note to Figure 9; additional impact categories from CML-IA method: FRD: fossil resource depletion, MRD: mineral and metal resource depletion)

8.5. Scenario 3 – Improving reuse (second-hand products)

Description and aim:

The scenario aims at assessing potential effects of the promotion of reuse practices (e.g. through donation at a charity organization or selling to second hand shops). The scenario focuses on textile products (clothes) and furniture.

Area of intervention:

- Hotspot addressed: impacts from the production of textiles and furniture.
- Product groups: clothes and furniture.
- Life cycle stage: EoL by adding a further use phase, before sending the product to final EoL scenario.

Policy relevance: Circular economy package (EC 2015).

Rationale for building the scenario:

In this scenario it is assumed that a share of the textile and furniture products that are purchased by an average EU citizen (i.e. which are part of the F.U. of the BoP household goods) is reused by other users, before getting to the EoL scenario modelled in the baseline (Table 34).

Table 34. EoL scenario for textiles and furniture, as assumed in the baseline of the BoP household goods.

Textiles		**Furniture**	
Treatment	**Share (%)**	**Treatment**	**Share (%)**
Landfilling	52	Landfilling	55
Incineration	37	Incineration	45
Recycling, of which: 87% as rags 13% as insulation material (in substitution of rock wool)	11, of which: 9.6 (rags) 1.4 (insulation material)		

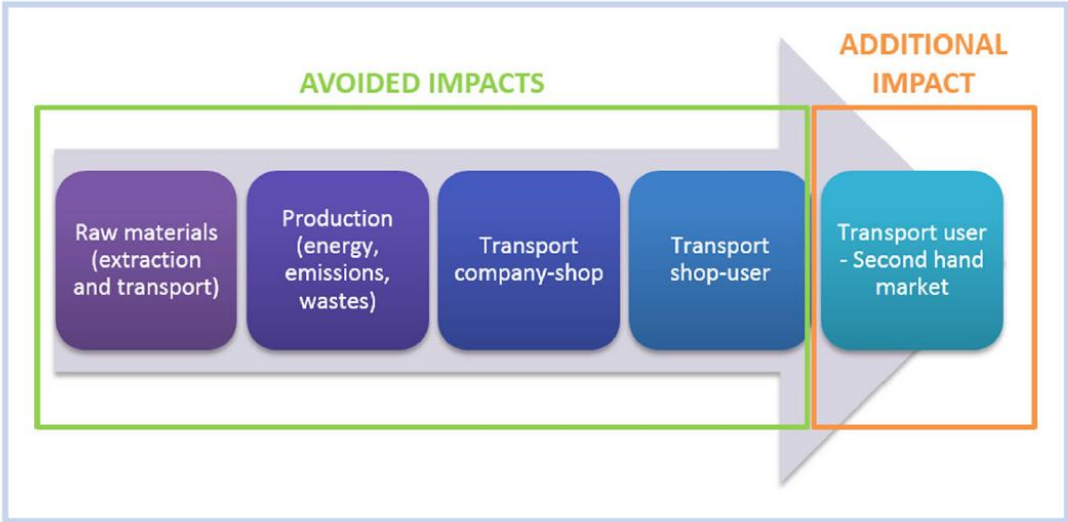
The reuse of products as second-hand items entails both the prolongation of the lifetime of that product and any additional activity needed to ensure the reuse, such as the transport of the product from the first user to the second one or from the first user to a second-hand shop and then to the second user.

As explained in section 3.1, the F.U. of the BoP household goods is composed by the number of items purchased in one year, calculated as apparent consumption per person per year. This means that the baseline model does not include explicitly the duration of the product as number of years for which that product is owned by the consumer. In fact, the F.U. does not consider the stock of products (e.g. T-shirts) owned by a citizen, but only the amount of new product purchased every year. The lifetime of the products is implicitly included in that number: in fact, if on average a product is lasting more years than another (as it could be the case for a wardrobe compared to a T-shirt), the number of new items purchased every year is most probably lower than for a less lasting product.

The way in which the baseline scenario is modelled allows for a more robust definition of the F.U. (because the apparent consumption can be easily calculated from statistics, without the need to make an assumption for the average lifetime of products). However, this specific feature limits the possibility to model reuse simply as an increase in the number of years for which the product is used. Therefore, a different approach needs to be considered.

The rationale applied to model the scenario is based on the methodology proposed by WRAP (2011) and further developed by Castellani et al. (2015) to calculate the potential environmental benefits of reuse through second-hand shops. The study by Castellani et al. (2015) assumes that, in case the item sold as second-hand product is bought to substitute the purchase of a new item, this has two main effects: an additional impact coming from the transport to the second-hand user and an avoided impact from the production of a new item (i.e. avoided impact of life cycle phases up to the retail and transport to client) (Figure 12). However, considering a full substitution (i.e. a substitution ratio of 1:1, re-used product : new product) is a limited approach when assessing the environmental benefits of re-use (second-hand) strategies.

Figure 12. Avoided impacts and additional impact coming from the reuse of products.

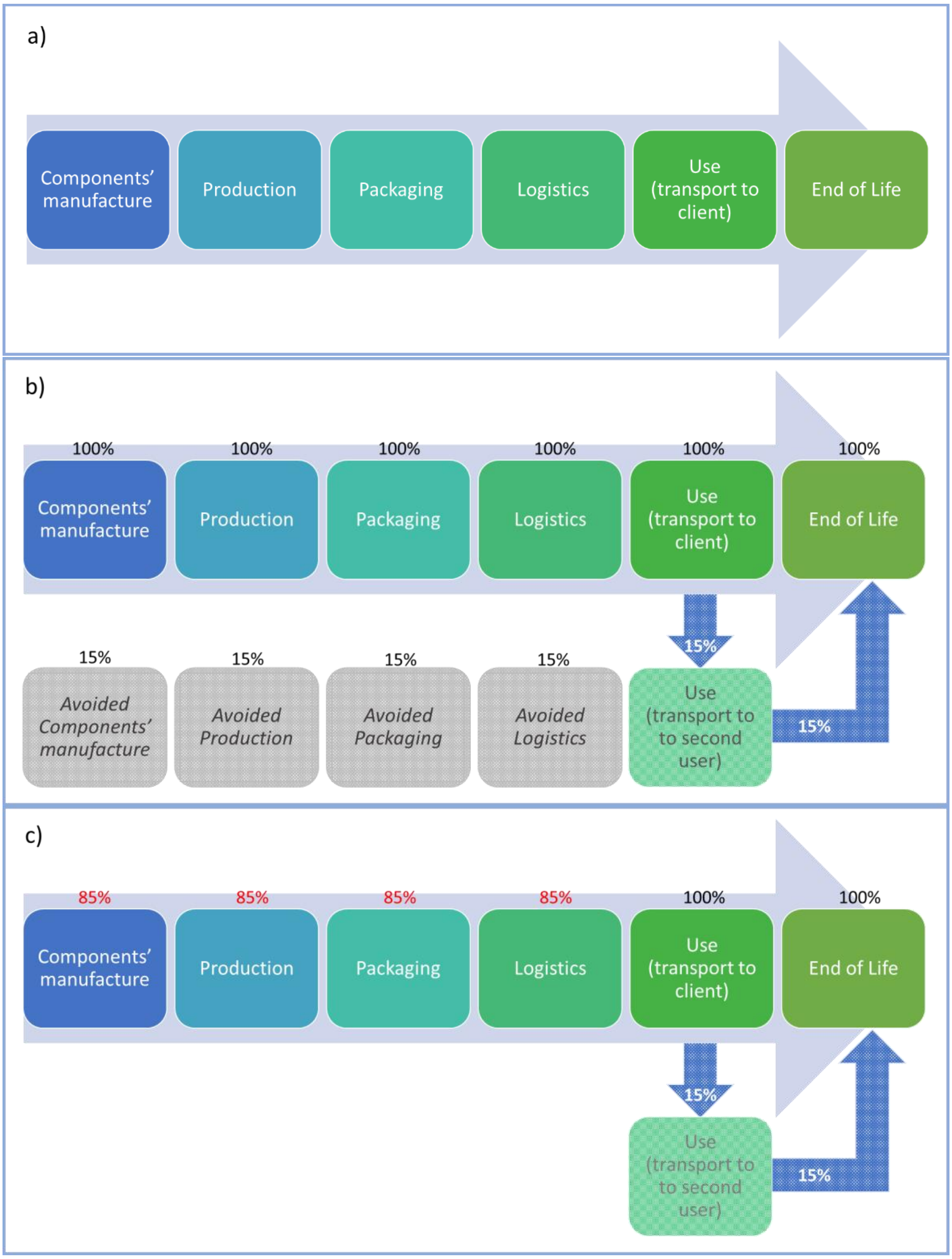


Source: Castellani et al. (2015).

In the present study, the additional transport of the reused product from the first user to the second one is modelled in the use phase of the reused product. The avoided impact of the first stages of the life cycle, thanks to the reuse of a share of products bought by citizens, is modelled as a reduction of the impacts in the first stages of the life cycle of the product.

Figure 13 compares the life cycle stages in the baseline and in scenario 3, which includes a share of products that are reused. In Figure 13a) a conventional life cycle for a product in the BoP household goods is depicted, from components manufacture to the EoL. When calculating the inventory of BoP household goods, the inventory of a reference product, as illustrated here, is multiplied by the quantity of new products of that type that are bought in one year (apparent consumption) to calculate the reference flow. In Figure 13b) it assumed (as an example) that 15% of the new products bought by EU citizens follow a slightly different route, with the addition of a "second-life" before the EoL. As explained before, this implies an additional transport compared to the conventional route, because the product needs to be transferred from the first user to the second one (either directly or through a reseller, e.g. a second-hand shop). In case the second-hand product fully substitutes the purchase of a new one, the avoided production of a new product (up to the purchase, i.e. including the logistics) should be included in the modelling. In scenario 3, this is done by reducing the amount of the upstream phase (before the first use) by 15%, to account for the fact that the "second life" of the 15% of the products bought in one year is assumed to replace the production of new ones. As illustrated in Figure 13c), in scenario 3 the use phase is still allocated to 100% of products (because also the products that are then reused have a first use phase) and the same happens for the EoL (because also the reused product will end up in the EoL scenario after their "second life").

Figure 13 a-c. Comparison of life cycle stages in case of a conventional life cycle of a product and in case of a reuse as second-hand-product: a) conventional life cycle, b) reuse of a fraction of products purchased, c) reuse and avoided impacts as modelled in scenario 3.



Parameters modified in the model:

To calculate the share of items purchased that goes into a "second life" (15% in the example showed in Figure 13), it is necessary to know how many people would engage in reuse practices (i.e. selling/donating and buying/using second-hand products) and which share of the product they buy would be affected by this activity.

Results of an Eurobarometer survey on the attitudes of EU citizens towards waste management and resource efficiency (Eurobarometer, 2014) show that on average (with variations across Member States) 55% of respondents would buy second-hand furniture and 34% would buy second-hand textiles.

Those data are confirmed to some extent by a survey of 8,670 respondents carried out in Belgium, Italy, Portugal, and Spain. The results indicated that 52% of the respondents participated in second-hand market activities (either as buyers or sellers or both) (OCU et al., 2016).

On the contrary, there is no information available on the share of products that may be sold through second-hand market, after their "first life". Therefore, two assumptions are made for the scenario.

As a first option (scenario 3a), it is assumed that only 25% of the furniture and apparel items bought by EU citizens goes into the second-hand market and have a "second life" before EoL. There could be several reasons for not selling them as second-hand products, e.g. they are discarded because they are damaged, they are considered old-fashioned (especially for clothes), it is difficult to carry them to the second user (especially for furniture), etc. In this case, the reduction applied to the first part of the life cycle of products (as illustrated in the example in Figure 13c) is 13.75% (equal to 25% of the items, applied by 55% of citizens) for furniture pieces and 8.5% (equal to 25% of the items, applied by 34% of citizens) for apparel pieces.

A second option (scenario 3b) explores the maximum potential of reuse, by assuming that 100% of the items purchased by the share of citizens that participate in reuse activities (55% in the case of furniture and 34% in the case of textiles) will have a second user. In this case, the reduction applied is 55% for furniture and 34% for textiles (apparel).

In both cases, the additional transport from the first user to the second one is assumed to be equal to the transport to client modelled in the use phase of the "first life".

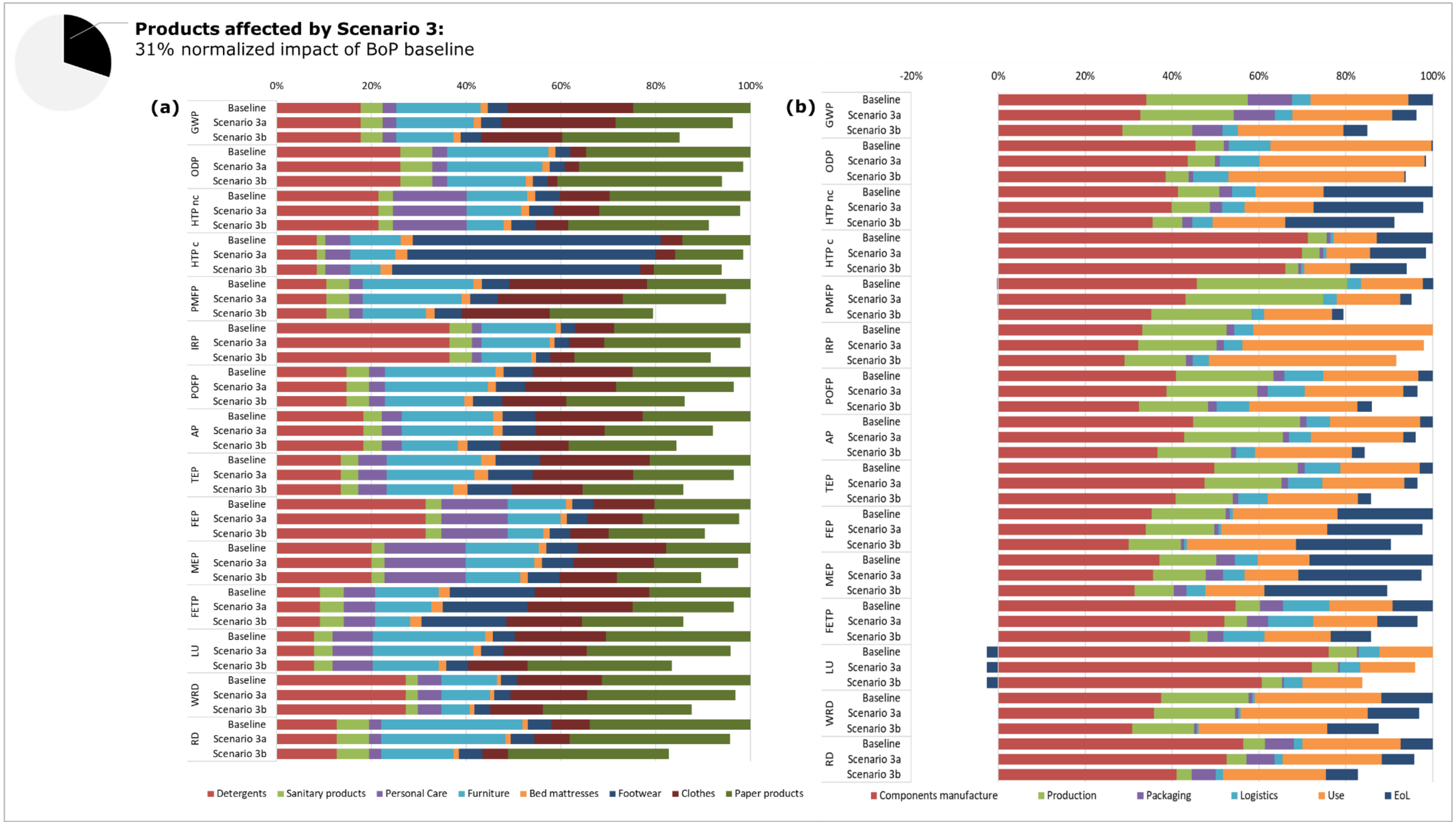
Results:

When scenario 3a is applied, the effect on the overall impact of the BoP household goods is quite limited and the reduction of impact is below 5% in all the impact categories (Figure 14).

When the more optimistic assumption of 100% of items reused is applied (scenario 3b), the effect is larger and the reduction of impacts is up to 20% in some impact categories. The highest reduction (21%) occurs for particulate matter, thanks to the avoided production of furniture components and of textiles, including the use of electricity from countries outside the EU.

In general, the reuse of clothes generates a larger impact reduction compared to furniture (Figure 14). This is because the transport of furniture pieces from the first to the second user needs to be done with a van or a truck, whereas the transport of clothes can be done by private car (or, in the case it is done by van, a higher number of pieces can be transported at the same time). The need of additional transport for furniture is also the reason for the slight increase of impact on ozone depletion in scenario 3a. On the contrary, when a higher share of reuse is applied, the additional impact is compensated by the higher savings in the production phase. For the first phases of the life cycle, up to the use phase, the scenarios entail a reduction of the impact (Figure 14), due to the assumptions made to model the extension of the lifetime of products, as explained before.

Figure 14. Scenario 3a (25% reuse) and scenario 3b (100% reuse) in comparison with the baseline scenario (with total from the baseline set as 100%): split into the contributions of (a) the various product groups and (b) the life cycle stages.



(For the abbreviations of the names of impact categories see note to Figure 9)

Since furniture and textiles together contributed on average to about 31% of the normalized impact of the entire BoP household goods, the result of scenario 3b can be considered promising. Of course, it is hardly feasible that people involved in reuse activities will apply this option to 100% of the furniture and apparel pieces that they own, however the scenario shows that there is an interesting potential in those activities. Some apparel brands, like Filippa K, Boomerang, Zara, H&M, and I:CO, have already put in place take-back schemes to ensure proper collection of textile products from customers in their stores for reuse/resell, and eventually recycle them if enable to reuse (Aziz, 2018). Awareness campaigns could also leverage the involvement of a higher share of citizens compared to the ones that already declared their willingness to participate in the second-hand market. It could be also interesting to explore the possibility to include footwear in the analysis. At the moment there are no data on the current share of footwear that is reused neither the share of citizens willing to buy or sell footwear after use, probably because it is a relatively small segment compared to the second-hand market for clothes. If those data will become available in the future, footwear could be easily included in the scenario and could contribute to increase the reduction of impacts from the household goods consumption sector.

8.6. Scenario 4 – Using textiles with recycled input materials for clothes manufacturing

Description and aim:

The scenario aims at assessing potential effects of the use of recycled textiles as input material for some of the household goods considered in the study.

Area of intervention:

— Hotspot addressed: impacts from the production of textiles as product components.

— Product groups: clothes, furniture, and footwear.

— Life cycle stage: components manufacture.

Policy relevance: Circular economy package (EC 2015).

Rationale for building the scenario:

The production of textiles (either from synthetic or natural fibres) has some relevant impacts, related to the use of virgin resources and, in case of natural fibres, to the agricultural activities needed to cultivate them. One of the options to reduce the environmental burden of textile production would be to use recycled input fibres. In principle, all textiles could be recycled at the end of their life (Hawley, 2006). However, the recycling of textiles (either from apparel or household items) is very rare in practice, and the recycling processes of textile fibres which are performed today are mainly down-cycling, which means a material of lower quality than the original material is produced, e.g. to be used as input in cleaning wipes or padding in car seats (Peterson, 2015).

There are several reasons fostering this situation. The first one is economic: since the cost of textiles today is very low (also because they are generally produced in low-wage countries), the use of virgin materials such as cotton and crude oil is cheaper than recycling of textile fibres (Peterson, 2015). Secondly, more technical-related issues such as the use of fibre blends in textile products, the need to separate fibres of different colours, and the presence of non-textiles materials (e.g. buttons and zippers) limit the viability of fibre-to-fibre recycling (Elander & Ljungkvist, 2016). Thirdly, the collection rate of textile waste is generally quite low, so there is a lack of input material for recycling activities. Of course, this could be also linked with the lack of demand of those materials, due to the economic reasons explained before. This would mean that, in case more economically viable options would be available, the collection might be improved.

The existing technologies for textile recycling techniques can be divided into two groups: mechanical recycling and chemical recycling (Björquist, 2017; Leonas, 2017; Vadicherla and Saravanan, 2014).

Mechanical recycling of textiles entails the disintegration of the textile material by mechanical action back to a fibrous form. Mechanical recycling may lead to a down-cycled material of mixed fibres. Shredded textiles are commonly used as bulk material, e.g. padding, inside new products (Björquist, 2017). An interesting exception regards denim waste, which can be more easily identified in textile waste sorting. There are several jeans companies, such as G-star and Nudie jeans, which use post-consumer denim waste in their products (Luiken and Bouwhuis, 2015). However, one problem with this type of recycling for yarn spinning, especially when using post-consumer waste, is the loss in fibre length. Therefore, recycled fibres are usually blended with a proportion of virgin fibres, to obtain a high quality yarn (Gulich, 2006).

Another type of mechanical recycling is the reprocessing of thermoplastic polymers, from plastic waste, to form new filaments or other types of products (Leonas, 2017). The most well-known example of commercial success for textile applications is the processing of PET bottles into new polyester fibres[20] (Vadicherla and Saravanan, 2014). Currently, almost 70% of PET from bottle is recycled into fibres (Shen et al., 2010).

Chemical recycling entails the chemical processing of the polymers of the fibres, which can be fully or partly depolymerized (Shen et al., 2010). The monomers or oligomers can then be used as feedstock to produce new polymers. The Japanese company Teijin has developed a closed-loop system for recycling of returned polyester garments by depolymerisation to dimethyl terephthalate (monomer) and subsequent re-polymerization to textile fibres (Teijin, 2017). The technology was developed in collaboration with Patagonia Inc., to recycle discarded polyester apparels chemically to new polyester fibre of enough quality to be used as raw material (Patagonia, 2011). The Swedish company re:newcell have patented a technology (Henriksson and Lindström, 2013) for producing a cellulose raw material from old cotton textiles. However, all these processes are still limited in terms of market coverage, because the best results can be obtained when input materials are composed by a single type of fibre. This is rarely the case with post-consumer textile waste, because most of the garments that are on the market today consist of a mixture of materials (Elander & Ljungkvist, 2016). The most common blend is between polyester and cotton and it is usually called "polycotton".

Several techniques are available for separating the two components of polycotton and then to recycle one of the two, even if there is yet no commercial large scale recycling of polyester and cotton blended textiles (Björquist, 2017):

— One of the options studied (and applied) is to dissolve cellulose of polycotton fabric in N-methylmorpholine N-oxide (NMMO) (Lyocell process) and then to recycle the polyester (Sankauskaitė et al., 2014).

— An approach that would preserve also the cellulose in cotton is to depolymerize the polyester. Alkaline hydrolysis was also used by Palme et al. (2017) and pure raw materials of polyester monomers as well as a cotton residue was produced from new hospital sheets containing cotton and polyester.

— A recent patent by VTT- Technical Research Centre of Finland (VTT, 2017) presents a modification of the viscose process, using cellulose carbamate instead of carbon disulfide (CarbaCell process). According to the inventors, this process can be easily implemented in existing viscose processing plants, can reduce the environmental impacts associated to the use of carbon disulfide and allows for the recovery of both fibres (cotton and polyester). The technology is now at a pilot stage.

As mentioned before, open-loop recycling of PET, from bottles to polyester fibres is a well-established and well-known technology. On the contrary, closed-loop recycling of fibres from textile waste is a process still under development, with only some examples already in place in the market (mainly at the pilot stage, especially in the case of recycling from polycotton).

The present scenario focuses on the first type of recycling, by modelling the use of recycled PET pellets and fibres, obtained from collected PET bottles, used as input material for polyester textiles in the representative products of the BoP household goods.

<u>Parameters modified in the model:</u>

A dataset representing the LCI of PET pellet production through the recycling of PET bottles is modelled, based on the process described in Arena et al. (2003) and Shen et al. (2011).

The process described by the LCI dataset is classified as semi-chemical recycling according to Shen et al. (2010). This process is chosen because the quality of the staple fibre obtained through mechanical recycling of PET from bottles is usually more suitable for use in non-woven textiles. On the contrary, the filament obtained through semi-mechanical recycling (i.e. mechanical recycling with the addition of some chemical additives) is more suitable for use in footwear, technical textiles, and apparel.

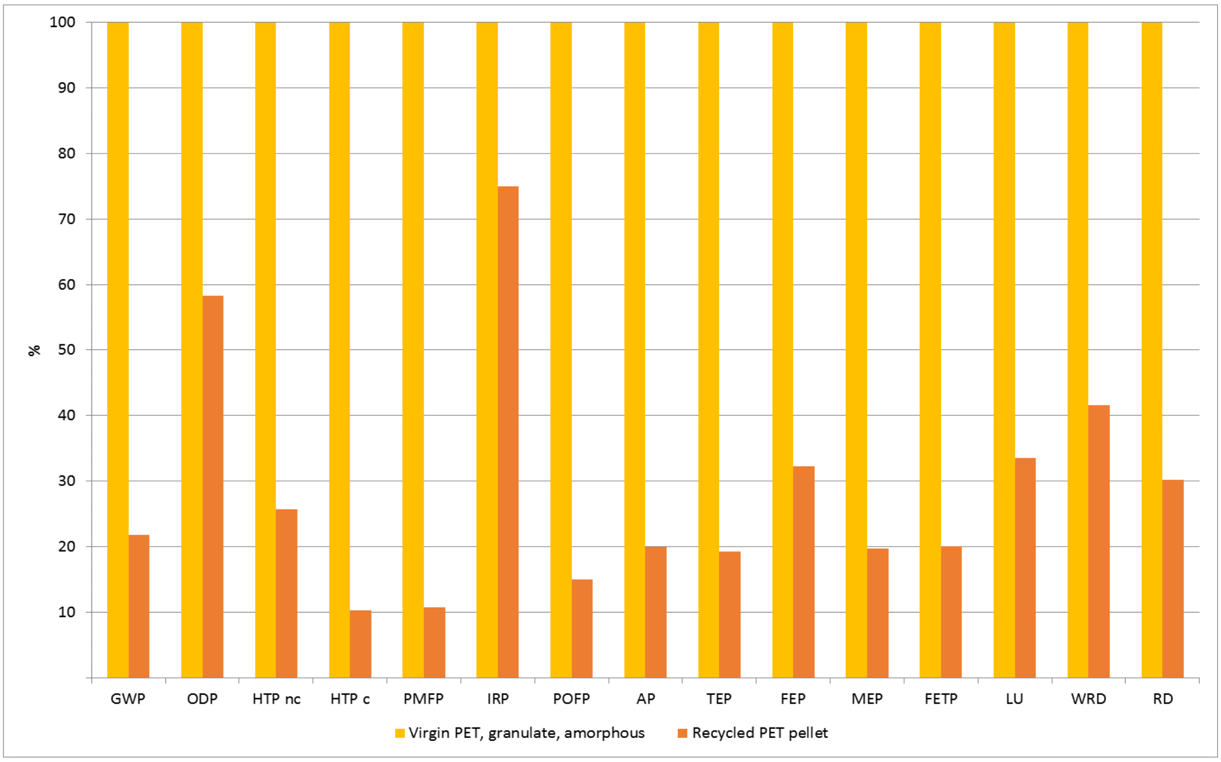
[20] In the textile industry, PET is referred to as polyester (Björquist, 2017).

This process entails two phases: the PET bottle-to-flake production and then the PET pellet production (from PET flakes). PET pellets are then used as input for the production of the polyester fibre used in textiles. The LCI for PET pellet production was substituted to the virgin PET pellet input (dataset "Polyethylene terephthalate, granulate, amorphous" from ecoinvent 3.2 database) in the dataset representing polyester textile production, used as input in the following representative products: sanitary pad, upholstered seat (sofa), footwear (all types), T-shirt, jeans, and men trousers.

Results

The environmental profile of the recycled PET pellets shows a general reduction of the impacts compared to the virgin PET (ecoinvent dataset) (Figure 15). In general, the impact of recycled PET pellets is between 60% and 90% for all the impact categories, with the exception of ionizing radiation (25%) and ozone depletion (40%). The highest reduction occurs for human toxicity, cancer effects, and particulate matter (90% in both cases).

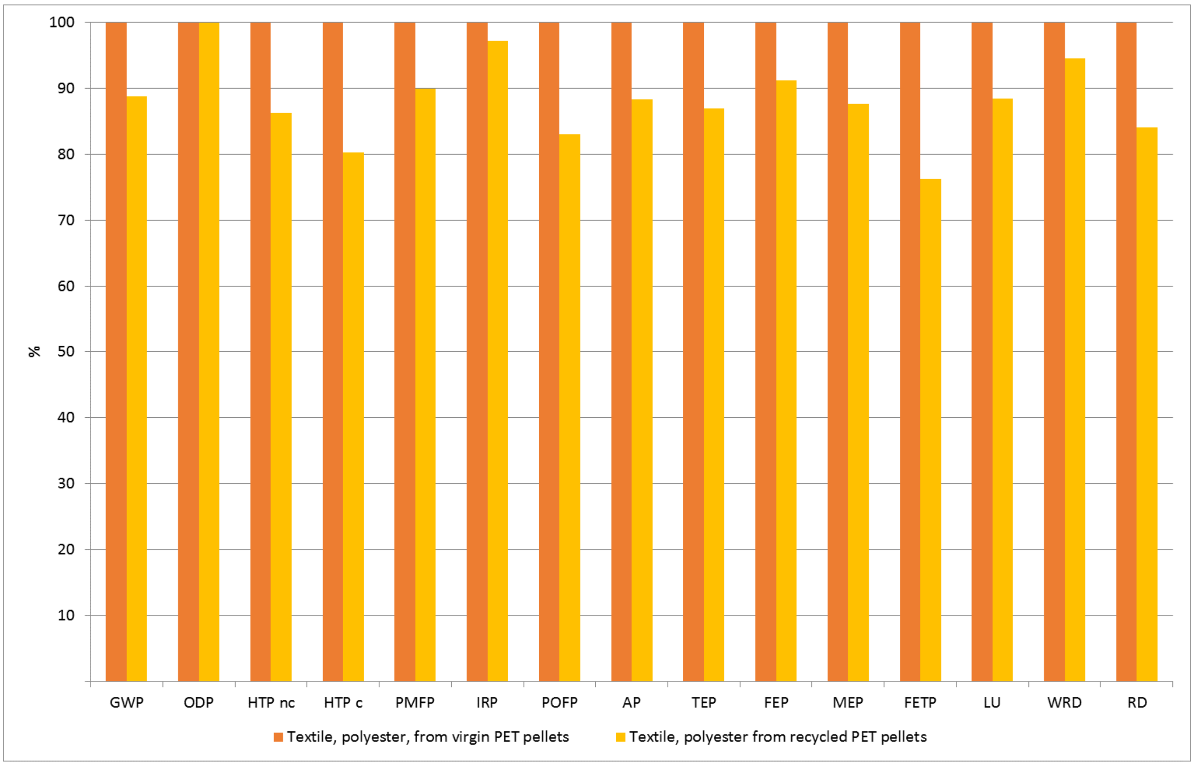
Figure 15. Comparison of the environmental profile of virgin PET and recycled PET.



(For the abbreviations of the names of impact categories see note to Figure 9)

When comparing the polyester textile obtained with the two types of PET pellets (virgin or recycled), the difference is lower, because of the contribution of other processes and materials needed to convert the pellets into fibres and then into textile (Figure 16).

Figure 16. Comparison of polyester textile obtained from virgin PET pellets or recycled PET pellets.

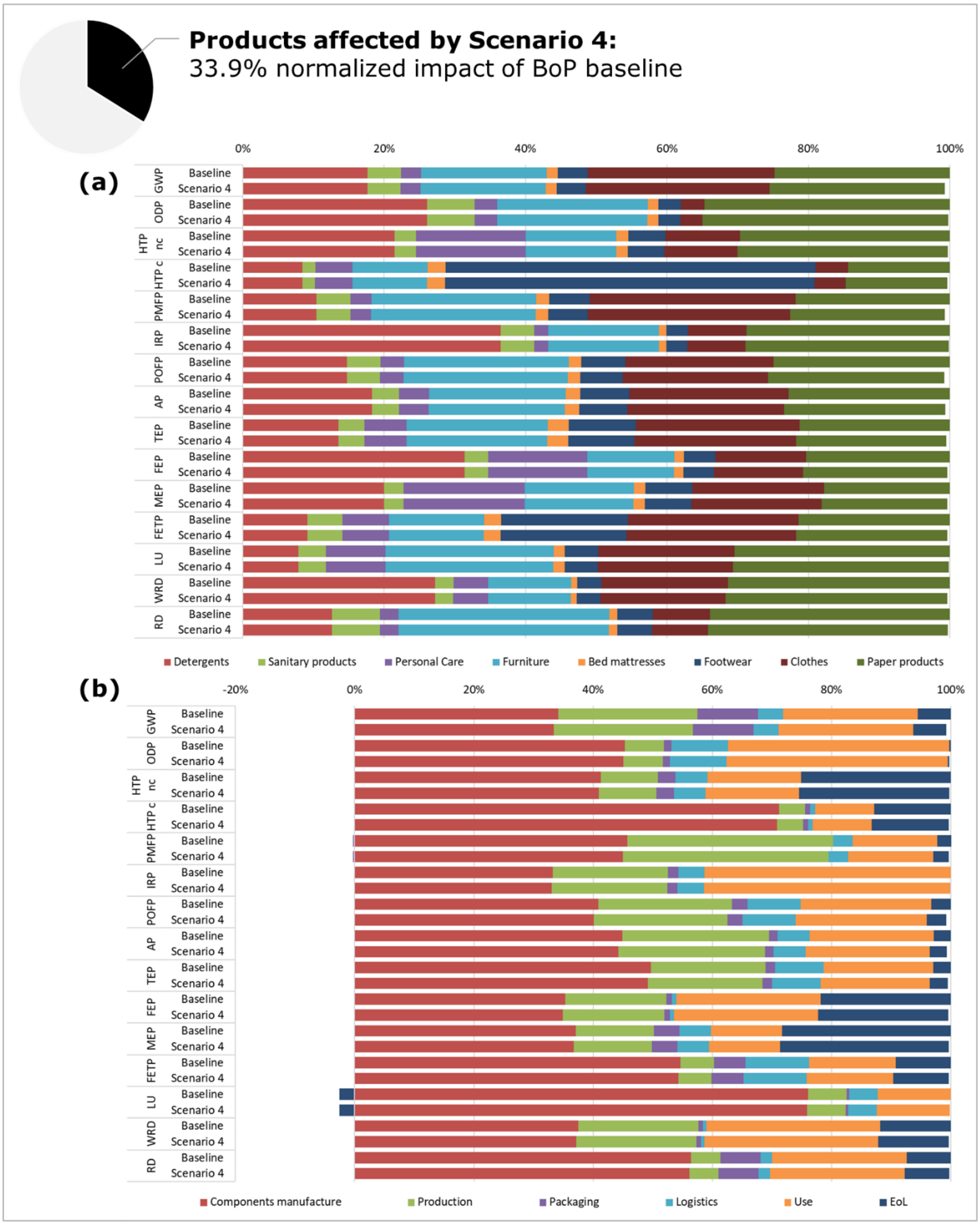


(For the abbreviations of the names of impact categories see note to Figure 9).

Figure 17 shows the results (with the contribution of product groups and life cycle stages) of scenario 4 at the BoP scale, i.e. the effect of using polyester textiles from recycled PET pellets in the reference products of the BoP household goods (as replacement of polyester textile whenever occurring in the products). As shown in the figure, the overall effect of the replacement on the impact of the BoP is generally below 1% for all the impact categories considered. This effect is very low considering that the eco-innovation evaluated is related to different products in the BoP household goods that contribute up to 33.9% of the normalized impact.

It would be interesting to assess the potential improvement that could come from the results of the ongoing research about the recycling of polycotton, once sufficiently robust inventory data would be available, because of the large share of products potentially involved. That type of solution could also have a potential role in helping the implementation of a circular economy strategy, because it is applicable at the end of life of textiles. For the same reason, it could also help to enlarge the share of recyclable textiles and the share of recycled content in apparel items.

Figure 17. Scenario 4 in comparison with the baseline scenario (with total from the baseline set as 100%) – split into the contributions of (a) the various product groups and (b) the life cycle stages.



(For the abbreviations of the names of impact categories see note to Figure 9)

8.7. Scenario 5 – EU Ecolabel scenario on liquid soap

Description and aim:

The aim of this scenario is to examine the potential environmental benefits coming from the use of an EU Ecolabelled product, compared to base-case liquid soap products modelled in the baseline scenario.

Area of intervention:

— Hotspot addressed: impacts from the whole life cycle of liquid soap.

— Product group: personal care.

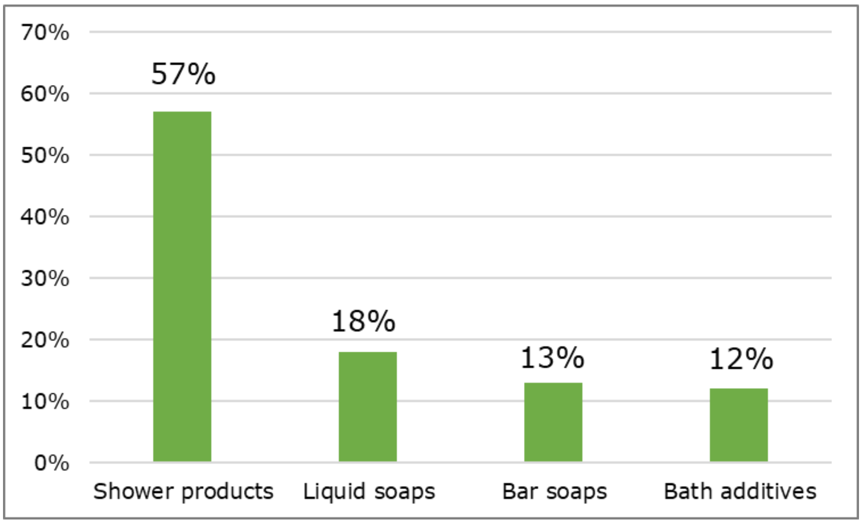
— Life cycle stage: components manufacture (formulation of the product) and use (dosage).

Policy relevance: Commission Decision of 9 December 2014 establishing the ecological criteria for the award of the EU Ecolabel for rinse-off cosmetic products (i.e. personal care).

Background information:

Liquid soaps represent a relevant percentage of all bath and soaps products, being more popular than bar soaps (Figure 18).

Figure 18. Market share of bath and soap products.



Source: Mintel Database. European Market, 2017.

The LCA study done for the base-case liquid soap included in the baseline scenario (Escamilla et al., 2012) unveiled that environmental impact hotspots occur in different life cycle stages of the product: use stage, release to water, packaging, and chemicals used as raw materials. The relative contribution to environmental impacts and the improvement potential of each stage is summarized below, according to LCA study results obtained using the IMPACT 2002+ endpoint impact method (all midpoint impact categories normalized, weighted, and aggregated to a single value):

— Components manufacture: 10% of environmental impacts are associated to this stage. The potential of improvement and the regulation of the EU Ecolabel are high. Selecting less harmful substances from each functional group will improve the environmental profile of the product, since besides this stage these changes will also have benefits during manufacturing, use of the product, and end of life wastewater treatment.

— For manufacturing, representing on average 11% of impacts, limited improvement potential is expected. Moreover, resources consumption during manufacturing is not regulated by EU Ecolabel.

— Packaging has a high improvement potential and several eco-innovations actions can be applied. Packaging of liquid soaps has a contribution on average of 17% of the overall impact. Decreases in weight results in direct decreases of environmental impacts. Measures to decrease the weight are: increase capacity, lighter packaging, and refilling systems. This issue is regulated by EU Ecolabel through the Packaging Impact Ratio criterion (Packaging), which calculates through a formula the maximum ration between the weight of the packaging and the weight of the content, including variables such as refilling systems and recycled content. Since decreasing the use of virgin materials decreases the environmental impact, increasing the recycled content will be explored as well.

— Distribution has an average of 8% of contribution of product environmental impact. Improving transport efficiency (logistics) and decreasing weight of packaging can reduce the environmental impact due to saving of fossil fuel use.

— Use contributes to an average of 24% of the impact of the product. Reducing dose and water consumption can bring benefits in this stage.

— Release of product into water after its use contributes to 19% of the impacts. Improvements on formulation using substances less toxic will reduce the impact coming from wastewater treatment.

In the baseline scenario, the functional unit for this product group has been defined as a bottle of liquid soap containing 255 g of product, related to the number of cleaning actions by bottle. The same functional unit is used in the eco-innovation scenario.

<u>Rationale for building the scenario:</u>

The eco-innovation scenario for liquid soap has been defined incorporating modifications from the base-case scenario, according to the current EU Ecolabel requirement criteria of rinse-off cosmetics (i.e. personal care). For those areas where improvement potential was identified but that are not directly covered by EU Ecolabel criteria, sensitivity analyses have been modelled. The summary of the main changes for each life cycle stage and the rationale for each modification are detailed in the sections below.

To define the **components manufacture**[21] for the eco-innovation scenario, the following steps and sources of information have been followed (for all the scenarios with a change in the formulation of products, i.e. scenarios 5, 6, 7, and 8):

— Analysis of the formulation of the base-case product. Those ingredients posing a higher environmental impact and/or which are restricted by the EU Ecolabel have been identified in order to be substituted in the eco-innovation product scenario.

— Analysis of components of currently EU Ecolabelled products. Five products representative from the countries with a major number of EU Ecolabelled products in the market have been selected. Information from their formulation has been gathered from a commercial market database (Mintel database).

— Theoretical formulation of a standard EU Ecolabelled product, ensuring (based on expert-knowledge) that the final product will comply with the fitness for use and technical performance required by EU Ecolabel, and that it is equivalent to the base-case product. The formulation has been modified according to the five available commercial formulations and considering the sustainability limitations from EU Ecolabel criteria. The formula was built based on current EU Ecolabelled products on the market and checked by experts in the field. However, its performance was not tested. The formulation used in the scenario is presented in Table 36.

— Analysis of the EU Ecolabel criteria for rinse-off cosmetics (i.e. personal care) with requirements regarding raw materials:

[21] The components manufacture life cycle stage comprises the substances used in the formulation of the final product (including the raw materials extraction and processing) and the transport of these substances from the supplier to the production site.

- Criterion 1 – Toxicity - Critical Dilution Volume (CDV)
- Criterion 2 – Biodegradability
- Criterion 3 – Limitation of hazardous substances

— The values of CDV and biodegradability have been analysed in both formulations in order to verify that the EU Ecolabelled formulation is compliant with the EU Ecolabel criteria and that all changes on formulation allow a better performance on these criteria (Table 35). For the EU Ecolabelled formulation the CDV is higher than the base-case formulation (but still far below the threshold), since adjustments had to be done in order to be compliant with Anaerobically non-biodegradable (ANBO) and Anaerobically non-biodegradable (aANBO) thresholds.

Table 35. Score for Criteria 1 and 2 of EU Ecolabel for soaps.

	CDV	ANBO (surf)	aANBO (surf)	ANBO (org)	aANBO (org)
EU criteria thresholds	18,000	0	0	25	25
Base-case formulation	5,799.00	0	1.20	0	93.60
EU Ecolabel formulation	6,971.60	0	0.00	23.90	23.90

Table 36. Components formulation for eco-innovation scenario. Liquid soap.

Input/output	Function	BASELINE SCENARIO		ECO-INNOVATION SCENARIO	
		Formulation (%)	Quantity (g)	Formulation (%)	Quantity (g)
Water		84.4	216.35	84.34	215.067
Sodium lauryl ether sulphate	Surfactant	6.8	17.53	7.50	19.125
Disodium Cocoamphodiacetate	Surfactant	2.5	6.503	-	-
Sodium chloride	Other	0.5	1.403	2.20	5.610
Cocoamidopropyl betaine	Surfactant	1.0	2.678	2.50	6.375
C8-C16 fatty alcohol glucoside	Surfactant	1.2	3.06	-	-
Coco glucoside	Surfactant	-	-	2.50	6.375
Polyol coconut fatty acid ester	Emolients	0.5	1.275	-	-
Citric acid monohydrated	PH adjustment	0.5	1.275	0.50	1.275
Benzyl alcohol	Preservatives	0.2	0.501	-	-
Potassium sorbate	Preservatives	0.03	0.085	0.30	0.383
Sodium benzoate	Preservatives	0.2	0.501	0.15	0.765
Sodium chloride	Other	2	5.1	-	-
Methylchloroisothiazolinone and Methylisothiazolinone (CMI:MI) (3:1).	Preservatives	-	-	0.01	0.026
TOTAL		100	255	100	255

This life cycle stage includes the transport of all ingredients to the production site except water. The same distances and the same transportation modes as in the base-case scenario were assumed (Table 37).

Table 37. Inventory values for transport of component. Liquid soap.

Transport of raw materials to production site		
Freight lorry 16-32 kt	500	km
Freight, sea, transoceanic	15,000	km

The **production** life cycle stage is not covered directly by the rinse-off cosmetics EU Ecolabel criteria. For this reason any changes from the base-case scenario have not been done for the eco-innovation scenario in this stage. Nevertheless, there are different EU environmental policies referring to the manufacturing process, such as EMAS, ISO 14001, etc. The production impact is mainly influenced by the energy consumption. A reduction of the impact could be achieved by the reduction of the energy consumed or the use of renewable energy sources. A sensitivity analysis has been done varying the energy consumption to estimate the influence of this improvement measure in the final impact results. Details and results are presented in section 8.13.

Regarding the **packaging**, the following variations have been introduced based on the EU Ecolabel packaging criterion. Criterion number 4 of rinse-off cosmetics EU Ecolabel criteria regulates the relative weight of packaging and content, establishing a maximum ratio of 0.28 g of packaging by gram of content, this ratio is named Packaging Impact Ratio (PIR). The formula for the calculation of this PIR includes primary and secondary packaging, as well as factors as refilling and recycled materials (Box 3).

Box 3. Packaging Impact Ratio (PIR).

$PIR = (W + (W_{refill} \times F) + N + (N_{refill} \times F))/(D + (D_{refill} \times F))$

Where:

— W — weight of packaging (primary + proportion of secondary (1), including labels)(g)

— W_{refill} — weight of refill packaging (primary + proportion of secondary (1), including labels) (g)

— N — weight of non-renewable + non-recycled packaging (primary + proportion of secondary (1), including labels) (g)

— N_{refill} — weight of non-renewable and non-recycled refill packaging (primary + proportion of secondary (1), including labels) (g)

— D — weight of product contained in the ‘parent’ pack (g)

— D_{refill} — weight of product delivered by the refill (g)

— F — number of refills required to meet the total refillable quantity, calculated as follows:

$$F = V \times R/V_{refill}$$

Where:

— V — volume capacity of the parent pack (mL)

— V_{refill} — volume capacity of the refill pack (mL)

— R — the refillable quantity. This is the number of times that the parent pack can be refilled

When F is not a whole number, it should be rounded up to the next whole number.

In case no refill is offered, PIR shall be calculated as follows:

$$PIR = (W + N)/D$$

The manufacturer shall provide the number of foreseen refilling, or use the default values of R = 5 for plastics and R = 2 for cardboard.

The current format of the packaging for the base-case product is a packaging of 255 mL of capacity with 39g weight, 100% virgin HDPE. These characteristics give an EU Ecolabel Packaging Impact Ratio (PIR) value of 0.306, whereas the current maximum PIR for these products according to EU Ecolabel criteria is 0.28. In the background report of the development of EU Ecolabel criteria for soaps, shampoos, and hair conditioners, 57 EU Ecolabelled products were analysed; results showed that non-refilling packaging average weight/content ratio for these products were 0.25, whereas for refilling products the average ratio was 0.17. For this reason, the following improvements are proposed:

1. Increase of the capacity from 255mL to 300mL.

Several capacity formats are found for these products on the market (Table 38). Therefore, it is considered feasible to assume an increase in the packaging capacity compared to the baseline scenario.

Table 38. Market share of packaging capacities for Liquid soap products (Escamilla et al., 2012).

Capacity (mL)	Percentage of products on the market (liquid soap, shampoos and hair conditioners) (%)
250	43
300	18
200	15
500	8
400	8
Other capacities	8

2. Change of material from virgin HDPE to HDPE with a 20% content of recycled PE.

Recycled content up to 25% in packaging is feasible without compromising the packaging barrier characteristics (both in an interior layer in multilayer packaging or in a mixed polymer in monolayer packaging). For recycled material, the inputs for recycling processes have been considered (i.e. electricity), without accounting for impact savings linked to substitution of virgin material in order to avoid double counting with End of life processing.

3. A refilling system with a lighter packaging (25g for refilling packaging).

According to EU Ecolabel criterion on packaging (criterion 4), five refilling actions have been considered, i.e. the parent packaging is refilled five times after its first use. It allows for important packaging material reduction. Some soap products have the option of refilling or reusable package, where the refill package is usually lighter than the conventional one. It is quite usual in hand-soaps where refillable package has a dispenser and refill package is a simple bottle. There exists some other soap products with refill packaging such as body liquid soap. Among all liquid soap products of the EU market, 10% have refilling systems. According to Background report of rinse-off cosmetics (Escamilla et al., 2012), refilling systems can provide packaging savings of nearly 80% of weight, which can be converted to approximately 80% of saving of environmental impact of the packaging stage, as it mainly results from raw material consumption. The assessment done in the background report shows that environmental impacts are directly proportional to the packaging weight. For instance, in accordance with the results obtained in the technical analysis, in the case of liquid soaps, by using a refilling system, the total environmental impact of the product decreases by 18% with respect to the original soap with non-refill packaging.

4. Lighter packaging due to material reduction: from 39g (for 255mL) to 42g (for 300mL).

Considering the refilling system and the capacities, the improved packaging for a functional unit of 255g of liquid soap is of 23.66g.

With these measures, the product will have a PIR value of 0.17 following the EU Ecolabel formula, being compliant with EU Ecolabel and being in line with data from current EU Ecolabelled liquid soap products.

For the end of life of packaging, the same hypotheses for the final treatment of packaging waste in the baseline have been considered. For the treatment of packaging waste, the base-case scenario considered a percentage of recycling of 31.9% for PE (Annex 2). Since the packaging is already considered as being 100% recyclable for the base-case scenario and the percentage is defined according to current EU statistics, no changes have been applied for the eco-innovation scenario. However, a sensitivity analysis has been done increasing the recyclability ratio. Details and results are provided in section 8.13.

For the **logistics** life cycle stage, the same values for both the base-case scenario and the eco-innovation scenario have been considered. However, a sensitivity analysis has been done testing the effect of using trucks with a better emission profile (EURO 6 vehicles). Details and results are provided in section 8.13.

Some EU Ecolabel requirements are related to the **use stage** regarding the dosage:

— EU Ecolabel requires for dosing system designs that allow a proper dosage avoiding spillage of the product due to over-doses;

— EU Ecolabel also has a criterion regarding fitness for use to guarantee a good washing efficiency.

For this reason, the dose has been reduced by 10% compared to the base-case scenario. This change reduces the quantity of soap by cleaning action for those life cycle stages linked to the product (manufacturing, packaging, and transport), whereas the quantity of water during use is unchanged. With this change, the quantity needed for the same number of cleaning actions, have changed from 255g to 229.5g. The quantity of annual consumption for the overall BoP would change from 1.82 kg/year to 1.64 kg/year (Table 39).

Some tests run by Deb Group (2018) concluded that a dose of 0.7 mL is the lowest dose sufficient to comfortably spread across all surfaces of most people's hand: the test concluded that this dose is the best balance between required effectiveness and economics. Most of liquid soap dispensers have a dosage system of about 1.5 mL. These data indicate that the doses defined in the base-case scenario can be decreased with a correct dosage system without compromising functionality.

Table 39. Dosage values for Use stage. Liquid soap.

	BASE-CASE SCENARIO		**ECO-INNOVATION SCENARIO**	
	Handwashing	Shower	Handwashing	Shower
Dosage (g)	2	13	1.8	11.7
Electricity	*Not included*	*Not included*	*Not included*	*Not included*
Water (L)	2.5	22	2.5	22

The quantity of water used has not been changed, being the same for the two scenarios, since EU Ecolabel does not cover use stage or information to users. Nevertheless, an environmental awareness from user could condition the use done for this product. Consumer behaviour can have a direct influence to the dose and the quantity of water consumed during a washing use. Therefore, this aspect has been addressed in a dedicated sensitivity analysis. Details and results are presented in section 8.13.

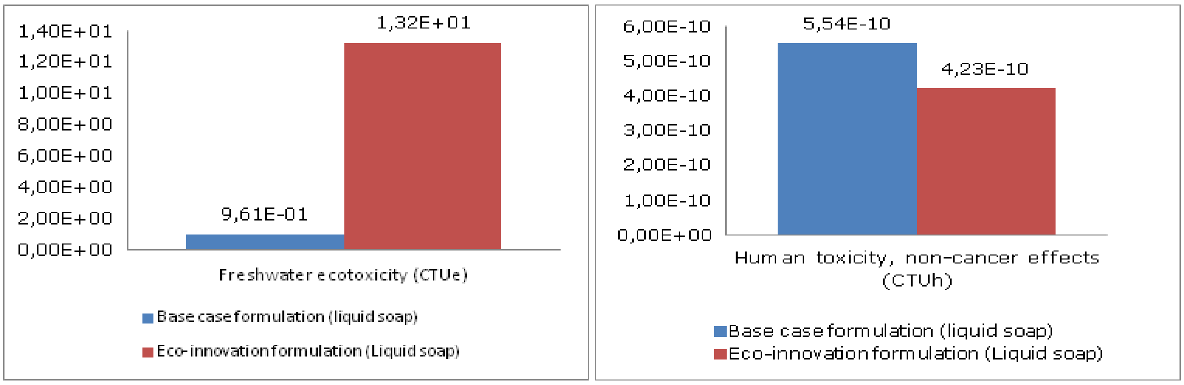
For the **End of life** stage, a standard urban wastewater treatment for the domestic wastewater generated (water consumed during use and the quantity of the product) has been modelled. These values have been kept from the base-case scenario without variation. EU Ecolabel includes a restriction on environmental hazardous substances, reducing the amount of toxic and pollutant substances that could end-up to the environment after the waste treatment stage. A further analysis has been done assuming direct release of these substances to the water compartment after use, as a worst-case scenario. With this analysis, the toxicity effect of these substances could be quantified, although several limitations are found in current impact methods and characterisation factors for these emissions (Table 40). When the substances of the two formulations are modelled as emissions to water, it can be observed that only few substances have characterisation factors (CFs), and only for toxicity categories (human toxicity and freshwater toxicity). The rest of impact categories do not have CFs for these emissions.

Table 40. Availability of characterisation factors for substances that are emitted to water at the EoL of liquid soap.

	BASELINE SCENARIO	**ECO-INNOVATION SCENARIO**	**CF for Human toxicity, cancer effects**	**CF for Freshwater toxicity**
Input/output	**Quantity**	**Quantity**		
Water	84.4%	84.34%	NA	NA
Sodium lauryl ether sulphate	6.8%	7.50%	NA	NA
Disodium Cocoamphodiacetate	2.5%	-	NA	NA
Sodium chloride	0.5%	2.20%	NA	NA
Cocoamidopropyl betaine	1.0%	2.50%	NA	NA
C8-C16 fatty alcohol glucoside	1.2%	-	NA	NA
Coco glucoside	-	2.50%	NA	NA
Polyol coconut fatty acid ester	0.5%	-	NA	NA
Citric acid monohydrated	0.5%	0.50%	NA	NA
Benzyl alcohol	0.2%	-	√	NA
Potassium sorbate	0.03%	0.30%	NA	NA
Sodium benzoate	0.2%	0.15%	√	√
Sodium chloride	2%		NA	NA
Methylchloroisothiazolinone and Methylisothiazolinone (CMI:MI) (3:1).	-	0.01%	NA	√

The impact on human toxicity is higher in the base case formulation than in the eco-innovation one (Figure 19), because of the presence of benzyl alcohol. On the other hand, the impact in the freshwater category is higher for the eco-innovation formulation due to the presence of CMI:MI. In both cases, results are not representative, since only 3 out of 13 substances have (eco)toxicity characterisation factors for water emissions.

Figure 19. Toxicity assessment of substances modelled as emissions to water.



For this reason, besides results of LCA, reference literature data on current impacts from the release of cosmetic and personal care products into the environment has been gathered. It is known that since these products are used in huge quantities in the EU, they are continuously released into the environment in very large amounts. Cosmetics pose the most pressing ecological problems compared to pharmaceuticals because they are used in much larger quantities and throughout the course of life and, being intended for external application, are not subjected to metabolic transformation; therefore they are introduced unaltered into the environment in large amounts during washing, showering or bathing (Juliano et al., 2017).

Even if most of the water containing substances from cosmetics and personal care products is treated in wastewater treatment plants, it has to be considered that the treatment plants are not always effective in removing chemicals used as cosmetic ingredients. Some of these substances can end up on surface water or they can accumulate in sewage sludge during wastewater treatment and then enter the environment as a fertilizer on crops. Some of the ingredients of these products are biologically active and are characterized by persistence and bioaccumulation potential, posing a threat to ecosystem and human health. Some cosmetic ingredients are considered environmental emerging pollutants of particular concern such as UV filters, some preservatives (parabens, triclosan), and microplastics (Juliano et al., 2017). The most problematic cosmetics ingredients for wastewater treatment (WWT) are restricted in EU Ecolabelled products (such as non-biodegradable surfactants, parabens, microplastics, etc.). These restrictions would represent environmental benefits related to the decrease of risk of pollution of water and soil. Nevertheless, these improvements are not always reflected in LCA results, as seen before, due to the limitations of the current LCA impact methods for toxicity categories.

Parameters modified in the model:

Following the rationale, Table 41 reports a summary of the parameters that have been changed in the eco-innovation model compared to the base-case.

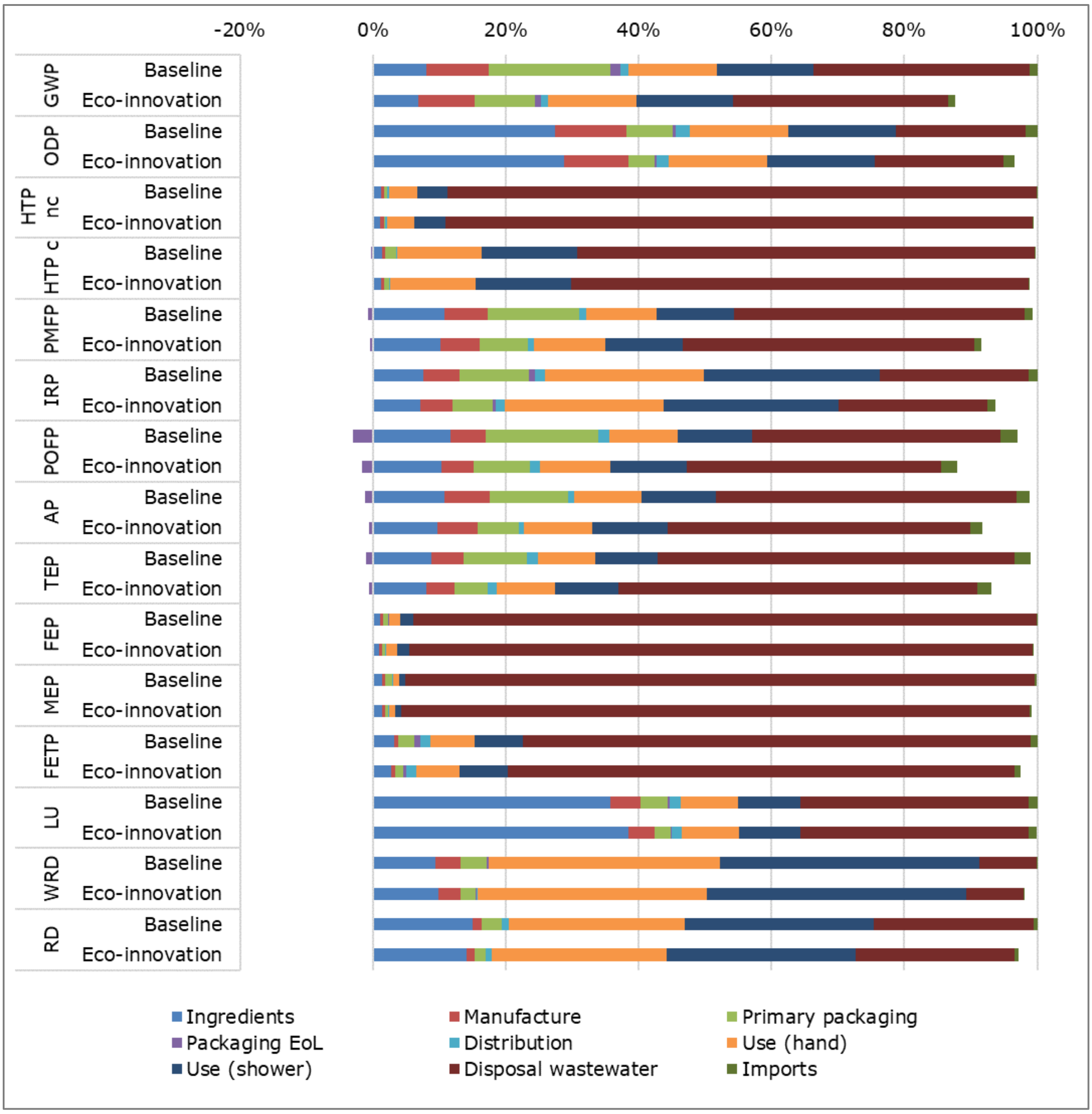
Table 41. Parameters modified in the eco-innovative scenario for liquid soap.

	Liquid soaps
Components manufacture	Formulation according to Criteria requirements included in EU Ecolabel (Table 36).
Packaging	Increase of the packaging capacity and reduction of material, 20% of HDPE from recycled material, and inclusion of a refilling system. The new value for packaging is 23.66g for functional unit (255g of product).
Use phase	Reduction of dosage: 10%. The new dosage is 1.8g for liquid soap used for hand washing and 11.7 for liquid soap used for shower (Table 39). As consequence of this, the quantity of annual consumption for the overall BoP changes from 1.82 kg/year to 1.64 kg/year.

Results:

Scenario results were analysed for the single product (Figure 20) and for the overall BoP (Figure 21). For the individual analysis of a liquid soap product, the analysis has been done for the same functional unit, i.e. hand cleaning actions and showers (50% of each type of use) for a bottle of 255g (base-case scenario). Due to the dosage reduction, the equivalent reference flow for the same number of cleaning actions for the eco-innovation actions is 229g for those life cycle stages related to the production of the product, whereas for the use stage and the end of life the same quantity of water has been considered, since it is linked to the number of washing actions. Main savings are related to the reduction of the amount of product used due to the reduced dose, which proportionally reduces the impacts in all life cycle stages. Reduction of impacts can be observed also in components manufacture and primary packaging and packaging EoL stages (Figure 20). When the environmental impact profile of both products are compared, the product of the eco-innovation scenario shows reductions in the environmental impact for all impact categories (Figure 20). Impact reductions vary between 12.4% (GWP) to 0.1% (LU) depending on the impact category, as it can be seen in the figure below. Savings are quite limited, since the most impacting life cycle stages, i.e. use (accounting for water use) and end of life, remain unchanged. Regarding the rest of the life cycle stages which have been modified in the eco-innovation scenario, the highest savings are found in packaging and the EoL of packaging (50% of reduction on average). Ingredients manufacturing presents also a reduction of around 10%, but it is related to the use of a lower quantity of ingredients by cleaning actions due to the reduction of dose, not for the substitution of ingredients. The rest of life cycle stages (distribution and import) show also improvements of around 10% in relation to the reduction of dose, although their relative contribution is low.

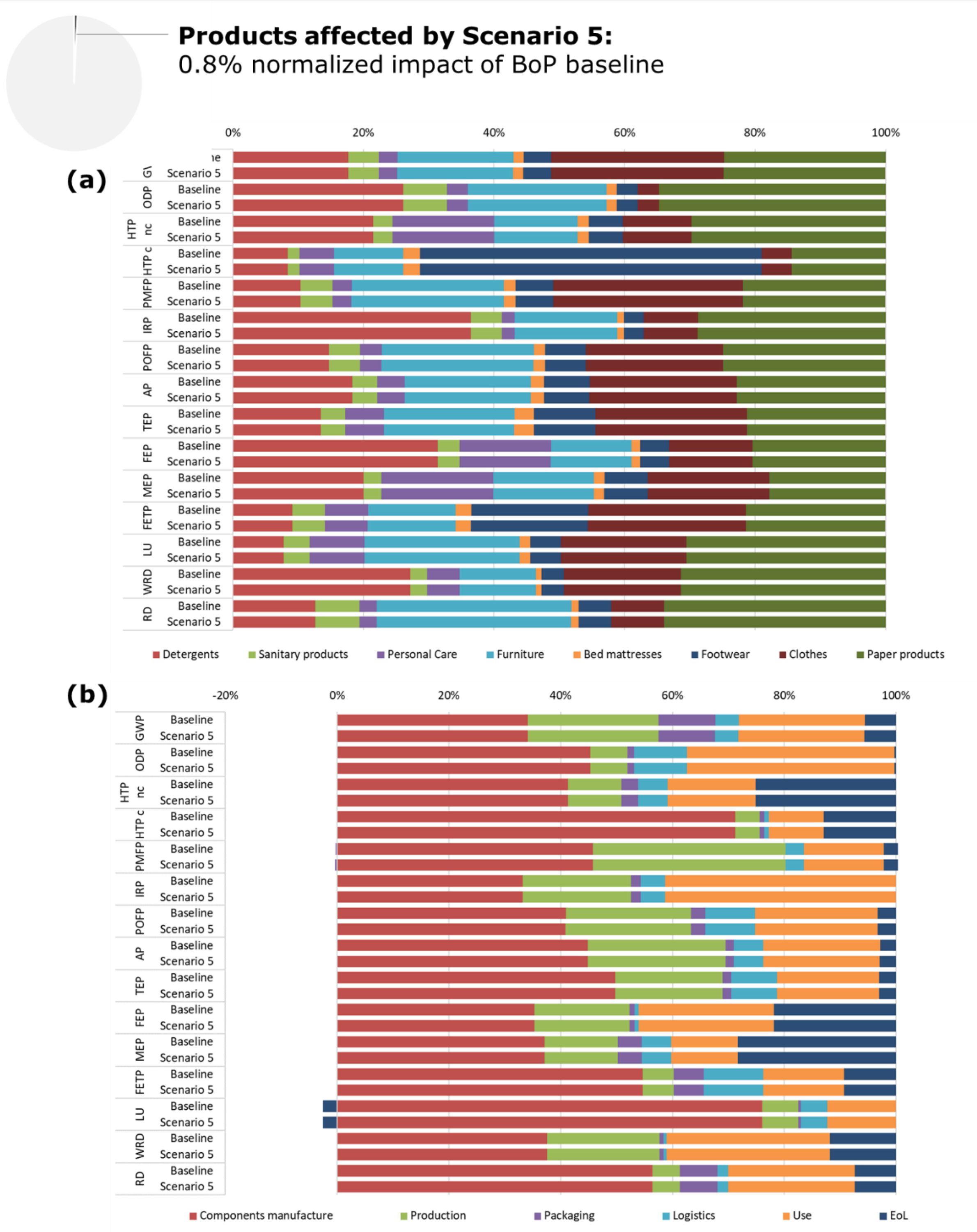
Figure 20. Individual analysis of liquid soap products - Comparative assessment of baseline and eco-innovation scenarios of liquid soap. "Imports" include the transport of the imported finished products.



(For the abbreviations of the names of impact categories see note to Figure 9)

If the eco-innovation scenario for liquid soap is considered in the context of the whole BoP household goods (Figure 21), it can be seen that improvements are quite limited, since personal care products have quite low contribution to impact in comparison to other product categories for the BoP in the base case. Liquid soap contributes to 0.8% of the normalized impact of the whole BoP. For this reason, the potential effect on the overall BoP from the improvements in this product is quite limited. Nevertheless, it can be seen that for Eco-innovation scenario, personal care products have a better performance in all impact categories, with reduction of the impacts of the category going from 1.5% (GWP) to 0.02% (LU), depending on the impact category. Nevertheless when considering the effect of 100% EU Ecolabelled liquid soaps in the overall environmental burdens of the BoP household goods, the effect is almost negligible. Although reductions of the overall BoP's impact are quite limited if only liquid soaps scenario is modified (generally below 1%), it would contribute to the overall eco-innovation BoP where these improvements are assessed together with the other four Eco-innovation scenarios. At the life cycle stage level, although very limited, reductions of impacts of the BoP household goods are mainly found in the packaging life cycle stage (0.4% on average).

Figure 21. Scenario 5 in comparison with the baseline scenario (with total from the baseline set as 100%) – split into the contributions of (a) the various product groups and (b) the life cycle stages.



(For the abbreviations of the names of impact categories see note to Figure 9)

8.8. Scenario 6 – EU Ecolabel scenario on shampoo

Description and aim:

The aim of this scenario is to examine the potential environmental benefits coming from the use of an EU Ecolabelled product, compared to base-case shampoo products modelled in the baseline scenario.

Area of intervention:

— Hotspot addressed: impacts from the whole life cycle of shampoo.

— Product group: Personal care.

— Life cycle stage: components manufacture (formulation of the product) and use (dosage).

Policy relevance: Commission Decision of 9 December 2014 establishing the ecological criteria for the award of the EU Ecolabel for rinse-off cosmetic products (i.e. personal care).

Background information:

The LCA results of the base-case shampoo in the background study for the selection of EU Ecolabel criteria (Escamilla et al., 2012) showed that hotspots from all life cycle stages are related to the use stage, release to water, packaging, and chemicals used as raw materials. The relative contribution to environmental impacts and the improvement potential of each stage is summarized below; according to LCA study results obtained using the IMPACT 2002+ endpoint impact method (all midpoint impact categories normalized, weighted, and aggregated to a unique value):

— Components manufacture: 9% of impacts are associated to this stage. The potential of improvement and the regulation of the EU Ecolabel are high. Selecting less harmful substances from each functional group will improve the environmental profile of the product, since these changes will also have benefits besides this stage: during manufacturing, use of the product, and end of life wastewater treatment.

— Manufacturing, representing on average 12% of impacts, has limited improvement potential since industrial processes are standard processes from databases and primary data from industry are not available. Moreover consumptions during manufacturing are not regulated by EU Ecolabel.

— Packaging has a high improvement potential and several eco-innovation actions can be applied. Packaging of shampoo has a contribution on average representing 22% of the overall impact. Decreases in weight result in direct decreases of environmental impacts. Measures to decrease the weight are: increase capacity, lighter packaging, and refilling systems. This issue is regulated by EU Ecolabel through the PIR criterion (Packaging) (Box 3). Also decreasing the use of virgin materials reduces the environmental impact, increasing the recycled content will be explored as well.

— Distribution represents on average 7% of the product environmental impact. Improving efficiency in logistics and decreasing weight of packaging bring savings due to reducing fossil fuel use.

— Use contributes to 28% of impact of the product, on average. Reducing dose and water consumption can bring environmental benefits in this stage.

Release of product into water after its use contributes to 20% of the environmental impacts. Improvements on formulation using substances less toxic will reduce the impact coming from wastewater treatment.

Rationale for building the scenario:

The eco-innovation scenario has been defined incorporating modifications from the base-case scenario, according to the current EU Ecolabel criteria of rinse-off cosmetics (i.e. personal care). For those areas where improvement potential was identified but they are not directly covered by EU Ecolabel criteria, sensitivity analyses have been modelled. The summary of the main changes for each life cycle stage are detailed in the paragraphs below.

The functional unit for this product group has been defined as a bottle of shampoo containing 255g of product in the baseline scenario. This functional unit has been maintained for comparison.

The **components manufacture** life cycle stage comprises the substances used in the formulation of the final product (including the raw materials extraction and processing) and the transport of these substances from the supplier to the production site.

To define the components for the eco-innovation scenario, the same approach, steps, and sources of information than the ones used for liquid soap (Scenario 5) have been followed. The resulting formulation is presented in Table 42.

Table 42. Components formulation for eco-innovation scenario. Shampoo.

		BASE-CASE SCENARIO		**ECO-INNOVATION SCENARIO**	
Input/output	**Observations**	**Formulation (%)**	**Quantity (g)**	**Formulation (%)**	**Quantity (g)**
Water		88.32	225.22	88.05	224.527
Sodium laureth sulphate	Anionic surfactant	7.00	17.85	7.00	17.85
Cocoamidopropyl betaine	Amphoteric surfactant	2.50	6.375	2.00	5.1
Fatty alkanolamides	Non-ionic surfactant	0.50	1.275	-	-
Coco glucoside	Non-ionic surfactant	-	-	0.80	2.04
Propylene glycol	Surfactant Viscosity controlling agent	1.50	3.825	-	-
Glycerine	Surfactant Viscosity controlling agent	-	-	1.50	3.825
Sodium benzoate	Preservatives	0.05	0.127	0.765	0.30
Benzyl alcohol	Preservatives	0.05	0.127	-	-
Lactic acid	pH adjustment	0.08	0.204	-	-
Potassium sorbate				0.15	0.3825
Sodium chloride		-	-	0.10	0.255
Citric acid		-	-	0.10	0.255
TOTAL		**100**	**255**	**100**	**255**

This life cycle stage includes the transport of all ingredients except water. Values are the same as for the base-case scenario (Table 43).

Table 43. Inventory values for transport of components. Shampoo.

Transport of raw materials to production site (except water)		
Freight lorry 16-32 kt	500	km
Freight, sea, transoceanic	15,000	km

The values of CDV and biodegradability have been analysed in both formulations in order to verify that the EU Ecolabelled formulation is compliant with the EU Ecolabel criteria and that all changes on formulation allow a better performance on these criteria. In this case, CDV is slightly higher, but the new formulation is compliant with biodegradability thresholds (Table 44).

Table 44. Score for Criteria 1 and 2 of EU Ecolabel for shampoo.

	CDV	ANBO (surf)	aANBO (surf)	ANBO (org)	aANBO (org)
EU criteria thresholds	18,000	0	0	25	25
Base-case formulation	2,009	0	7.00	0	599.30
EU Ecolabel formulation	3,528	0	0.00	0	12.7

The **production** life cycle stage is not covered directly for the rinse-off cosmetics EU Ecolabel criteria. For this reason, as done in liquid soap, any changes from the base-case scenario have not been done for the eco-innovation scenario in this stage. Accordingly, a sensitivity analysis has been done by varying the energy consumption in order to estimate the influence of this improvement measure in the overall impact results. Details and results are presented in section 8.13.

For the **logistics** life cycle stage, the same values than the base-case scenario have been kept for the eco-innovation scenario. The same sensitivity analysis performed for liquid soap has been done, changing the road vehicles for vehicles with a better emission profile (changing from EURO4 to EURO6). Details and results are presented in section 8.13.

For the characteristics of the **packaging**, the following variations have been introduced based on the EU Ecolabel packaging criterion.

The current format of the packaging for the base-case product is a packaging of 250mL of capacity with 39g weight, 100% virgin HDPE. This characteristic gives a PIR value of 0.306, whereas the current maximum PIR for these products according to EU Ecolabel criteria is 0.28. In the background report of the development of EU Ecolabel criteria for soaps, shampoos, and hair conditioners, 57 EU Ecolabelled products were analysed. Results showed that non-refilling packaging average weight/content ratio for these products were 0,25; whereas for refilling products the average ratio was 0.17. For this reason, the following improvements are proposed.

1. Increase of the capacity from 255mL to 300mL.
2. Change of material from virgin HDPE to HDPE with a 20% content of recycled PE.
3. Lighter packaging due to material reduction: from 39g (for 255mL) to 42g (for 300mL); which represent 35.7g of packaging for containing 255g of product.

Considering the refilling system and the capacities, the improved packaging for a functional unit of 255g of liquid soap is of 35.7g for functional unit.

With these measures, following the EU Ecolabel formula the product will have a PIR value of 0.25, being compliant with EU Ecolabel and being in line with data for current EU Ecolabelled liquid soaps products.

For the end of life of packaging, the same hypotheses for the final treatment of packaging waste have been considered (as in Annex 2). A sensitivity analysis has been done considering higher recycling ratios for PE material, following the same considerations than for liquid soaps.

Some EU Ecolabel requirements are related to the **use** stage regarding the dosage:

— EU Ecolabel asks for dosing system design, which allows a proper dosage avoiding spillage of the product due to over-doses.

— EU Ecolabel also has a criterion regarding fitness for use to guarantee a good washing efficiency.

For this reason the dose has been reduced by 10% with the respect to dose on base-case scenario, i.e. from 10.5g to 9.45g (Table 45). This change has no effect on the modelling of the individual scenario, but the quantity of annual consumption for the overall BoP household goods would change from 3.13 kg/year to 2.817 kg/year.

Table 45. Dosage values for Use stage. Shampoo.

Parameter	BASE-CASE SCENARIO	ECO-INNOVATION SCENARIO
Dosage (g)	10.5	9.45
Electricity	*Not included*	*Not included*
Water (L)	22	22

The quantity of water used is the same for the two scenarios, since EU Ecolabel does not cover use stage or information to users about water. Nevertheless, the environmental awareness of users could condition the use phase of this product. Consumer behaviour can have a direct influence to the dose and the quantity of water consumed during washing use. For this reason, a sensitivity analysis has been done reducing the quantity of water respectively by 5% and 10%, in order to see how this measure would affect the overall environmental impact of the product. Details and results are presented in section 8.13.

For the **End of life** stage, a standard urban wastewater treatment for the domestic wastewater generated (water consumed during use and the quantity of the product) is modelled. These values have been kept from the base-case scenario without variation.

Parameters modified in the model:

Table 46 reports a summary of the parameters that have been changed in the base-case model, following the justifications exposed in the rationale.

Table 46. Parameters modified in the eco-innovation scenario for shampoo.

	Shampoo
Components manufacture	Formulation according to Criteria requirements included in EU Ecolabel (Table 42)
Packaging	Increase of the packaging capacity, reduction of material, and 20% of HDPE from recycled material. The new value for packaging is 35.7g for functional unit (255g of product)
Use phase	10% dosage reduction. The new dosage is 9.45g per shower (Table 45). As consequence of this, the quantity of annual consumption for the overall BoP changes from 3.13 kg/year to 2.82 kg/year.

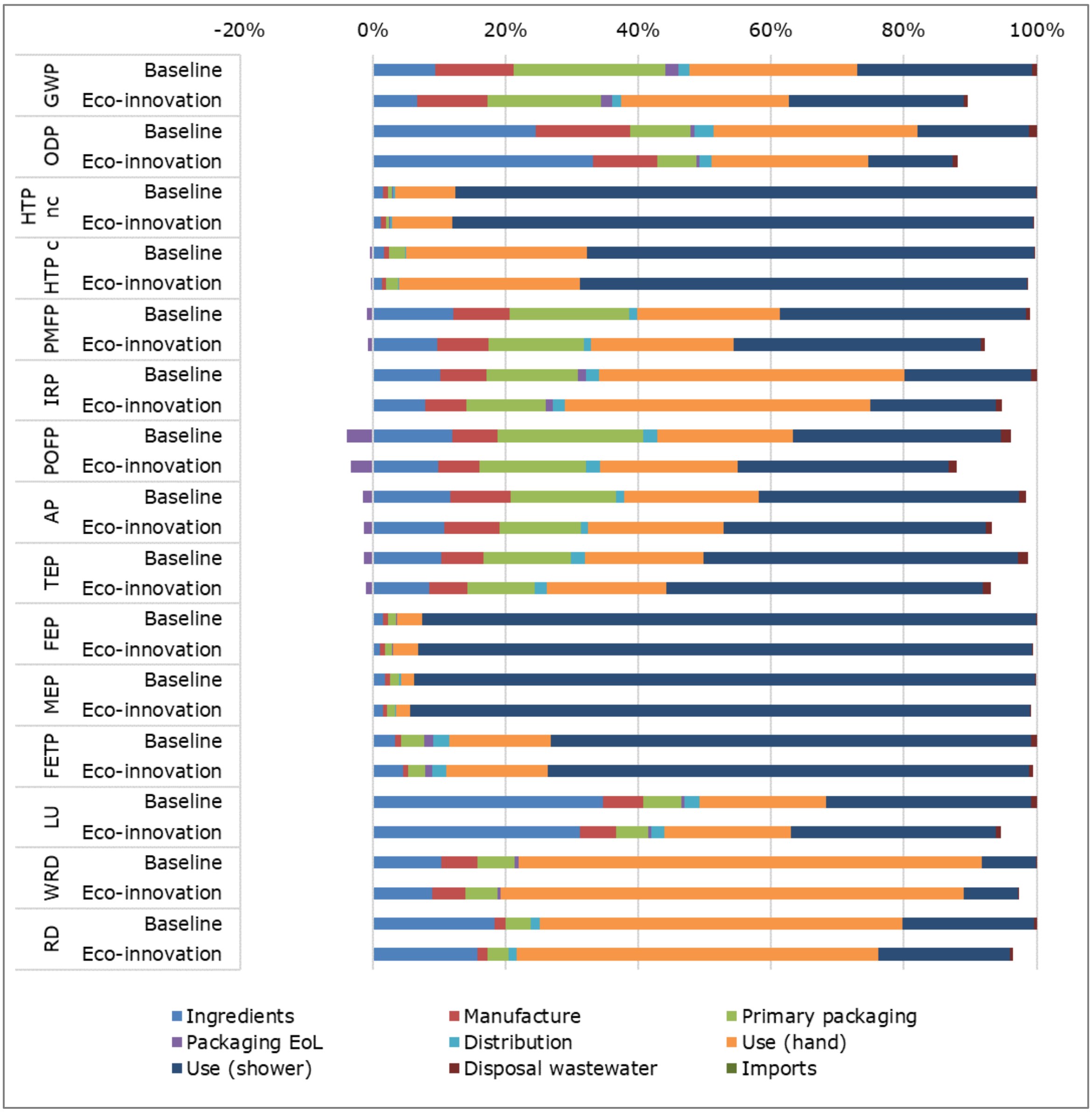
Results:

Scenario results were analysed for the single product (Figure 22) and for the overall BoP (Figure 23). For the individual analysis of shampoo products, the analysis has been done for the same functional unit (shower actions for a bottle of 255g in the case of the base-case scenario); due to the reduction on dose, the equivalent reference flow for the same number of cleaning actions for the eco-innovation actions is 229.5g for those life cycle stages related to the production of the product, whereas for the use stage and the end of life the same quantity of water has been considered, since it is linked to the number of washing actions.

Main savings are related to the reduction of the amount of product use due to the reduced dose, which proportionally reduces the impacts in all life cycle stages. Impact minimization can be observed also in components manufacture, primary packaging, and EoL of packaging stages. All impact categories are reduced except ozone depletion, which increases its value due to some ingredients present in the eco-innovation scenario formulation, especially due to the sodium benzoate, which has a higher concentration in the eco-innovation scenario. Environmental savings vary between 0.5% (FETP, HTPnc) and 10% (GWP), depending on the impact category (Figure 22).

Savings are quite limited, since the most impacting life cycle stages, i.e. use (accounting for water use) and end of life remain unchanged. For the rest of the life cycle stages modified, the highest savings are found in packaging and EoL of packaging (20% of reduction on average. Ingredients manufacturing presents also a reduction of around 10%, but it is related to the use of a lower quantity of ingredients by cleaning actions due to the reduction of dose, not for the substitution of ingredients. The rest of life cycle stages (distribution and import) show also improvements of around 10% in relation to the reduction of dose, although their relative contribution is low.

Figure 22. Individual analysis of shampoo products - Comparative assessment of baseline and eco-innovation scenarios of shampoo. "Imports" include the transport of the imported finished products.

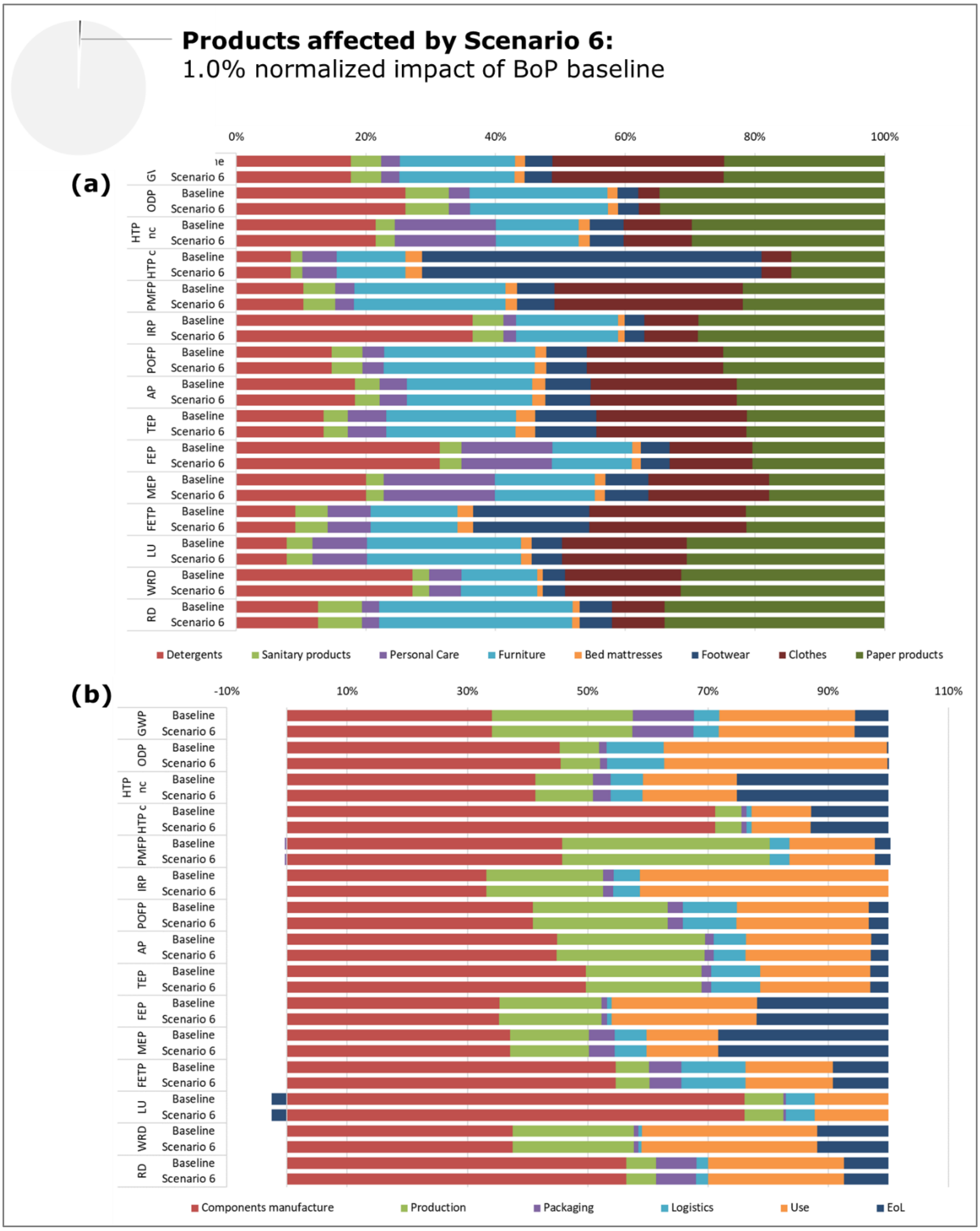


(For the abbreviations of the names of impact categories see note to Figure 9)

When the eco-innovation scenario for shampoo is considered for the category of Personal care products, it can be seen that improvements on the overall BoP are quite limited, since shampoo contributes to only 1.0% of the normalized impact of the whole BoP household goods. For this reason, the potential effect on the overall BoP from the improvements in this product is quite limited (Figure 23). Moreover, inside the category of personal care, there are other products such as shampoo, hair conditioning products or solid bars that have remained unchanged and have relevant contribution.

Despite these limitations, it can be seen that for Eco-innovation scenario, product care has a better performance in all impact categories, with reduction of all the impacts of the categories except ODP.

Figure 23. Scenario 6 in comparison with the baseline scenario (with total from the baseline set as 100%) – split into the contributions of the various product groups.



(For the abbreviations of the names of impact categories see note to Figure 9)

Nevertheless, the effect on the overall BoP ranges between 0.01% and 0.04%, depending on the impact category. ODP is the only category with highest impacts in eco-innovation scenarios compared to the baseline scenario (+0.11%). No variations are observed in FETP. Although it is not appreciated in Figure 23 because reductions are very limited, reductions of impacts of BoP by life cycle stages are mainly found in packaging (0.25% on average). Minor improvements are also found in the life cycle production and logistics, with variations lower than 0.02%.

8.9. Scenario 7 – EU Ecolabel scenario on dishwasher detergent

Description and aim:

The aim of this scenario is to examine the potential environmental benefits coming from the use of an EU Ecolabelled dishwasher detergent product, compared to base-case dishwasher detergent (DD) products modelled in the baseline scenario.

Area of intervention:

— Hotspot addressed: impacts from the whole life cycle of dishwasher detergent.

— Product group: detergents.

— Life cycle stage: components manufacture (formulation of the product) and use (dosage).

Policy relevance: Commission Decision (EU) 2017/1216 of 23 June 2017 establishing the EU Ecolabel criteria for dishwasher detergents.

Background information:

The stage that has a higher contribution on the environmental impact of DD is the use phase. The impact is mainly caused by the energy used to heat the water during the wash cycle. On average, the second most contributing stage in the potential impact of DD is the manufacture of components. The ingredients used in the formulation could be important contributors to the total environmental impact, especially in the impact categories of terrestrial ecotoxicity, marine eutrophication, and marine ecotoxicity. This impact is related with different ingredients: surfactant, builder, sodium carbonate, alkali, and citric acid. When other life cycle stages are considered, packaging has a significant impact because of the non-recycled content of the secondary packaging, and the wastewater treatment (included in the end of life stage) contributes to the impact in some impact categories.

The background study for the selection of EU Ecolabel criteria for Dishwasher Detergents (DD) (Arendorf et al., 2014a) have analysed different variables to identify their contribution to the environmental impacts. The impact assessment method used for the LCA study is ReCiPe and the study highlighted that:

— The washing program defines the temperature and duration of the cycles, and it affects the energy consumed during the washing. A reduction of washing temperature has an important reduction in different impact categories, such as climate change, human toxicity, or freshwater and marine ecotoxicity;

— A reduction of the dosage does not affect the size of the impacts;

— The surfactant origin is relevant for the impact category of land transformation;

— The energy source considered in the analysis is important: for example, considering the French energy mix reduces the impact on climate change by more than 80%. The source used to generate energy is related to lower emissions and resource consumptions;

— Ingredients have a higher influence on the impact categories of human toxicity, terrestrial ecotoxicity, freshwater ecotoxicity, and marine ecotoxicity. The ingredient used in the formulation will affect the potential environmental impact of those categories.

Rationale for building the scenario:

Different modifications have been included in the eco-innovation scenario of DD since EU Ecolabel covers most of the life cycle stages of Detergents. For phases not covered by EU Ecolabel criteria, a sensitivity analysis has been performed.

Dosage for Dishwasher Detergents has been changed, following the recommendations included in Criterion 1 of EU Ecolabel. This modification alters the quantity of annual consumption for the overall BoP: from 2.43 kg/year to 2.31 kg/year.

The **components manufacture** includes the environmental impact of the raw material production, and the transport from the producer to the DD production location. Different criteria are related to this stage and have been considered to define the eco-innovation scenario: toxicity to aquatic organisms, biodegradability, excluded and restricted substances, and sustainable sourcing of palm oil, palm kernel oil, and their derivatives.

The proposed formulation for the eco-innovation scenario is presented in Table 47. On the other hand, the assumptions considered for the transport have been maintained.

Table 47. Components formulation for eco-innovation scenario. Dishwasher detergent.

Components manufacture	BASE-CASE SCENARIO	ECO-INNOVATION SCENARIO
Sodium citrate dihydrate	30.0%	25.0%
Maleic acid/acrylic acid copolymer sodium salt	6.0%	3.0%
Sodium percarbonate	7.0%	15.0%
TAED (92 % active)	2.0%	3.0%
Sodium silicate	10.0%	4.0%
Linear fatty alcohol ethoxylate	2.0%	0.75%
Fatty alcohol alkoxylate	-	0.75%
Protease savinase	0.0%	0.01%
Amylase termamyl	0.5%	0.01%
Sodium carbonate	43.5%	43.48%
GLDA ((N,N-Dicarboxymethyl glutamic acid tetrasodium salt))	-	5%
Transport of raw materials (from base-case scenario): 500km (lorry) for road transport, and 15000km (transoceanic ship) for sea transport.		

The formulation has been defined considering different EU Ecolabel products currently in the market. Moreover, values of CDV and biodegradability have been analysed in both formulations in order to verify that the EU Ecolabelled formulation is compliant with the EU Ecolabel criteria and that all changes on formulation allow for a better performance on these criteria.

Table 48. Score for Criteria 2 and 3 of EU Ecolabel for detergents.

	CDV	ANBO (surf)	aANBO (surf)	ANBO (org)	aANBO (org)
EU criteria thresholds	22500	0	0	1	3
Base-case formulation	29818	0	1.20	1.20	0.00
EU Ecolabel formulation	9073.00	0	0	0.57	0.71

Base-case formulation is not compliant with current EU Ecolabel criteria on ANBO (Organic substances not readily biodegradable) since the value is higher than the EU Ecolabel threshold. The formulated product is able to comply with requirements included in Criteria 2 and 3. The new formulation proposed is compliant with all three criteria.

The **production** of the DD is not covered in the EU Ecolabel scope. Despite there are different legislations affecting the efficiency of manufacturing process, they are usually voluntary and some differences may exist between EU countries. A sensitivity analysis has been conducted to estimate the improvement potential of including good environmental actions during the production phase. Details and results are provided in section 8.13.

Logistics phase is not directly affected by EU Ecolabel. However, the reduction of the dosage used in the use stage according to Criterion 1 (Dosage requirements) is affecting the relative impact of transporting one product. Notwithstanding that the difference is minor, it has been included in the analysis of the logistics phase. On the other hand, a sensitivity analysis has been performed assuming the use of vehicles with a lower emission profile during the transport of the product. Details and results are provided in section 8.13.

EU Ecolabel includes a criterion of **packaging** (criterion 6.a.), where the following requirements are included:

— Weight/utility ratio (WUR)[22]: it establishes the ratio between the weight of the primary packaging and the weight of the number of doses contained in the packaging. Only considering the primary packaging, the WUR for dishwasher detergents shall not exceed 2.4 g/wash. However, those primary packaging which are made of more than 80% of recycled materials is exempted of the requirement.

— Design for recycling: the packaging shall be designed to facilitate its recycling. Different materials and components excluded from packaging elements are listed in the criterion.

According to these requirements, an eco-innovation scenario has been defined for DD packaging. The base-case scenario includes a flow rap film of PP as primary packaging. For the eco-innovation scenario this film has been substituted by a water soluble film. The polyvinyl alcohol (PVA) film is commonly used for packaging due to its characteristics: it is a water soluble biodegradable film (WaterSol, 2016). Contrarily to the base-case where a removable packaging is considered, in this case a water soluble film in direct contact with the tablet as a thin skin is considered. A weight reduction of 30% has been assumed. For the eco-innovation scenario the weight of the box has been maintained, however 100% of cardboard recycled has been assumed (Table 49).

Table 49. Eco-innovation scenario for packaging stage.

Packaging		BASE-CASE SCENARIO	ECO-INNOVATION SCENARIO
Primary packaging	Flow rap film	0.35 g/wash	Substituted by a water soluble plastic (PVA)
Secondary packaging	Cardboard box	3 g/wash	100% from recycled material
	Shrinkwrap (LDPE)	0.18 g/wash	No changes

End of life of packaging is affected by these changes included in the packaging design. The flow rap film, considering it as water soluble, is not a waste in the eco-innovation scenario. A sensitivity analysis was performed to assess potential improvements due to increasing the recycling ratio of the packaging. Details and results are provided in section 8.13.

Regarding the **use phase**, the EU Ecolabel includes the Criterion 8 on User Information, where different advices are presented:

— Dosing instructions: the recommended dosage for a standard load shall be included in the package.

— Environmental information: an advice about using the correct dosage and the lowest recommended temperature in order to minimise energy and water consumption shall appear on the packaging.

Moreover, a Criterion about fitness for use of the DD is included in EU Ecolabel: the product shall have a satisfactory cleaning performance at the lowest temperature and dosage recommended by the manufacturer.

Dishwashers usually have a large number of programmes. The cleaning result is dependent on time or programme duration, temperature, and detergent used. Programs included in a dishwasher vary the duration and the temperature to achieve a good cleaning performance.

For the eco-innovation scenario, the lowest cleaning temperature has been considered, since the dishwasher detergent should be tested to have a satisfactory cleaning

[22] WUR is calculated as follows: $WUR = \Sigma ((W_i + U_i)/(D_i * R_i))$ Where: Wi: weight (g) of the primary packaging (*i*); Ui: weight (g) of non-post-consumer recycled packaging in the primary packaging (*i*).; Di: number of reference doses contained in the primary packaging (*i*); Ri: refill index. Ri = 1 (packaging is not reused for the same purpose) or Ri = 2 (if the applicant can document that the packaging component can be reused for the same purpose and they sell refills).

performance at the lowest temperature and dosage recommended (Michel et al., 2017). This assumption leads to reduced use of electricity and water (Table 50).

Table 50. Eco-innovation scenario defined for use phase of dishwashing detergent.

Use	BASE-CASE SCENARIO	ECO-INNOVATION SCENARIO	units
Dosage	20	19	g
Electricity	1.42	0.90	kWh
Water	18.5	10	L

There are no Criteria referring to **end of life** of DD. However, EU Ecolabel includes requirements that affect the end of life of the product: the restrictions included in the use phase have an impact reduction in the end of life phase. The water consumed during the use phase is reduced, and subsequently the wastewater treated is lower.

Parameters modified in the model:

Table 51 reports a summary of the parameters that have been changed in the base-case model, following the justifications exposed in the rationale.

Table 51. Parameters modified in the eco-innovation scenario for dishwasher detergent.

	Dishwasher detergent
Components manufacture	Formulation according to Criteria requirements included in EU Ecolabel (Table 47)
Packaging	Substitution of PP film with water soluble film, a weight reduction of 30% has been assumed. For secondary packaging, 100% of cardboard from recycled material
Use phase	Reduction of dosage: from 20 to 19 grams of product; electricity: from 1.42 to 0.90 kWh; and water: from 18.5 to 10 litres of water consumed.
End of life	The reduction of dosage and water used during use affects the end of life of the product.

Results:

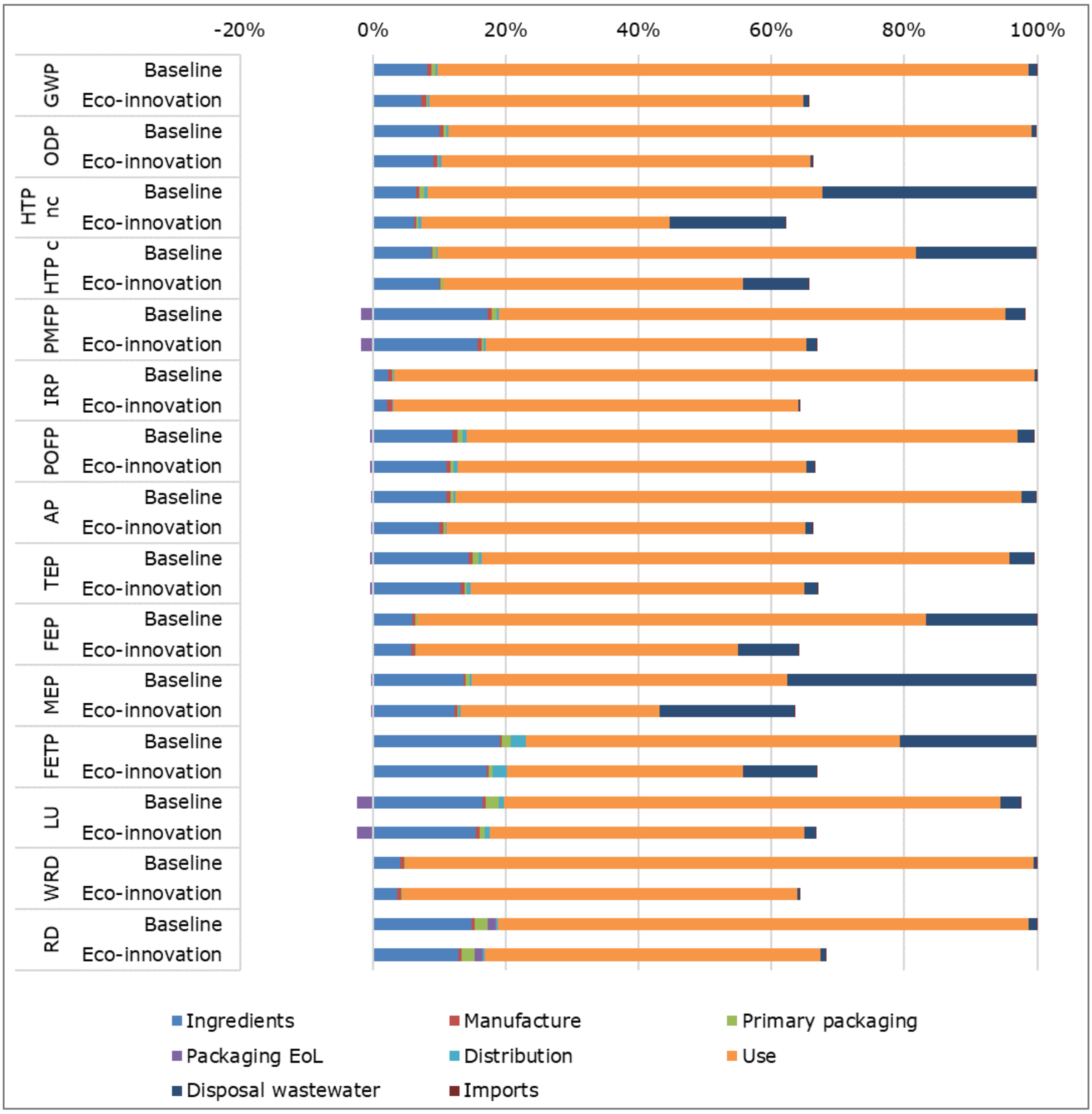
Scenario results were analysed for the single product (Figure 24) and for the overall BoP (Figure 25). The comparison between both scenarios for dishwasher detergents is presented in this section (Figure 24). The unit of comparison is one washing cycle. Therefore, the base-case scenario has been analysed per 20g of product used during one washing cycle and the results for the eco-innovation scenario are presented per 19g of product used during one washing cycle.

Most of the impact is related to the use phase, due to the energy consumed during the washing. The reduction of the resources (water and energy) consumed during this phase when using an environmentally-friendly program generates an improvement of the environmental profile of DD. Between 32% and 38% of impact reduction is achieved for all the impact categories. Moreover, the reduction of water used during the wash cycle has an environmental benefit in the disposal phase because a lower amount of waste water is treated (45% of impact reduction on average). This reduction is more evident for those impact categories where the end of life phase has a higher contribution: human toxicity, freshwater eutrophication, marine eutrophication, and freshwater ecotoxicity (Figure 24).

Environmental improvements can be found also in the other life cycle stages: Ingredients also present improvements (7% of reduction on average), together with packaging (45%)

although this last life cycle stage has lower contribution to the overall impact. The distribution stage also shows improvements of around 5% caused by the reduction of dose.

Figure 24. Individual analysis of dishwasher detergent products - Comparative assessment of baseline and eco-innovation scenarios of dishwasher detergent. "Imports" include the transport of the imported finished products.



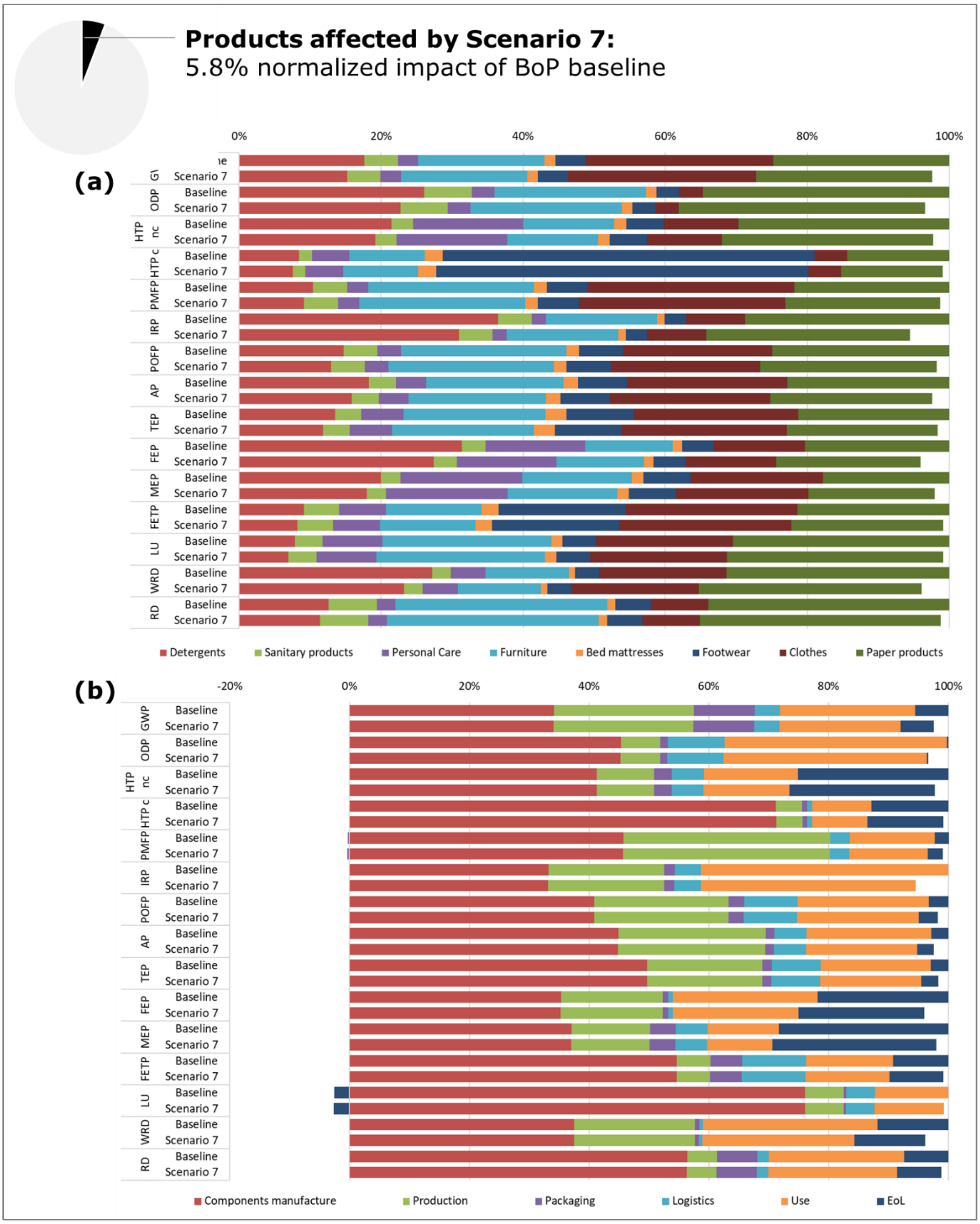
(For the abbreviations of the names of impact categories see note to Figure 9)

The average EU consumption considered in the BoP has been adjusted considering the reduced amount per washing cycle, according to the eco-innovation scenario proposed: 2.31kg of DD consumed for an EU citizen per year.

Dishwasher detergents contribute to 5.8% of the normalized environmental impact of the BoP household goods in the baseline scenario. Due to the relevance of DD products, the eco-innovation scenario for DD products allows a significant improvement within the Detergents category, with reductions of the impact going from 9.4% (FETP) to 15.1% (IRP). When the overall effect on the BoP is analysed, the most affected impact categories are: Ionizing radiation, Freshwater eutrophication, and Water resource depletion, with a reduction of 5.5%, 4.0%, and 3.9% respectively (Figure 25).

When the eco-innovation scenario is analysed considering the life cycle stages, it can be seen that the life cycle stages with higher environmental savings are the use (8.7% of reduction on average), followed by packaging (0.9% of reduction), and EoL (0.8%). Components have also small savings (0.1%) (Figure 25).

Figure 25. Scenario 7 in comparison with the baseline scenario (with total from the baseline set as 100%) – split into the contributions of (a) the various product groups and (b) the life cycle stages.



(For the abbreviations of the names of impact categories see note to Figure 9)

8.10. Scenario 8 – EU Ecolabel scenario on laundry detergent

Description and aim:

The aim of this scenario is to examine the potential environmental benefits coming from the use of an EU Ecolabelled product, compared to base-case laundry detergent (LD) products modelled in the baseline scenario.

Area of intervention:

— Hotspot addressed: impacts from the whole life cycle of laundry detergent.

— Product group: detergents.

— Life cycle stage: components manufacture (formulation of the product) and use (dosage).

Policy relevance: Commission Decision (EU) 2017/1218 of 23 June 2017 establishing the EU Ecolabel criteria for laundry detergents.

Background information:

The environmental profile of LD is similar to the one of DD: both include use phases which are very energy consuming. The life cycle stage with the largest contribution to the overall environmental impact is the use phase. The energy used for heating the washing water during the use stage has an important contribution to impact categories as fossil fuel depletion or global warming potential.

The potential environmental impact of the use stage could be reduced adjusting the temperature of the washing programme. According to the EU Ecolabel background report for LD (Arendorf et al., 2014b), a reduction of 10ºC of wash temperature could represent a reduction of the potential environmental impact of 10% on average across impact categories.

Other variables influencing the use phase are the energy sources used for heating the water and the dosage of product used. Using lower dosage in a washing cycle reduces the environmental impacts in a percentage between 6 to 16%, depending on the impact category analysed.

Ingredients used in the formulation have an important relevance to different impact categories: terrestrial ecotoxicity, land transformation, freshwater ecotoxicity, and marine ecotoxicity. The impact generated depends on the ingredients used: specific ingredients have a large contribution to some impact categories. The selection of the most environmentally friendly ingredients could have an important reduction of the total environmental impact of the scenario, mainly in categories related with toxicity impacts: human, terrestrial, freshwater and marine ecotoxicity. Moreover, the surfactant origin can contribute to natural land transformation.

Other life cycle stages that influence the total environmental impact of LD are end of life and packaging. The wastewater treatment and the non-recycled content of the cardboard part of the packaging contribute to eutrophication and agricultural land occupation, respectively. Impact in the end of life could be reduced if the formulation of the product is adjusted with better environmental friendly ingredients.

Rationale for building the scenario:

Eco-innovation actions included for this product group are defined in this section. For phases not covered by EU Ecolabel criteria, a sensitivity analysis has been assessed.

Regarding the **components manufacture**, an improved formulation has been defined to reduce the environmental impact of LD. EU Ecolabel includes different criteria about substances used as detergent ingredients. They are Criterion 2: Toxicity to aquatic organisms, Criterion 3: Biodegradability, Criterion 4: Sustainable sourcing of palm oil, palm kernel oil and their derivatives, and Criterion 5: Excluded and restricted substances.

The proposed formulation for the eco-innovation scenario is presented in Table 52. On the other hand, the assumptions considered for the transport have been maintained as they were in the baseline scenario.

Table 52. Components formulation for eco-innovation scenario. Laundry detergent.

Components manufacture	BASE-CASE SCENARIO	ECO-INNOVATION SCENARIO
Water	70.22%	61.69%
Citric acid (builders)	1.61%	-
Salts of citric acid and other salts (builders)	0.67%	2.5%
Sodium phosphonate (sequestrants)	0.41%	-
Enzymes- Amylase	0.58%	0.1%
Enzymes- Protease	-	0.1%
Enzymes- Cellullase	-	0.1%
Dye	0.03%	-
Fragrances	0.71%	0.2%
Optical brighteners	0.03%	-
Optical brighteners	0.03%	-
Sodium alkyl ether sulphates (mix of oleo- and petro-based)	3.55%	9.0%
LAS Alkylbenzene sulfonate (petro)	6.83%	-
Soap	2.41%	3.0%
Ethoxylates oleochemicals + petrochemical) & other non-ionic surfactants	5.91%	7.0%
Sodium Hydroxide (Alkalinity sources)	1.16%	1.5%
Triethanolamine (Alkalinity sources)	1.16%	-
Glycerine (solvents)	1.43%	2.5%
Propylene glycol (solvents)	1.43%	2.5%
Preservatives (other ingredients)	0.46%	-
Polymers (other ingredients)	0.46%	0.5%
Sodium chloride (other ingredients)	0.46%	1.8%
Others (other ingredients)	0.46%	-
Benzisothiazolinone	-	0.1%
Methylisothiazolinone	-	0.1%
Glucoside	-	7.0%
Phosphonate	-	0.3%
Antifoam agent (Polydimethylsiloxane)	-	0.01%
Transport of raw materials (from base-case scenario): 500km (lorry) for road transport, and 15,000km (transoceanic ship) for sea transport.		

The values of CDV and biodegradability have been analysed in both formulations in order to verify that the EU Ecolabelled formulation is compliant with the EU Ecolabel criteria and that all changes on formulation allow a better performance on these criteria (Table 53).

Table 53. Score for Criteria 2 and 3 of EU Ecolabel for detergents.

	CDV	ANBO (surf)	aANBO (surf)	ANBO (org)	aANBO (org)
EU criteria thresholds	31,500	0	0	0.45	0.55
Base-case formulation	37,803.00	0	0	0.43	2.02
EU Ecolabel formulation	19,535.00	0	0	0.19	0.19

Base-case formulation is not compliant with EU Ecolabel criteria: it fails to comply with the score on CDV and biodegradability for organic substances. Some of the organic substances with higher impact, due to their biodegradability have been eliminated in the new formulation (e.g. Alkylbenzene sulfonate); or their concentration has been reduced in the formulation: fragrances or sodium alkyl ether sulphates.

As for the other product groups, the **production** of the LD is not covered in the EU Ecolabel scope. Similarly to what was done in the other scenarios, a sensitivity analysis has been conducted to estimate the improvement potential of including good environmental actions during the production phase. Details and results are provided in section 8.13.

Logistics phase is not covered by EU Ecolabel criteria. A sensitivity analysis has been performed assuming that vehicles with a better emission profile are used during the transport of the product. Details and results are provided in section 8.13. Nevertheless, an improvement in this phase is achieved due to the reduction of the dosage used in the use phase.

As for Dishwasher Detergents, EU Ecolabel criteria include a criterion of **packaging**, where the following requirements are included:

— Weight/utility ratio (WUR): the WUR for primary packaging of laundry detergents shall not exceed 1.4g of liquid or gel detergent per kg of laundry. However, those primary packaging made of more than 80% of recycled materials are exempted of the requirement.

— Design for recycling: the packaging shall be designed to facilitate its recycling. Different materials and components excluded from packaging elements are listed in the criterion.

Base-case scenario considers a 650mL bottle of HDPE, a cap of PP, and a paper label. Considering a reference load of 4.5kg, base-case packaging is not compliant with weight/utility ratio defined in EU Ecolabel. For the eco-innovation scenario, the packaging capacity has been changed according to the most used liquid laundry packaging: 1,500 mL of capacity (Table 54).

Table 54. Market share of packaging capacities for Laundry detergents.

Capacity (mL)	**Percentage of products** (liquid laundry detergent) (%)
1,500	46.15
1,000	23.08
3,000	7.69
960	7.69
2,700	7.69
2,000	7.69

Source: Mintel Database. European Market, 2017.

An estimation of the packaging weight has been defined in order to comply with the requirements defined in the Criterion 6 of EU Ecolabel:

— HDPE bottle: there are different weights in the market, varying from 40g to 70g approximately. In order to comply with the WUR requirement, the weight has been defined as 55g.

— PE cap: standard cap of 7g has been assumed.

— Label: the same weight for the label has been considered in the eco-innovation scenario, 1g.

Table 55 shows a summary of WUR calculation. End of life of packaging is affected by these changes included in the packaging design. On the other hand, a sensitivity analysis is considered increasing the recycling ratio of the packaging. Details and results are provided in section 8.13.

Table 55. WUR calculation. Laundry detergent.

	Dosages per packaging	Packaging weight per wash	kg of laundry per wash	Packaging weight per kg of laundry	WUR
Base case scenario	8.67	4.60	4.5	1.02	2.04
Eco-innovation scenario	21.43	2.94	4.5	0.65	1.30

Regarding the **use** phase, the EU Ecolabel includes the Criterion 8 on User Information where different advices are presented: dosing instructions and environmental information to minimise energy and water consumptions and to reduce water pollution. Moreover, a Criterion about fitness for use of the LD is included in EU Ecolabel: the product shall have a satisfactory cleaning performance at the lowest temperature and dosage recommended by the manufacturer.

Two aspects have been tested in this phase:

— Dosage used during a washing program. The reference dosage defined in Criterion 1 of EU Ecolabel is 16g/kg of laundry. Considering a load of 4.5 kg for the calculation of the dosage recommended, the base-case scenario is not compliant with the dosage requirements. For this reason the dosage has been reduced to 71.4g in the eco-innovation scenario (changing from 75 to 70mL: 70mL x 1.02g/mL = 71.4 grams)

— Temperature used in the washing program. The base-case scenario considers a temperature wash of 40ºC, reducing the temperature to the lowest recommended temperature using eco programs of the washing machine the energy consumed during the laundry is reduced (TopTen EU).

The eco-innovation scenario has been modelled accordingly (Table 56).

Table 56. Improved scenario defined for use phase of laundry detergent.

Use	BASE-CASE SCENARIO	IMPROVED SCENARIO	Units
Dosage	76.5	71.4	g
Electricity	0.638	0.488	kWh
Water	50	50	kg

The restrictions included in the use phase have an impact reduction in the **end of life phase**: reduction of dosage used per washing cycle.

Parameters modified in the model:

Table 57 reports a summary of the parameters that have been changed in the base-case model, following the justifications exposed in the rationale.

Table 57. Parameters modified in the eco-innovation scenario for laundry detergents.

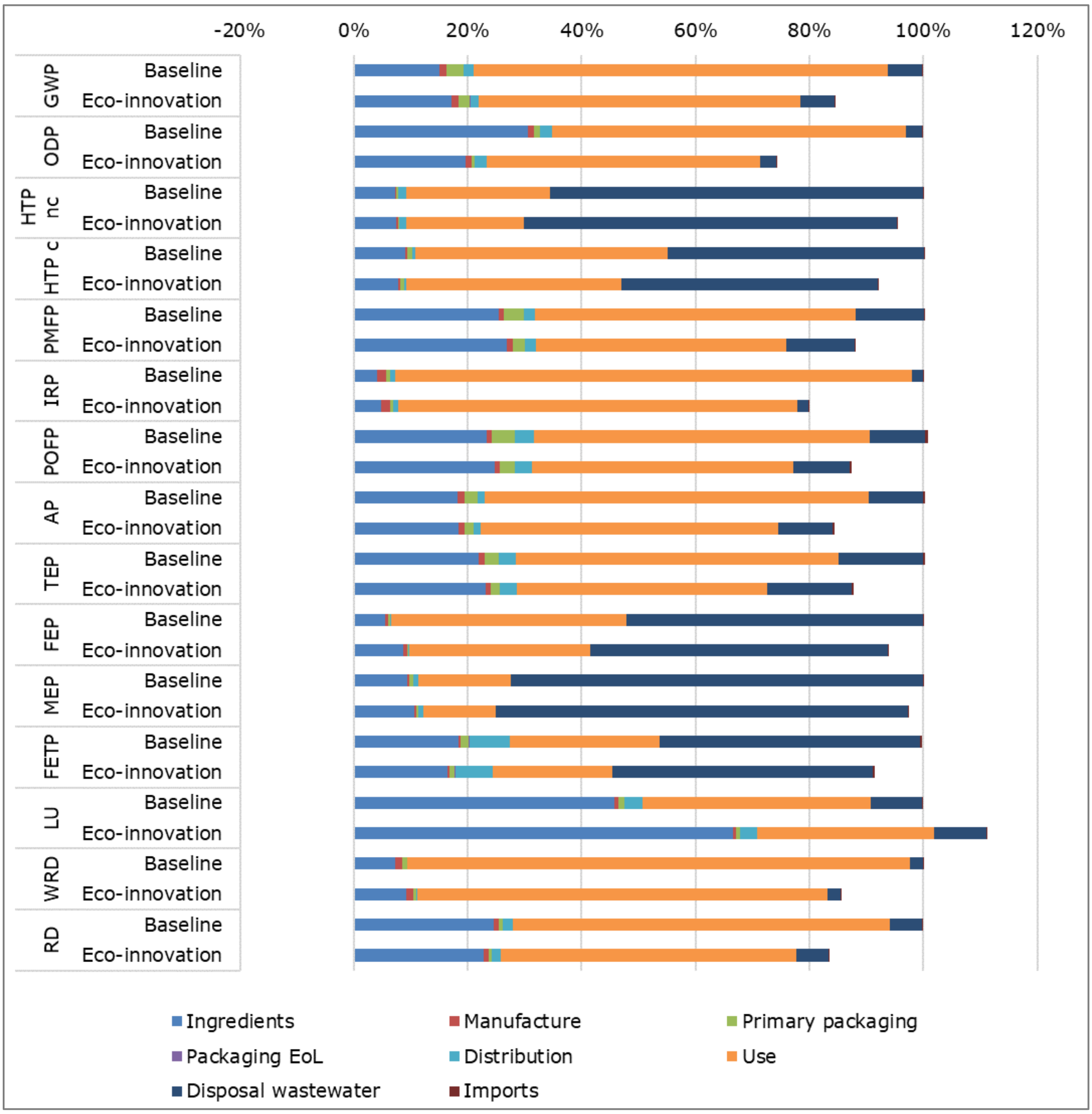
	Laundry detergents
Components manufacture	Formulation according to Criteria requirements included in EU Ecolabel (Table 52).
Packaging	Increase of packaging capacity (1500 mL) and reduction of material to comply with packaging requirements.
Use phase	Reduction of dosage: from 75 mL to 70 mL of product; electricity: from 0.638 to 0.488 kWh

Results:

Scenario results were analysed for the single product (Figure 26) and for the overall BoP (Figure 27). The eco-innovation profile of this product includes a reduction of the dosage used, in order to comply with Criterion 1 of dosage requirements. The comparison has been done considering the different reference dosage defined in each scenario: 75mL for the base case scenario and 70mL for the improved scenario.

The most impacting phases are the use stage and the disposal of the product (wastewater treatment) (Figure 26). The reduction of the energy used during the washing machine cycle affects the impact on the use stage, decreasing the environmental impact of the product between 15% and 23%, depending on the impact category considered. The eco-innovation scenario does not include an improvement in the end of life phase, for this reason the impact of this life cycle stage is the same as in the baseline scenario.

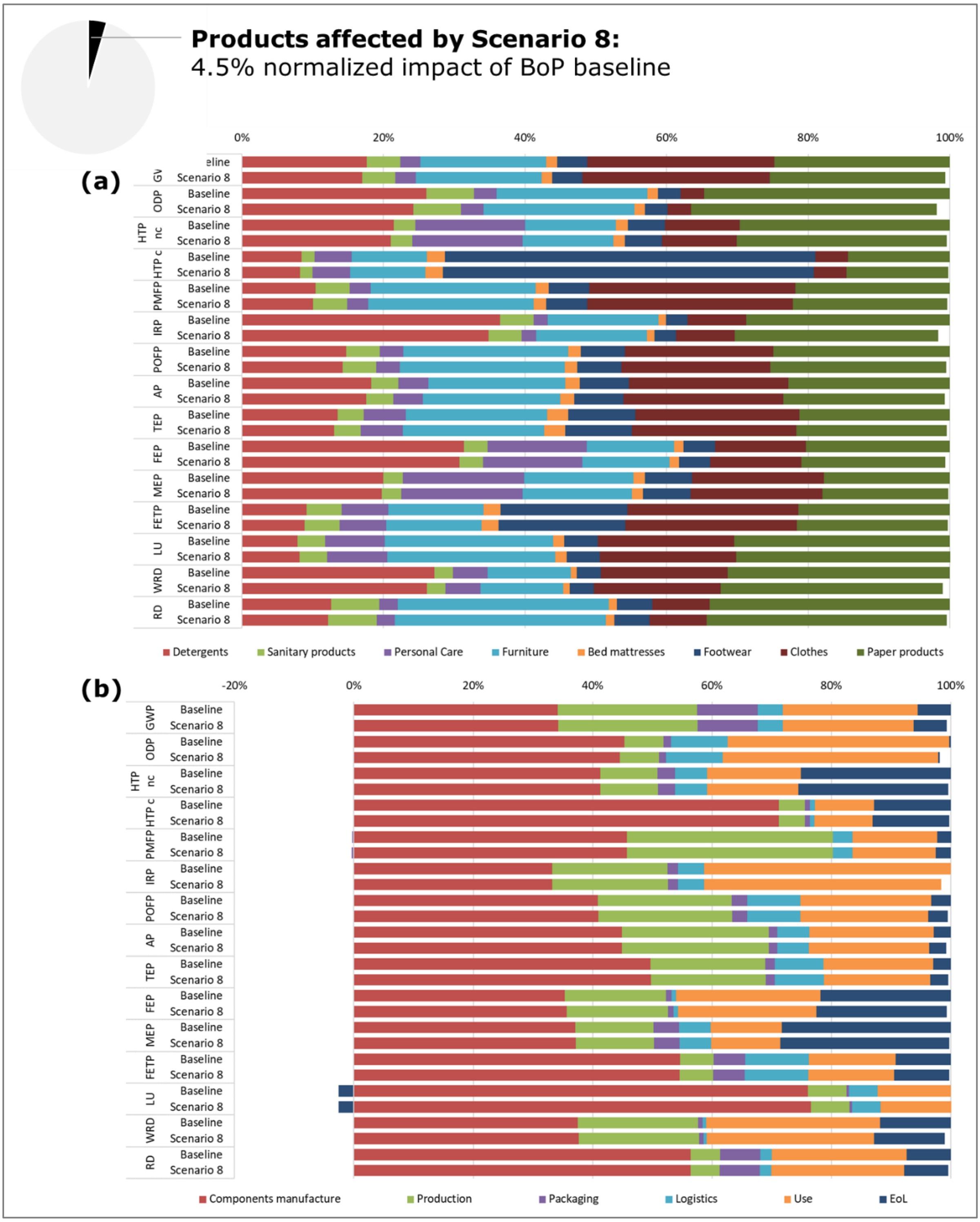
Figure 26. Individual analysis of laundry detergent products - Comparative assessment of baseline and eco-innovation scenarios of laundry detergent. "Imports" include the transport of the imported finished products.



(For the abbreviations of the names of impact categories see note to Figure 9)

For the land use impact category, the eco-innovation scenario represents a higher impact than the base-case due to the raw materials used in the formulation: the proposed formulation includes glucoside, being the highest contributor to the impact (Figure 26).

Figure 27. Scenario 8 in comparison with the baseline scenario (with total from the baseline set as 100%) – split into the contributions of (a) the various product groups and (b) the life cycle stages.



(For the abbreviations of the names of impact categories see note to Figure 9)

Laundry detergent products represent 4.5% of the normalized environmental impact of the BoP in the baseline scenario. When assessing a 100% replacement of LD products for EU Ecolabelled LD products, the environmental impact of the whole BoP

Regarding the changes on the overall BoP environmental impact, the relative impact of the introduction of EU Ecolabel LD product goes from 1.8% of reduction in ozone depletion to

0.22% in marine eutrophication. For the land use impact category, the environmental impact considering the EU Ecolabel LD product increases by 0.3% (Figure 27).

The inclusion of Eco-innovation LD scenario allows an improvement of Detergents category, with a reduction of its impact going from 1% (MEP) to 7% (ODP) for the impact of this product group. On the contrary, the impact to land use increases by 4%.

When the reduction of impacts of BoP are analysed at the life cycle stage level, it can be seen that the life cycle stage with the highest environmental savings take place in the use phase (2.7% of reduction on average), followed by packaging (0.6% of reduction). Components have also small savings of 0.2% on average (Figure 27).

8.11. Scenario 9 – EU Ecolabel scenario on upholstered seat

Description and aim:

The aim of this scenario is to examine the potential environmental benefits coming from the use of an EU Ecolabelled product, compared to base-case upholstered seat (sofa) modelled in the baseline scenario.

Area of intervention:

- Hotspot addressed: impacts from the whole life cycle of upholstered seats.
- Product group: furniture.
- Life cycle stage: components manufacture (choice of materials, design for disassembly) and EoL (recycling of materials).

Policy relevance: Commission Decision (EU) 2016/1332 of 28 July 2016 establishing the ecological criteria for the award of the EU Ecolabel for furniture.

Background information:

It is worth to note that the LCA results of the baseline scenario show that furniture is one of the product groups included in the BoP with higher contribution to the overall impact compared to other product groups (also due to the weight of the representative products and the amount of materials used to produce them).

The main environmental impacts along the upholstered seat's life cycle stages are mainly due to:

- Energy used to extract and transport the raw materials
- Use of Coal in the production of the electricity needed to produce the flame retardants (contribution to particulate matter).

Rationale for building the scenario:

This section summarizes the eco-innovation actions included in the upholstered seat eco-innovation scenario and the rationale for all the assumptions taken.

Regarding the **components manufacture**, eco-innovation measures selecting more sustainable materials (such as organic cotton, wood, and other tree-based products with chain of custody certification FSC, etc.) could be performed to improve the upholstered seat. However, the effects of some of the measures (such as the environmental benefits related to sustainable management of forest, see Table 24) cannot be fully analysed through the LCA. Therefore, the type of components included in the EU Ecolabelled sofa is assumed to be similar to the ones in the base-case.

Regarding the flame retardants, nitrogen- and phosphorus-based flame retardants have been maintained since they are classified as non-hazardous thereby complying with Criterion 2 of the EU Ecolabel for furniture.

The eco-innovation introduced in the scenario is the use of only one type of textile instead of two. Polyester textile is employed in the eco-innovation scenario instead of the mixed cotton and polyester textile of the base-case scenario. The fact of using only one textile within the production process of the upholstered seat will benefit the recycling process at the end of life of the product. Therefore, as it is shown in Table 58 the final amount of textile in the eco-innovation scenario is 7.2 kg of polyester.

Table 58. Materials used in the manufacturing of upholstered seat.

Components	BASE-CASE SCENARIO		ECO-INNOVATION SCENARIO	
	Formulation (%)	Quantity (kg)	Formulation (%)	Quantity (kg)
Medium density particleboard (MDP)	61.76	37.8	61.76	37.8
Solid timber	7.84	4.8	7.84	4.8
Steel	7.84	4.8	7.84	4.8
Textile, cotton	7.84	4.8	0	0
Textile, polyester	3.92	2.4	12	7.2
Polyurethane foam	8.82	5.4	8.82	5.4
Phosphorus (used in flame retardants)	0.98	0.6	0.98	0.6
Melamine (flame retardant)	0.98	0.6	0.98	0.6

Since the **production process** of the upholstered seat is not covered by the EU Ecolabel, it has not been considered for the eco-innovation scenario. However, different EU environmental policies referring to the manufacturing process such as the Environmental Management and Audit Scheme EMAS (EMAS webpage) and the international standard ISO 14001 are well implemented along EU industry with significant environmental benefits demonstrated. A sensitivity analysis has been done to estimate the effect of energy efficiency measures applied at the manufacturing stage on the environmental profile of the final product. Details and results are provided in section 8.13.

The **logistics stage** of the upholstered seat is not covered by the EU Ecolabel, therefore no improvements are considered for the eco-innovation scenario.

An additional sensitivity analysis has been performed considering road vehicles with a better emission profile that can improve the environmental profile of the final product. Details and results are provided in section 8.13.

Since the EU Ecolabel does not settle any specific requirement regarding the **packaging**, the eco-innovation scenario does not consider any improvements at this stage.

A sensitivity analysis has been performed based on the selection of sustainable materials as well as the percentage of the recycled content. Details and results are provided in section 8.13.

The **use phase** has been maintained the same as the base-case scenario since no EU Ecolabel criteria is related to the use phase.

According to EU Ecolabel criteria, the upholstered seat should be recyclable at the **end of life**; its design should therefore have considered disassembly as a feasible option, fulfilling the EU Ecolabel Criterion 9 Requirement for final product. The new eco-innovation scenario takes into account higher recycling rates than the base-case due to the improvements of the selected components in the design phase and the manufacturing for disassembly.

The scenarios have been modelled based on existing initiatives and publications that have demonstrated the feasibility of reusing and recycling upholstered seat products, therefore the base-case assumption of 100% of end of life products going to landfill and incineration will be reduced with the incorporation of a recycling pathway.

The European Environmental Bureau (EEB) has commissioned a study in 2017 to foster the transition to a circular economy furniture sector at EU level where the baseline scenario tackles a 10% recycling of upholstered seats (Forrest et al., 2017). The same study mention the example of the French Expanded Product Responsibility law, which sets a re-use and recycling target of 45% for household furniture waste by 2017 in France.

Therefore, the eco-innovation scenario has been modelled with 10% of recycling (wood, metal, and plastic streams) and the rest going to landfill (50%) and incineration (40%) (Table 59).

Table 59. End of life for upholstered seat in the eco-innovation scenario.

Recycling rates	BASE-CASE SCENARIO	ECO-INNOVATION SCENARIO
Recycling	Wood, Metal and Plastic: 0%	Wood, Metal and Plastic: 10%
Landfill	55 %	50 %
Incineration	45 %	40 %

Parameters modified in the model:

Table 60 reports a summary of the parameters that have been changed in the base-case model, following the justifications exposed in the rationale.

Table 60. Parameters modified in the eco-innovation scenario for upholstered seat.

	Upholstered Seat
Components manufacture	Design according to EU Ecolabel restrictions (details in Table 58)
End of life	Recycling rates improvement according to good disassembly design, considering 10% recycling of wood, metal and plastic: 50% landfill and 40% incineration.

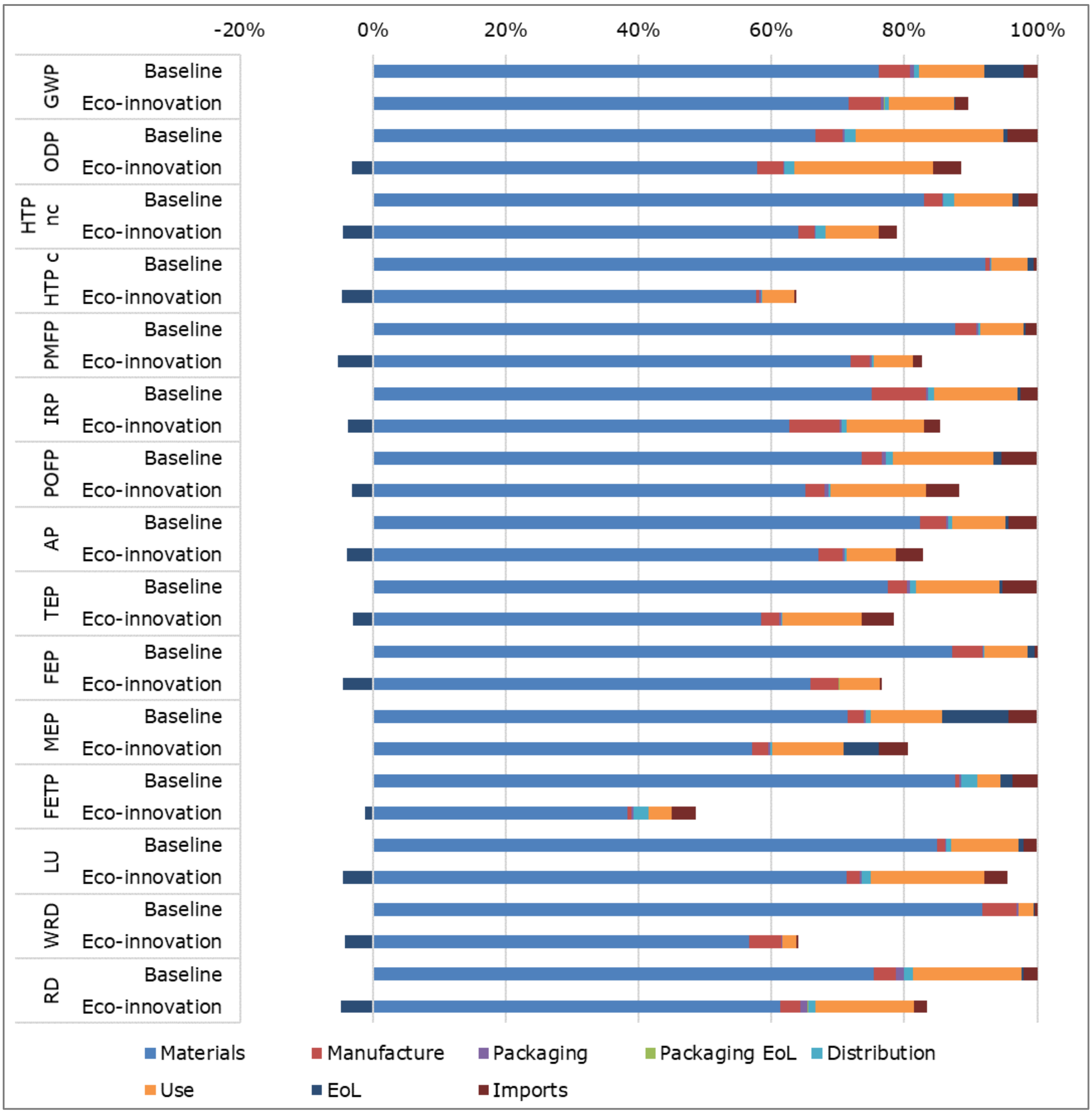
Results:

Scenario results were analysed for the single product (Figure 28) and for the overall BoP (Figure 29). All the above assumptions have been modelled, and the environmental performance of one piece of furniture (sofa, 60 kg) based on eco-innovation measures has been calculated.

The comparison of the base-case and the eco-innovation scenarios illustrates that the new scenario has a lower environmental impact. The impact categories that show a higher environmental improvement are Freshwater ecotoxicity (51.4%), Land use (46.1%), Human toxicity, cancer effects (34.8%), and Water resource depletion (34.6%) (Figure 28).

When life cycle stages of upholstered seat products are examined, most of them have the same environmental impact in both scenarios (base-case and eco-innovation). The main advantages on the environmental profile of the new scenario of upholstered seat are in the end of life phase due to the recycling rate of the components when the product becomes a waste. Another improvement can be seen in the materials contribution to the overall impact.

Figure 28. Individual analysis of upholstered seat products - Comparative assessment of baseline and eco-innovation scenarios of upholstered seat. "Imports" include the transport of the imported finished products.



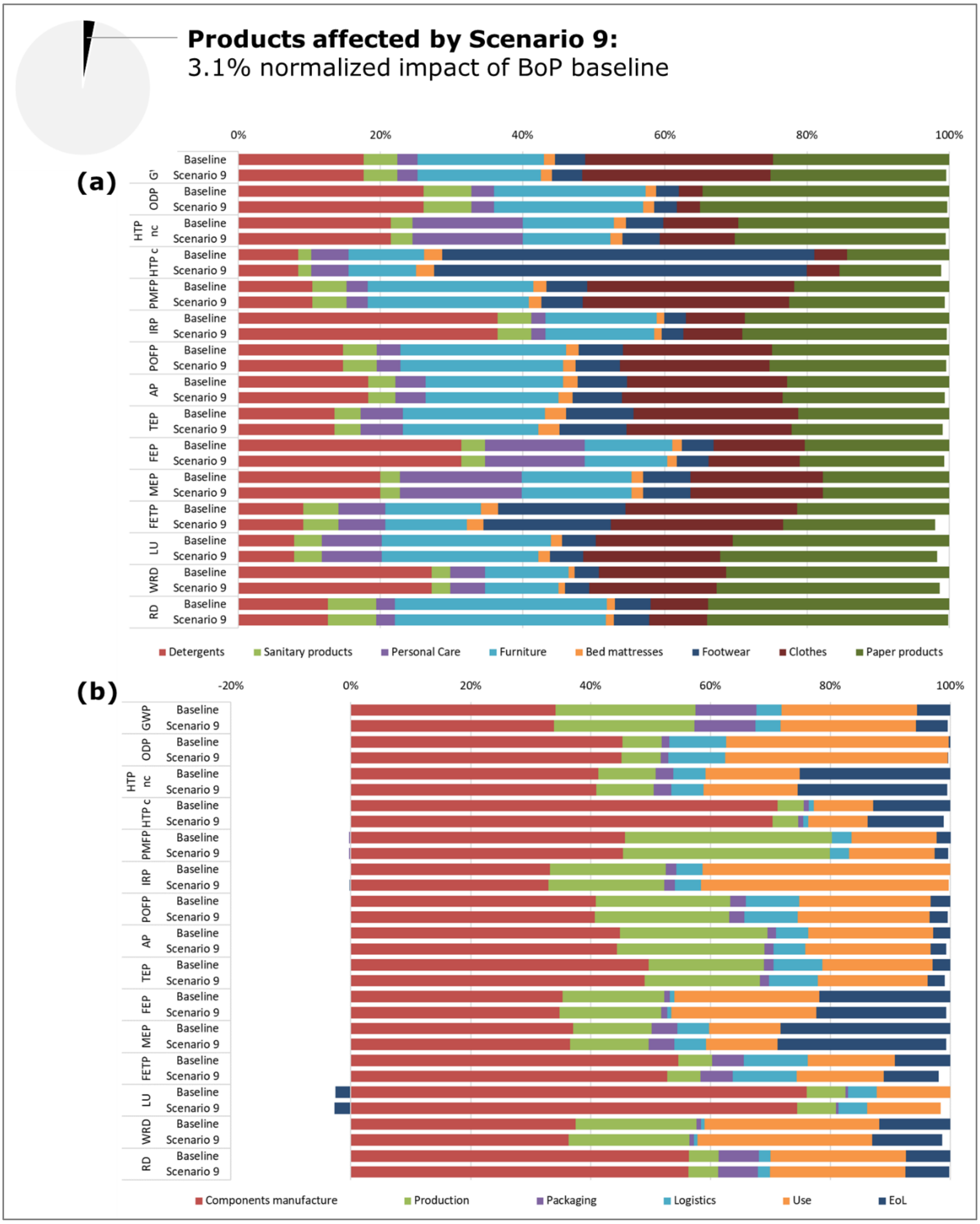
(For the abbreviations of the names of impact categories see note to Figure 9)

Upholstered seat products contribute to 3.1% of the normalized impact of the overall BoP household goods. When the whole BoP is analysed with the new upholstered seat scenario, changes on the environmental profile of the whole BoP are generally low (below 2%), being Freshwater ecotoxicity (-2.0%) and Land use (-1.7%) the ones showing the largest decrease (Figure 29).

The eco-innovation scenario for upholstered seats allows a general improvement within the furniture product group, with a reduction in Freshwater ecotoxicity (14.8%), Water resource depletion (11.7%), Human toxicity, cancer effects (10.4%), and Land use (7.3%).

When the comparison of the two scenarios is analysed by life cycle stage, the main environmental savings are found in the life cycle stages of components manufacture (1.2% of reduction of impacts) and EoL (1.9% of reduction) (Figure 29).

Figure 29. Scenario 9 in comparison with the baseline scenario (with total from the baseline set as 100%) – split into the contributions of the various product groups.



(For the abbreviations of the names of impact categories see note to Figure 9)

8.12. Scenario 10 - Overall potential from the analysed EU Ecolabel scenarios

In order to analyse the combined potential effect of the five eco-innovation scenarios testing the EU Ecolabel for single product types, they have been assessed in a combined scenario, including all the modifications illustrated before. In this scenario, it is firstly assumed that 100% of the products in the market belonging to the product types affected by modifications (liquid soap, shampoo, dishwashing detergent, laundry detergent, and upholstered seat) would implement the innovations presented, i.e. would respect EU Ecolabel criteria for each specific product group. The assumption of 100% uptake is quite unrealistic, but it is used to assess the maximum improvement potential related to the eco-innovations tested.

A more realistic assumption has been tested as well, as second option. In this case, 20% uptake by the product on the market is assumed, with reference to the aimed strictness of the EU Ecolabel criteria, which should correspond to the best 10-20% of the products available on the Community market in terms of environmental performance, according to the EU Ecolabel regulation.

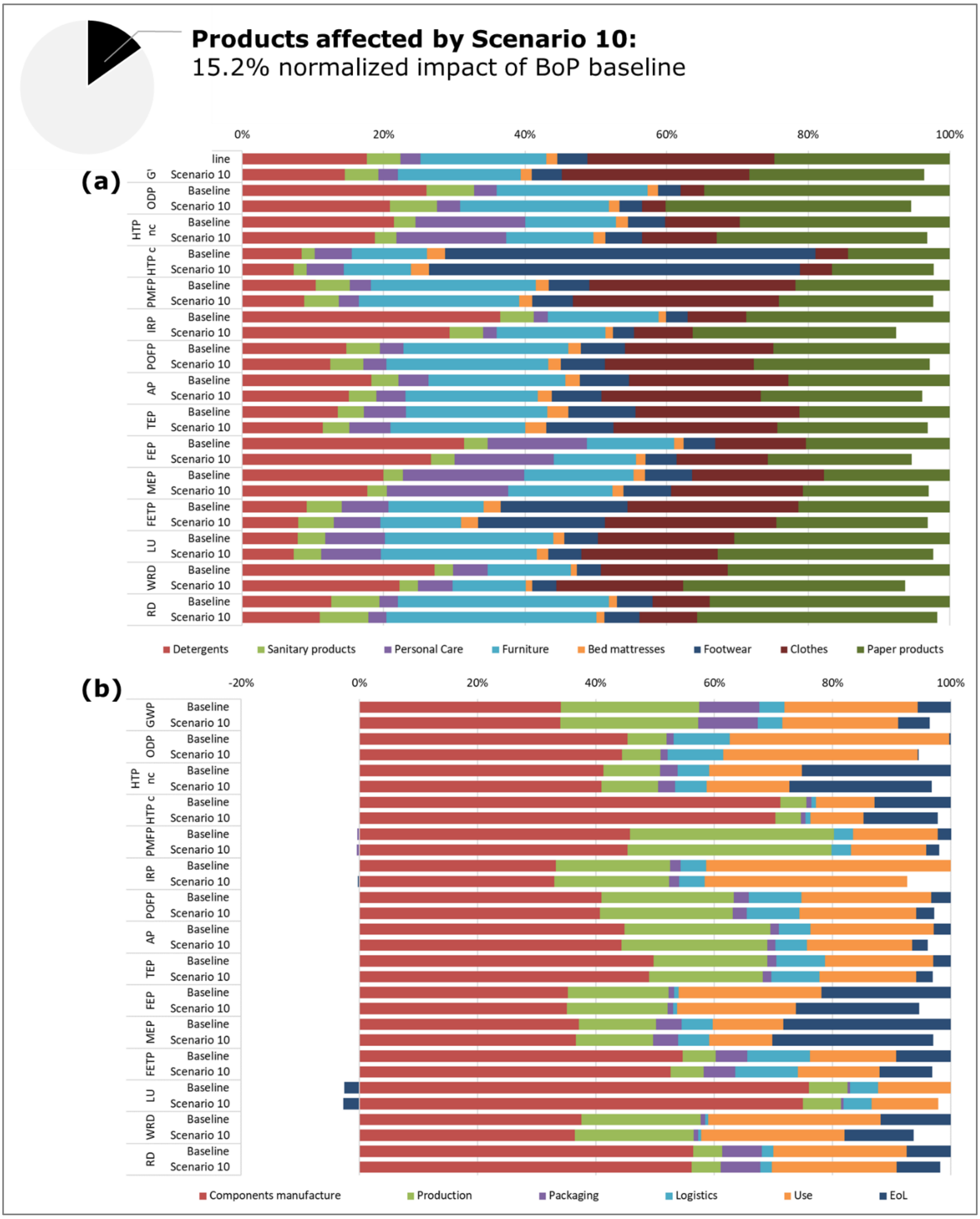
In this section the comparative results for the eco-innovation BoP including the five eco-innovation scenarios are represented. The categories modified in the eco-innovation BoP are Personal care (shampoos and liquid soaps), Detergents (dishwasher and laundry detergents), and Furniture (upholstered seats).

Results are shown by type of product and by life cycle stage for the case of 100% market uptake (Figure 30). The overall relative reduction of the BoP Scenario in comparison with the base-case by impact category indicates that all values are reduced for all impact categories. The highest reduction is obtained for ionising radiation (7.5%), followed by water depletion (6.3%), ozone depletion (5.5%), and freshwater eutrophication (5.4%), whereas the lowest reduction is observed for resource depletion (1.8%) (Figure 30). The product category with the highest improvements is detergents, followed by furniture. Personal care has limited effect to the overall reduction of impacts of the eco-innovation scenario, because of their relatively limited contribution to the overall impact of the BoP in the baseline scenario.

When the comparison of the baseline and eco-innovation BoP is done by life cycle stage, it can be observed that higher savings are found in the use stage (between 5% and 17% of reduction, depending on the impact category). The packaging phase shows reductions up to 12% in Land use, although an increase in particulate matter. End of life stage also has relevant reductions in most of the impact categories (up to 59% in ozone depletion), although trade-offs take place in ionizing radiation and land use. Production and logistics life cycle stages are the ones contributing the least to the reductions in the environmental impact (<0.5%) (Figure 30).

The relative reduction in percentage per impact category and product is detailed in Table 61, for both assumptions on uptake (100% and 20%).

Figure 30. Scenario 10 in comparison with the baseline scenario (with total from the baseline set as 100%) – split into the contributions of the various product groups.



(For the abbreviations of the names of impact categories see note to Figure 9)

Table 61. Relative reductions of environmental impacts for Eco-innovation scenarios. Reductions are above 5% (green), between 1.5% and 4.99% (yellow) and below 1.49% (red).

	Considering 100% of uptake of Eco-innovation scenarios (%)						Considering 20% of uptake of Eco-innovation scenarios (Goal of market share of EU Ecolabel) (%)					
	TOTAL BoP	Liquid soap	Shampoo	LD	DD	Uphols. seat	TOTAL BoP	Liquid soap	Shampoo	LD	DD	Uphols. seat
GWP	-3.60	-0.03	-0.04	-0.66	-2.42	-0.40	-0.72	-0.01	-0.01	-0.13	-0.48	-0.08
ODP	-5.45	0.00	0.11	-1.82	-3.37	-0.31	-1.09	0.00	0.02	-0.36	-0.67	-0.06
HTC nc	-3.21	-0.01	-0.01	-0.40	-2.30	-0.48	-0.64	< -0.01	< -0.01	-0.08	-0.46	-0.10
HTC c	-2.26	-0.01	-0.01	-0.24	-0.89	-1.11	-0.45	< -0.01	< -0.01	-0.05	-0.18	-0.22
PMFP	-2.34	-0.02	-0.03	-0.34	-1.26	-0.67	-0.47	< -0.01	-0.01	-0.07	-0.25	-0.13
IRP	-7.55	-0.01	-0.02	-1.64	-5.49	-0.37	-1.51	< -0.01	< -0.01	-0.33	-1.10	-0.07
POFP	-2.81	-0.01	-0.02	-0.48	-1.75	-0.41	-0.56	< -0.01	< -0.01	-0.10	-0.35	-0.08
AP	-3.90	-0.03	-0.03	-0.73	-2.43	-0.66	-0.78	-0.01	-0.01	-0.15	-0.49	-0.13
TEP	-3.10	-0.02	-0.03	-0.45	-1.65	-0.94	-0.62	< -0.01	-0.01	-0.09	-0.33	-0.19
FEP	-5.39	-0.01	-0.01	-0.65	-4.01	-0.69	-1.08	< -0.01	< -0.01	-0.13	-0.80	-0.14
MEP	-2.99	-0.01	-0.02	-0.22	-2.03	0.00	-0.60	< -0.01	< -0.01	-0.04	-0.41	0.00
FETP	-3.15	-0.01	<0.01	-0.28	-0.85	-1.99	-0.63	< 0.01	< -0.01	-0.06	-0.17	-0.40
LU	-2.31	0.01	-0.01	0.31	-0.85	-1.73	-0.46	< -0.01	< -0.01	0.06	-0.17	-0.35
WRD	-6.32	-0.01	-0.03	-1.01	-3.91	-1.36	-1.26	< -0.01	-0.01	-0.20	-0.78	-0.27
RD	-1.81	-0.01	-0.01	-0.41	-1.20	-0.17	-0.36	< -0.01	< -0.01	-0.08	-0.24	-0.03

8.13. Sensitivity analyses on EU Ecolabel scenarios

The results for the different analysis performed are presented in this section, in relation to those improvement actions, which are not included in the scenarios since they are not directly covered by EU Ecolabel, but they have been identified as being feasible and having a potential relevant improvement potential on the overall products impact.

As illustrated in Table 26, the improvement options analysed are: the reduction of electricity use during the production phase of all the products considered (5%, 10%, and 20% reduction compared to the baseline scenario); the use of Euro 6 lorries instead of Euro 4 ones for distribution of goods; and an improvement of the recycling rates for packaging materials at their EoL (60% or 100% recycling of plastic and 90% or 100% recycling of cardboard). In addition, two sensitivity analyses were focused specifically on soaps and shampoos, acting on consumers' behaviour, assuming that citizens that buy EU Ecolabelled products would be more environmentally friendly and would reduce the amount of water used per washing (by 5% or 10%). This change would have an impact also on the amount of wastewater to be treated, so this effect is analysed too.

The reasoning followed to define the assumptions for the sensitivity analyses presented before is reported in the paragraphs below.

Reduction of industrial processing energy

Public sustainability reports including energy consumptions from key companies in the market have been gathered to determine a percentage of reduction of energy in comparison to base-case scenario.

Good practices identified to reduce the energy consumption are:

— Optimisation of manufacturing procedures with the aim of using less washing water and/or reducing its temperature.

— Insulation measures for buildings (walls, windows) to reduce energy consumption for heating and air conditioning; same for hot water piping;

— Optimisation of production planning (sequence of batches produced using same equipment);

— Replacement of old equipment by new, energy efficient electrical devices (e.g. pumps, extruders).

— Energy recovery from hot wastewater or air.

Some goals and reductions from reference industries are detailed as example from their sustainability reports, for instance:

— P&G: reduction of 15% from 2010 to 2015; goal of reduction of 20% from 2010 to 2020. (P&G. 2015)

— Henkel: goal of reduction of 15% from 2010 to 2015. (Henkel, 2014)

Improvement of road transport vehicles for distribution

In the baseline scenario transport is modelled assuming the use of lorries with an emission profile compliant with Euro 4 standard. For the sensitivity analyses a more advanced emission profile, i.e. Euro 6, has been assumed.

Increasing recycling ratio of packaging End of Life (EoL)

The following considerations were taken into account to define the sensitivity analysis on packaging EoL:

— The packaging is 100% recyclable, according to EU Ecolabel criteria, which require packaging designed for recycling without incompatible materials.

— The product will be empty at their end of life, thank to dosage design and according to EU Ecolabel.

— The consumer profile buying EU Ecolabelled products is proved to have a higher environmental awareness, so that it is assumed that they dispose correctly the packaging waste for their recycling.

Reduction of water use during use and EoL

During the last years a reduction of the domestic water consumption in many EU Member States could be observed as a result of various factors (Eurostat, 2017), including the reduction of water losses through improved maintenance of the networks, the introduction of water-saving household appliances and an increasing level of awareness concerning of consumers.

According to a Eurobarometer survey (2017), the majority of EU citizens think that protecting the environment is very important to them personally. Findings have remained broadly consistent over the last ten years, although since the last survey there has been a slight increase in the proportion saying it is 'very important': 56% compared with 53% in 2014. When asked about environmental activities they have undertaken in the past six months, 27% of respondents stated that in the last six months they had cut down their water consumption, among other actions such as separating most of their waste for recycling (65%), buying local products (43%), cut down their energy consumption (35%) or buying products marked with an environmental label (19%).

For this reason, a sensitivity analysis has been done reducing the quantity of water use in a 5% and a 10%, in order to see how this measure would affect the overall environmental impact of the products.

Results:

The improvement actions that show higher potential for reducing the impacts are the reduction of water use at the use phase of products and the improvement of recycling rates for packaging materials.

The reduction of water use (and of wastewater treated) could contribute to improve the environmental profile of liquid soap and of shampoo, because these two stages are the most impacting ones considering the life cycle of those products. For both products, the impact on human toxicity (cancer and non-cancer effects), freshwater eutrophication, marine eutrophication and water depletion is reduced by 10%, whereas a 5% reduction is observed for climate change, particulate matter, ionising radiation and acidification.

Improving the recycling rates of packaging materials at the EoL of packaging has a mixed effect on the environmental profile of liquid soap and shampoo. In the case of 100% recycling, the impact on climate change and photochemical ozone formation is reduced by 10% compared to the baseline scenario. However, a slight increase is observed for other impact categories (such as ionising radiation, freshwater eutrophication and water depletion, probably because of the use of electricity in the treatment of materials before recycling. A similar pattern, but with more limited effects (3% reduction of the impact on climate change) is observed for the laundry detergent, whereas the action has negligible effect on the profile of dishwasher detergent and upholstered seat.

The use of Euro 6 lorries for the distribution of products has some effect only on the profile of liquid soap (5% reduction of the impact on terrestrial eutrophication and 4.6% reduction of the impact on photochemical ozone formation) and on laundry detergent (2% reduction on the same impact categories mentioned for the soap). For the other products, the effect of this action can be considered negligible.

The improvement of energy efficiency of the production phase, which implies a reduction in the amount of energy used, seems to be a less relevant option for all the products considered. The highest reduction (3%) is obtained for ozone depletion in the profile of the shampoo, whereas the effect is generally below 1% for the other products and even lower (below 0.1%) for the detergents.

8.14. Summary of results from scenario analysis

Table 62 represents a summary of the results of the scenarios assessed for the BoP household goods, as variation (%) of impact compared to the baseline scenario. Results that show an increase compared to the baseline are highlighted in red, whereas results that show a reduction are highlighted in green.

Table 62. Summary of results of the scenarios analysed. Results are expressed as variation (%) compared to the baseline BoP household goods.

	CC	ODP	HTP-nc	HTP-c	PM	IR	POF	AP	TEU	FEU	MEU	ECOTOX	LU	WU	FRD	MRD
SC.1: Larger use of TCF pulp	-0.3%	-0.2%	-0.1%	-0.7%	3.7%	-0.2%	-0.5%	-0.2%	-0.6%	-0.1%	-0.4%	-0.3%	1.0%	0.4%	-0.3%	-0.1%
SC.2a: EU electricity mix for textile production	-6.1%	2.9%	-1.9%	0.0%	-13.1%	8.9%	-6.5%	-7.6%	-6.3%	-0.1%	-4.2%	-0.1%	0.9%	-0.1%	-2.1%	1.4%
SC.2b: 2030 EU electricity mix for textile production	-8.0%	2.6%	-3.9%	-0.8%	-14.0%	2.6%	-8.7%	-11.8%	-8.2%	-2.9%	-5.4%	-0.4%	1.8%	-0.5%	-4.1%	2.0%
SC.3a: Improving reuse (25% reuse)	-4.0%	-2.4%	-2.9%	-1.6%	-4.5%	-2.4%	-3.9%	-4.1%	-3.9%	-2.4%	-2.9%	-4.2%	-5.8%	-3.5%	-3.4%	-3.8%
SC.3b: Improving reuse (100% reuse)	-16.0%	-9.4%	-11.4%	-6.3%	-18.2%	-9.6%	-15.4%	-16.4%	-15.6%	-9.7%	-11.5%	-17.0%	-23.0%	-13.8%	-13.7%	-15.2%
SC.4: Textiles with recycled input materials	-0.7%	-0.2%	-0.4%	-0.4%	-0.7%	-0.1%	-0.7%	-0.6%	-0.5%	-0.4%	-0.3%	-0.3%	-0.1%	-0.7%	-1.4%	-0.8%
SC.5: Ecolabel scenario on liquid soap	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%
SC.6: Ecolabel scenario on shampoo	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.1%
SC.7: Ecolabel scenario on dishwasher detergent	-2.2%	-2.3%	-2.3%	-0.9%	-0.8%	-5.3%	-1.6%	-2.3%	-1.6%	-4.0%	-1.9%	-0.8%	-0.7%	-1.4%	-3.3%	-1.3%
SC.8: Ecolabel scenario on laundry detergent	-0.6%	-1.4%	-0.7%	-0.2%	-0.2%	-1.6%	-0.4%	-0.7%	-0.4%	-0.6%	-0.2%	-0.2%	0.0%	0.0%	-1.0%	-1.1%
SC.9: Ecolabel scenario on upholstered seat	-0.4%	-0.3%	-0.6%	-1.1%	-0.6%	-0.4%	-0.4%	-0.6%	-0.9%	-0.7%	-0.7%	-1.7%	-1.7%	-2.8%	-0.2%	-0.2%
SC.10: Overall potential form Ecolabel scenarios	-3.4%	-3.9%	-3.6%	-2.2%	-1.7%	-7.2%	-2.6%	-3.8%	-2.9%	-5.4%	-2.9%	-2.8%	-2.4%	-4.2%	-4.7%	-2.5%

([1]) Abbreviations: GWP (Climate change), ODP (Ozone depletion), HTP nc (Human toxicity, non-cancer effects), HTP c (Human toxicity, cancer effects), PMFP (Particulate matter), IRP (Ionizing Radiation HH), POFP (Photochemical ozone formation), AP (Acidification), TEP (Terrestrial eutrophication), FEP (Freshwater eutrophication), MEP (Marine eutrophication), FETP (Freshwater ecotoxicity), LU (Land use), WRD (Water resource depletion), RD (Mineral, fossil & renewable resource depletion).

The scenario analysis done on the BoP household goods helped to identify some potential trade-offs that may occur when applying some of the actions that were tested as potential improvements for the sector. Some of them are related to the use of a different electricity mix (as in scenario 2a and scenario 2b), which reduces the impact on some impact categories (such as climate change) but generates also additional impacts on other impact categories (e.g. ionising radiation, due to the higher share of nuclear energy compared to the energy mix used in the baseline).

Another issue that may generate additional impacts along with reduction of impacts for some categories is the change of raw materials. In the scenarios analysed, this happened for the EU Ecolabel formulation of the shampoo (+0.1% impact on ODP) and of the laundry detergent (+0.3% on LU, due to the choice of natural-based surfactants). However, in these cases the additional impact generated is limited (below 0.5%).

Similarly, a larger use of TCF pulp (tested in scenario 1) proved to be useful for reducing the impact on freshwater ecotoxicity (which is the main aim of chlorine-free bleaching), but could generate additional impacts on PMFP (with an increase that is larger than the reduction obtained for FEP) and HTP-nc. Therefore, results of scenario 1 confirm the choice of not including the use of TCF pulp as a mandatory EU Ecolabel criterion.

Apart from the use of a less impacting energy mix, also reuse of products seems to have high potential for reducing the impact associated with purchase and use of household goods. The expected reduction is obviously proportional to the share of products that are reused. In scenario 3b it is assumed that the share of EU citizens that declared to be willing to reuse products would do it for 100% of the furniture pieces and clothes that they own. This means that the potential effect of this kind of action could be even larger, if a larger share of population would engage in reuse and if reuse would be extended to other types of household goods (e.g. footwear).

Regarding the EU Ecolabel scenarios, results obtained from the assessment of each individual product by functional unit has shown that significant environmental improvements can be obtained at product level. For these individual assessment, it can be observed that the inclusion of eco-innovation actions have significant environmental savings for some products and impact categories, going from 1% to 41% of impact savings depending on the product and impact category. Regarding the rinse-off cosmetic products, the improvements by product are quite limited since the life cycle stages with higher contributions (use and EoL) have not been modelled in the eco-innovation scenarios. Improvements in liquid soap and shampoos products span from 12% to 0.1%; liquid soap has the higher improvement 12% (GWP or POFP); 10% (GWP) for shampoos. Among the detergent products considered, the dishwasher detergent shows the highest reduction in all the impact categories, compared to the laundry detergent. This is partially due to the reduction in water use that is assumed for the dishwasher detergent. The highest reduction of impact for dishwasher is on HTP nc (38%), followed by FEP, MEP and WRD (36%). For the laundry detergent, the highest reduction is on ODP (26%) and IRP (20%). Finally, the EU Ecolabel version of upholstered seats shows relevant improvements by functional unit, mainly on LU (41%) and FETP (37%).

The effect of choosing EU Ecolabel products is assessed on the whole BoP by considering two hypotheses: 100% of uptake of eco-innovation products and considering the market share goal of EU Ecolabel products (20%).

For the comparative results of BoPs, the influence of each product group has been evaluated individually, showing limited improvement potential, due to the relative weight of each product in the composition of the BoP. Those product groups with a lower influence on the overall BoP improvement are liquid soaps and shampoos, whereas laundry detergent has the highest influence on the environmental impact of the whole BoP household goods.

The comparison between the baseline scenario and scenario 10 with the overall effect of choosing EU Ecolabel products (with the five product categories modified) shows significant improvements, with reduction in all impact categories going from 1.78% (as RD) to 7.26%

(IRP). The highest environmental savings are found in the following life cycle stages: EoL (average of 13.4% of reduction) use stage (average of 11.4% of reduction), followed by packaging (2.2%) and components (1%).

From the results of the study, the following main conclusion can be drawn:

— All EU Ecolabel scenarios, based on EU Ecolabel criteria, improved the environmental profile of the products, with significant variations by functional unit. This proves that EU Ecolabel is a good tool to promote more sustainable products within the market, contributing to a more sustainable system of production and consumption.

— Regarding the results obtained in the sensitivity analyses performed, it can be concluded that the measures tested (e.g. energy efficiency in manufacturing) have a very limited effect on the environmental impacts related to the production and EoL stages. This fact confirms that the EU Ecolabel criteria already cover the aspects that are more relevant for the environmental profile of the products considered (since sensitivity analyses have only been run on issues for which no EU Ecolabel criteria is defined)

— The improvement of the whole BoP when the five EU Ecolabel scenarios are considered in comparison with the base case is quite limited, although all impact categories decrease their values. It can be stated that the use of EU Ecolabel products for the selected products is not sufficient to reduce significantly the impact of consumption associated to household goods. Environmental savings have only limited significance if a 100% market composition by EU Ecolabel products is assumed. If 20% of EU Ecolabelled products are considered, variations on the results are not relevant in comparison with the base-case scenarios. These results obtained can be explained by different factors, including some limitations of the study, which are discussed below.

The most important limitation to these results is that only a small portion of products of the whole BoP of Household goods have been modified (5 out of 30 products), in only three out of the eight product groups (personal care, detergents and furniture). Some of the product groups and products that were not modified in the EU Ecolabel scenarios (e.g. clothes, footwear, sanitary products, and bed mattresses) are currently covered by EU Ecolabel criteria, but they were not modified compared to the baseline scenario. For this reason, it would be recommendable to extend the analysis to other products and product categories in order to be able to assess the effect of an eco-innovation scenario covering as many products as possible in order to have a more representative sample of EU Ecolabelled products in the overall EU Ecolabel scenario. This also suggests that having the possibility to award the EU Ecolabel to more product groups on the market could provide significant environmental benefits.

9. Conclusions

The Basket of Products (BoP) household goods has been built to assess the impact associated to the purchase and use of household goods in the EU. The baseline model includes a selection of product groups and it is built with a bottom-up approach, using life cycle inventories of representative products for each product group.

In total, 30 representative products were modelled[23], covering the following product groups: detergents, personal care (rinse-off cosmetics), absorbent hygiene products, furniture, bed mattresses, footwear, clothes (textile products) and paper products. The amount of representative products in the functional unit of analysis (i.e. consumption by an average EU citizen in one year) was relatively low (in some cases, below 50% of the entire consumption in the respective product group). Therefore, it was decided to upscale the apparent consumption of each product (i.e. the amount included in the basket) so to represent the 100% of the apparent consumption of the product groups selected. However, it has to be considered that the product groups selected for the BoP do not represent all the household goods that EU citizens purchase and use in their everyday life. There is a multiplicity of household good which are consumed and not modelled so far. The impact generated by those product groups could be considered in the future, by enlarging the list of representative products considered or by complementing the bottom-up approach followed for the BoP with information coming from top-down analysis (such as input-output assessment of household consumption). In general, the use of representative products may reduce the representativeness of the model, because it implies the exclusion of products that are less relevant in terms of the amount consumed but that potentially may be associated with high impact intensity. However, the use of a bottom-up approach, with process-based inventories allows for having more detailed life cycle inventories, and it is more useful when modelling scenarios. Moreover, the bottom-up approach allows for periodical updates of the BoP: the amount and structure of consumption could be updated to more recent reference years using data on apparent consumption (i.e. BoP composition and relative relevance of representative products) taken from Eurostat (Prodcom).

The baseline model of the BoP household goods (representing the annual purchase and use of household goods by EU citizens for the reference year 2010) was assessed using ILCD impact assessment method and also using the LCIA method adopted in the context of the EU Environmental Footprint (called here "EF 3.0"), where some impact categories were updated with a selection of recent impact assessment models and factors.

According to the results of the hotspot analysis, the life cycle stage that contribute the most to the overall impact is the manufacture of components (namely due to the environmental impacts of the extraction, manufacturing and the supply-chain of each individual raw materials, ingredients or intermediate products) that are used to produce the final products. Among the product groups included in the BoP, the ones that contribute the most to the overall impact are detergents, furniture, paper products and clothes. This contribution is the result of two combined factors: i) the environmental profiles (covering around 15 midpoint categories) of the representative products analysed, and ii) the amount of products included in the functional unit (i.e. amount of products purchased by an average citizen in one year). Each product group has different hotspots in terms of the type of impact and the life cycle stage in which the impact is generated.

Regarding the relevance of impact categories, the most relevant impacts of the BoP household goods occur in abiotic resource depletion, water depletion, and human toxicity,

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[23] Detergents (all-purpose cleaners and sanitary cleaners, detergents for dishwashers, detergents for hand dishwashing, liquid laundry detergents, and powder laundry detergents), sanitary products (absorbent hygiene products: baby diapers, sanitary pads, tampons, and breast pads), personal care (rinse-off cosmetic products) (bar soaps, liquid soaps, shampoos, and hair conditioner), furniture (bedroom wooden furniture, kitchen furniture, upholstered seats, non-upholstered seats, wooden tables), bed mattresses, footwear (work and waterproof (WW), sport, leisure, and fashion footwear), clothes (textile products) (t-shirt, blouse, trousers, and jeans), paper products (newspapers, books, and toilet paper).

cancer effects. The relative share of these categories varies according to the set of normalisation factors used (EU-27 or global references). However, when applying the EF 3.0 impact method, freshwater eco-toxicity becomes the most relevant category, followed by ionising radiation and fossil resources used (applying global normalization factors).

Between 2010 and 2015 most of the reference products showed an increase in the amount consumed per EU citizen. This fact resulted in an increasing trend of the environmental impact of the production and consumption of household goods in the EU, due to a larger consumption. The baseline for the year 2010 was used to test ten scenarios: four scenarios of eco-innovation (larger use of TCF pulp, reduced impact of electricity in the textile sector, improved re-use, and employing textiles with recycled input material for clothes manufacturing) and six EU Ecolabel scenarios (liquid soap, shampoo, dishwasher detergent, laundry detergent, upholstered seat, and a combined scenario with all these products). Among the scenarios assessed, the options that allow for a higher reduction of impacts are the ones related to the use of less impacting electricity mixes (Scenario 2 for clothes) and to the reuse of products (Scenario 3 for textile products and furniture). Results of the hotspot analysis for the baseline scenario and results of scenario 2a and scenario 2b show that for products that are largely imported from outside the EU (textile products), impacts due to the use of electricity in the production phase, which happens in countries that have an electricity mix with lower share of renewable sources compared to the EU, is more relevant than the impact associated to the transport from overseas. Results of scenario 3b, where 100% reuse is assumed for furniture and clothes (textile products), show a reduction of impact that is generally higher than 10% for all the impact categories. Furthermore, the potential of this action could be even higher if other product categories could be considered (e.g. footwear).

Results of the scenario analysis conducted on the BoP household goods unveiled some recommendations, ranked by effectivity (according to the scenarios):

— The reuse of products can be an effective way to improve the environmental profile of household consumption in the EU, as shown by the two scenarios on reuse of furniture pieces and clothes. The market for second-hand products in the EU is still limited, but could be enlarged in the future, in terms of product groups involved and number of people engaged. More generally, users' behaviour could have a relevant effect on the environmental impact of household goods consumption and should be taken into account when defining policies for sustainable consumption in the EU.

— The transition towards relying on an electricity mix with less impact intensity per kWh can reduce the environmental impact of the production of household goods, as observed in the scenarios evaluated. Beyond clothes (textile products), the improvement of the impact intensity of electricity can positively affect the production and consumption of other products (e.g. detergents during the use phase).

— The use of recycled materials (such as polyester in textiles) can reduce the environmental impact of household goods products. This eco-innovation action positively affects all the impact categories. However, its implementation can sometimes be limited by the technological development.

— Some eco-innovation actions (e.g. the use of totally chlorine free pulp for paper products) can reduce the environmental impact in some categories but generate trade-offs in other impact categories. The implementation of these actions needs to be evaluated towards addressing potential trade-offs and their causes.

Regarding the scenarios on single EU Ecolabel products (liquid soap, shampoo, dishwasher detergent, laundry detergent, upholstered seat) and the scenario considering together those five EU Ecolabel products (Scenario 10), the results show that:

— The environmental profile of EU Ecolabel products is generally better than the one of the average products in the market, despite that all life cycle stages are not systematically covered by the EU Ecolabel, in contrast to the BoP household goods where all life cycle stages are covered.

— The effect that the choice of EU Ecolabel products can have on the overall impact coming from purchase and use of household goods resulted to be relatively limited mainly due to the rather low share of the products -for which scenarios were tested- over the entire environmental impacts of the BoP (from 0.4% to 7.0% of the normalized impact for the baseline BoP). Moreover, the scenarios were assuming a 100% replacement of the products on the market with an EU Ecolabel option. This means that under more realistic market shares, the contribution to impact reduction is even lower.

— When considering the effect of EU Ecolabel on the five products altogether (Scenario 10), the decrease in the environmental impact was up to 7%. However, the scope of this analysis did not cover the overall effect of the EU Ecolabel scheme on the consumption of household goods and some of the product groups and products that are currently covered by EU Ecolabel criteria were not modified in the Ecolabel scenarios (e.g. clothes, footwear, sanitary products, and bed mattresses). For this reason, it would be recommendable to extend the analysis to other products and product categories in order to be able to assess the effect of an eco-innovation scenario covering as many products as possible in order to have a more representative sample of EU Ecolabelled products in the overall Ecolabel scenario.

— For certain products, such as detergents and personal care products, a relevant share of the improvement potential is related to a proper use by consumers (e.g. by saving water and energy and avoiding over dosing during the use phase). For this reason, promoting purchase of more sustainable products may be not sufficient, but it has to be accompanied with awareness campaigns promoting a more responsible consumption behaviour towards improving the environmental impacts related to the use (e.g. dosage, energy use) and end of life cycle stages (e.g. reuse of products).

— The BoP household good may help prioritise both the products for which criteria might be needed as well as investigate the need of criteria covering different life cycle stages. In fact, the majority of the impacts of the tested products were coming from component manufacturing which is usually not covered by EU Ecolabel criteria.

Additionally, there are EU Ecolabel criteria that currently the LCA impact assessment methods cannot quantify and, thus, observe their effect in the environmental impacts. In general, LCA cannot include qualitative criteria neither cover 100% of the substances and flows included in the life cycle of products or related to EU Ecolabel criteria, due to:

— The availability of data in commercial LCA databases (ecoinvent in this case). Some specific substances are not found in databases and generic substances are used instead, for this reason some differences among formulations are not reflected in the LCA model. (i.e. soap ingredients or flame retardants used in textiles for upholstered seats).

— Another limitation is related to impact methods, since some emissions to air or water do not have characterization factor available in current method. This is relevant mostly for the categories related to toxicity.

— Some criteria in relation to e.g. biodegradability, coatings, etc. cannot be modelled so far in LCA. This is especially relevant for products where manufacturing emissions are relevant such as in the case of furniture.

— Some EU Ecolabel criteria make reference to aspects such as material traceability of sources, sustainable production origin (organic raw materials, certified wood, etc.), for which an improvement in LCA modelling would be needed.

As general conclusion, the results of this study confirm that EU Ecolabel can potentially effectively contribute to minimise the environmental impacts of household goods consumption in the EU.

EU Ecolabel can help reducing the environmental impact of consumption and production, by promoting products with reduced environmental impacts and fostering continuous improvements in their environmental performances. Nevertheless, the current limited market penetration of EU Ecolabel products is a constraint for the effectiveness of this scheme and the real market might generate a lower decrease of the environmental impacts compared to the modelled scenarios which assumed a 100%-uptake of the products in the market. In this sense, the higher the uptake, the larger the effectiveness of the scheme in reducing the environmental impact.

Along the same lines, adding product categories to the EU Ecolabel scheme would widen the effect of the scheme in the environmental impacts of household consumption, by promoting environmentally-friendly criteria in the life cycle of more consumed products. As stated in the "Study on the Evaluation of the Implementation of the EU Ecolabel Regulation" (European Commission, 2017), it is necessary to develop a more strategic approach for the EU Ecolabel to ensure bigger cumulative benefits.

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List of abbreviations and definitions

aANBO	Anaerobically non-biodegradable
ANBO	Aerobically non-biodegradable
AOX	Adsorbable Organic Halogens (or halogenated organic compounds)
APC	All-Purposes Cleaners
BoM	Bill of Materials
BoP	Basket of Products
COD	Chemical Oxygen Demand
CTUe	Comparative Toxic Unit for ecosystems
CTUh	Comparative Toxic Unit for human
CDV	Critical Dilution Volume
DD	Dishwasher Detergent
ECF	Elemental chlorine free
EEB	European Environmental Bureau
EF	Environmental Footprint
EMAS	Eco-Management and Audit Scheme
EoL	End of life
EPD	Environmental Product Declaration
FRN	Furniture Reuse Network
FSC	Forest Stewardship Council
FU	Functional Unit
GPP	Green Public Procurement
HDPE	High-density Polyethylene
ILCD	International Life Cycle Data System
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LD	Laundry Detergent
LDPE	Low-density polyethylene
MDP	Medium density particleboard
PEF	Product Environmental Footprint
PEFCRs	Product Environmental Footprint Category Rules
PET	Polyethylene terephthalate
PIR	Packaging index ratio
PVA	Polyvinyl alcohol
SAP	Superabsorbent Polymer
TCF	Totally chlorine free

VOC	Volatile Organic Compounds
WUR	Weight Utility Ratio
WW	Work and Waterproof (footwear)

Abbreviations of impact categories used in the study

AP	Acidification potential (impact category)
FEP	Freshwater eutrophication (impact category)
FETP	Freshwater ecotoxicity (impact category)
FRD	Fossil resource depletion (impact category)
GWP	Global Warming Potential (impact category)
HTP c	Human toxicity, cancer effects (impact category)
HTP nc	Human toxicity, non-cancer effects (impact category)
IRP	Ionizing radiation effects, human health (impact category)
LUC	Land use changes (impact category)
MEP	Marine eutrophication (impact category)
MRD	Mineral resource depletion (impact category)
ODP	Ozone depletion (impact category)
PMFP	Particulate matter (impact category)
POFP	Photochemical ozone formation (impact category)
RD	Resource depletion (impact category)
TEP	Terrestrial eutrophication (impact category)

List of boxes

List of figures

List of tables

Annexes

Annex 1. Bill of materials of the representative products in the BoP

The following tables report the bill of materials for each of the representative products included in the BoP household goods.

Table 63. BoM of all-purpose cleaner.

All-purpose cleaner formulation	**Assumption on concentration (wt %)**	**Ecoinvent dataset**
Alkylphenol ethoxylate	10%	Ethoxylated alcohols {GLO} (1/3 AE11, 1/3AE3, 1/3 AE7)
Ethylene glycol butyl ether	3%	Ethylene glycol diethyl ether {GLO}
Sodium carbonate	3%	Soda ash, dense {GLO}| modified Solvay process, Hou's process
Sodium hydroxide	3%	Sodium hydroxide, without water, in 50% solution state {GLO}
Water	81%	Water, deionised, from tap water, at user {RoW}
Volume of final product	*500mL (1 bottle)*	

Table 64. BoM of dishwashing detergent.

Dishwashing product formulation	**Assumption on concentration (wt %)**	**Ecoinvent dataset**
Sodium citrate dihydrate	30%	Citric acid {GLO}
Maleic acid/acrylic acid copolymer sodium salt	6%	SAP Sodium Polyacrylate (dataset created)
Sodium percarbonate	7%	Sodium percarbonate, powder {GLO}
TAED (92 % active)	2%	EDTA, ethylenediaminetetraacetic acid {GLO}
Sodium silicate	10%	Layered sodium silicate, SKS-6, powder {GLO}
Linear fatty alcohol ethoxylate	2%	Ethoxylated alcohols {GLO} (1/3 AE11, 1/3AE3, 1/3 AE7)
Protease savinase	1%	Empty process
Amylase termamyl	0.50%	Empty process
Sodium carbonate	43.50%	Soda ash, dense {GLO}| modified Solvay process, Hou's process
Weight of final product	*20g (1 tab)*	

Table 65. BoM of hand dishwashing detergent.

Hand dishwashing product formulation	**Assumption on concentration (wt %)**	**Ecoinvent dataset**
Softened Water	84%	Water, completely softened, from decarbonised water, at user {RER}
Ethanol denaturated	0%	Ethanol, without water, in 99.7% solution state, from ethylene {GLO}
Phenoxyethanol	1%	Ethylene glycol {GLO}
Propylene Glycol	0%	Propylene glycol, liquid {GLO}
Surfactant system (anionic – non-ionic)*	14%	1/4 Ethoxylated alcohol (AE3) {GLO}; 1/4 Ethoxylated alcohol (AE7) {GLO}, 1/2 Fatty alcohol sulfate {RER}
NaOH	0.1%	Sodium hydroxide, without water, in 50% solution state {GLO}
NaCl	0.1%	Sodium chloride, powder {GLO}
Perfume	0.25%	*Empty process*
Dye (2 types)	0.05%	*Empty process*
Preservatives	0%	*Empty process*
Volume of final product	*1 L (1 bottle)*	

Table 66. BoM of laundry (liquid) detergent.

Laundry (liquid) product formulation	Assumption on concentration (wt %)	Ecoinvent dataset
Water	70.22%	Water, deionised, from tap water, at user {RoW}
Citric acid (builders)	1.61%	Citric acid {GLO}
Salts of citric acid and other salts (builders)	0.67%	Citric acid {GLO}
Sodium phosphonate (sequestrants)	0.41%	Sodium phosphate {GLO}
Enzymes	0.58%	*Empty process*
Dye	0.03%	Cyanuric chloride {GLO}
Fragrances	0.71%	*Empty process*
Optical brighteners	0.03%	Fluorescent whitening agent, distyrylbiphenyl type {GLO}
Optical brighteners	0.03%	Fluorescent whitening agent, DAS1, triazinylaminostilben type {GLO}
Sodium alkyl ether sulfates (mix of oleo- and petro-based)	3.55%	Fatty alcohol sulfate {RER}| market for
LAS Alkylbenzene sulfonate (petro)	6.83%	Alkylbenzene sulfonate, linear, petrochemical {GLO}
Soap	2.41%	Soap {RER}
Ethoxylates oleochemicals + petrochemical) & other non-ionic surfactants	5.91%	Ethoxylated alcohol (AE3) {GLO}
		Ethoxylated alcohol (AE7) {GLO}
		Ethoxylated alcohol (AE11) {GLO}
Sodium Hydroxide (Alkalinity sources)	1.16%	Sodium hydroxide, in 50% sol. state {GLO}
Triethanolamine (Alkalinity sources)	1.16%	Triethanolamine {GLO}
Glycerine (solvents)	1.43%	Glycerine {GLO}
Propylene glycol (solvents)	1.43%	Propylene glycol, liquid {GLO}
Preservatives (other ingredients)	0.46%	Benzo[thia]diazole-compound {GLO}
Polymers (other ingredients)	0.46%	Polycarboxylates, 40% active substance {GLO}
Sodium chloride (other ingredients)	0.46%	Sodium chloride, powder {GLO}
Others (other ingredients)	0.46%	Chemical, organic {GLO}
Volume of final product	*650 mL (1 bottle)*	

Table 67. BoM of absorbent hygiene products.

Materials in Absorbent Hygiene Products	Weight per baby diaper [g]	Weight per sanitary pad [g]	Weight per tampon [g]	Weight per breast pad [g]	Ecoinvent dataset
Fluff pulp	13.18	5.31	-	3.12	Sulfate pulp {GLO}
Superabsorber (SAP)	11.05	0.24	-	0.76	SAP Sodium Polyacrylate (as modelled in Mirabella et al. (2013))
Polyethylene, low density (LDPE)	2.23	0.59	-	-	Packaging film, low density polyethylene {RER}
Polypropylene (PP)	5.76	0.59	0.16	0.04	Textile, polypropilene {GLO}
Polyethylene-terephtalate (PET)	-	0.59	-	-	Polyurethane, flexible foam {RER}
Adhesive	1.01	0.38	-	-	Empty process
Elastics	0.14	-	-	-	Polyurethane, flexible foam {RER}
Other materials: tape, elastic back ear, frontal tape, various synthetic polymers	2.63	-	-	-	Polypropylene, granulate {RER}
Release paper	-	0.29	-	-	Linerboard {RER}
Primary material (cotton or viscose)	-	-	2.25	-	Cotton fibre {GLO}
Cotton yarn	-	-	0.1	-	Yarn production, cotton fibres/GLO
Polypropylene applicator	-	-	2	-	Polypropylene, granulate {RER}
Paper				0.08	Linerboard {RER}
Weight of final product	*36 g*	*8 g*	*4.5 g*	*4 g*	

Table 68. BoM of bed mattresses.

Materials in Bed Mattresses	Weight per latex matt. [kg]	Weight per PUR matt. [kg]	Weight per spring matt. [kg]	Ecoinvent dataset
Latex, synthetic	14.78	-	-	Latex {RER}
PUR foam	-	13.2	3.14	Polyurethane, flexible foam {RER}
Steel	-	-	11.46	Steel, chromium steel 18/8, hot rolled {RER}
Polyester, textile	1.12	0.65	0.92	Textile, polyester {GLO}
Wool, textile	0.92	0.53	0.76	Textile, wool {GLO}
Polypropylene, textile	0.69	0.4	0.57	Textile, polypropilene {GLO}
Cotton, textile	0.30	0.17	0.24	Textile, knit cotton {GLO}
Viscose, textile	0.26	0.15	0.22	Textile, viscose {GLO}
Zinc oxide	0.49	-	-	Zinc oxide {GLO}
Sulphur	0.33	-	-	Sulphur, from crude oil, consumption mix, at refinery (ELCD)
Polyester, padding	-	1.6	0.99	Textile, polyester {GLO}
Cotton, padding	-	-	1.48	Textile, knit cotton {GLO}
Wool, padding	-	-	0.41	Textile, wool {GLO}
Weight of final product	*19.5 kg*	*17.2 kg*	*20.8 kg*	

Table 69. BoM of liquid soap.

Liquid soap formulation	Assumption on concentration (wt %)	Ecoinvent dataset
Water	84.0%	Water, deionised, from tap water, at user {RoW}
Sodium lauryl ehter sulphate	6.9%	Sodium sulfate, anhydrite {RER}
Disodium Cocoamphodiacetate	2.6%	Fatty alcohol {RER}| production, from coconut oil
Sodium chloride	0.6%	Sodium chloride, powder {RER}
Cocoamidopropyl betaine	1.1%	Fatty alcohol {RER}| production, from coconut oil
C8-16 fatty alcohol glucoside	1.2%	Fatty alcohol {RER}| production, petrochemical
Polyol coconut fatty acid ester	0.5%	Fatty alcohol {RER}| production, from coconut oil

Liquid soap formulation	Assumption on concentration (wt %)	Ecoinvent dataset
Citric acid monohydrated	0.5%	Polycarboxylates, 40% active substance {RER}
Benzyl alcohol	0.2%	Benzyl alcohol {RER}
Sodium benzoate	0.2%	Benzoic-compound {RER}
Potassium sorbate	3.0%	Potassium hydroxide {RER}
Sodium chloride	2.0%	Sodium chloride, powder {RER}
Volume of final product	*255 mL (1 bottle)*	

Table 70. BoM of solid soap.

Solid soap composition	Assumption on concentration (wt %)	Ecoinvent dataset
Saponified oils - tallow	57.0%	Esterquat {RER}| treatment of tallow to
Saponified oils - coconut oil fatty acids	14.0%	Fatty acid {GLO}
Saponified oils - stearic acid	14.0%	Fatty acid {RER}| production, from vegetable oil
Glycerine	5.5%	Glycerine {Europe without CH}| esterification of rape oil
Perfume	1.4%	*Empty process*
Colorants	0.1%	*Empty process*
EDTA	0.2%	EDTA, ethylenediaminetetraacetic acid {RER}
Titanium dioxide	0.1%	Titanium dioxide {RER}
Water	8.0%	Water, deionised, from tap water, at user {RoW}
Weight of final product	*100 g*	

Table 71. BoM of shampoo.

Shampoo formulation	Assumption on concentration (wt %)	Ecoinvent dataset
Sodium laureth sulphate	7.0%	Sodium sulfate, anhydrite {RER}
Cocoamidopropyl betaine	2.5%	Fatty alcohol {RER}| production, from coconut oil
Fatty alkanolamides	0.5%	Fatty acid {RER}| production, from vegetable oil
Propylene glycol	1.5%	Propylene glycol, liquid {RER}

Sodium benzoate	0.1%	Benzoic-compound {RER}
Benzyl alcohol	0.1%	Benzyl alcohol {RER}
Lactic acid	0.1%	Lactic acid {RER}| production | Alloc Def, U
Water	88.3%	Water, deionised, from tap water, at user {RoW}
Volume of final product	*255 mL (1 bottle)*	

Table 72. BoM of hair conditioner.

Hair conditioner formulation	**Assumption on concentration (wt %)**	**Ecoinvent dataset**
Cetyl stearyl alcohol	3.3%	Fatty alcohol {GLO}
2-octyldocecaine	0.3%	Fatty acid {RER}
Lanoline	0.3%	Slack wax {US}
Provit B5	0.4%	*Empty process*
Nutrilan keratine	0.0%	*Empty process*
Dioactadecyl dimethyl ammonium chloride	1.0%	Ammonium chloride {GLO}
Cetyl trimethyl ammonium chloride	0.8%	Ammonium chloride {GLO}
Propylene glycol	2.0%	Propylene glycol, liquid {RER}
Methyl hydroxypropyl cellulose	0.6%	Carboxymethyl cellulose, powder {RER}
Polyvinyl	0.1%	*Empty process*
Perfume	0.2%	*Empty process*
Parabens	0.2%	Benzoic-compound {RER}
Water	90.8%	Water, deionised, from tap water, at user {RoW}
Volume of final product	*255 mL (1 bottle)*	

Table 73. BoM of footwear

Materials in the shoes	**Weight per Sport shoes [kg]**	**Weight per Leisure shoes [kg]**	**Weight per Fashion shoes [kg]**	**Weight per WW shoes [kg]**	**Ecoinvent dataset**
Acetone	0.00	0.00	0.00	-	Acetone, liquid {GLO}
Acrylic	-	-	0.00	-	Polymethyl methacrylate, beads {GLO}
Aluminum	-	0.01	0.01	0.02	Aluminium, cast alloy {GLO}

Materials in the shoes	Weight per Sport shoes [kg]	Weight per Leisure shoes [kg]	Weight per Fashion shoes [kg]	Weight per WW shoes [kg]	Ecoinvent dataset
Azodicarb propellant	0.01	-	-	0.00	Empty process
Ba Zn stearate	-	0.01	-	-	Empty process
Biological waste	-	-	-	0.07	Empty process
Carbon black	0.00	-	0.00	-	Carbon black {GLO}
Cardboard	0.00	-	0.07	-	Core board {GLO}
Cellulose	-	-	-	0.01	Cellulose fibre, inclusive blowing in {RoW}
Copper	-	-	-	0.03	Copper {GLO}
Cotton fiber	0.00	0.25	0.03	0.01	Cotton fibre {GLO}
Cyclohexane	0.00	0.00	0.00	-	Cyclohexane {GLO}
Ethanol	0.00	0.00	0.00	-	Ethanol, without water, in 95% solution state, from fermentation {GLO}
Ethyl acetate	0.01	0.00	0.00	-	Ethyl acetate {GLO}
EVA	0.17	0.08	0.00	0.13	Ethylvinylacetate, foil {GLO}
Fiberglass	-	-	-	0.04	Glass fibre {GLO}
Hardener chemical (ethylene)	0.00	-	-	-	Ethene (ethylene), from steam cracking, production mix, at plant, gaseous EU-27 S (from ELCD)
Jute	-	0.09	-	-	Jute fibre {GLO}| market for | Alloc Def, U_no transport
Leather	-	-	0.05	0.14	Chrome-tanned finished leather (own elaboration)
Limestone flour	0.02	0.04	0.02	0.02	Limestone, unprocessed {GLO}
MEK	0.01	0.00	0.00	-	Methyl ethyl ketone {GLO}
Mg carbonate	0.00	-	-	0.00	Magnesium {GLO}
Natural rubber	0.00	0.06	0.01	0.00	Empty process
Nitrile rubber	0.00	0.01	0.00	0.00	Acrylonitrile-butadiene-styrene copolymer {GLO}
Nylon 6 fiber	0.01	-	0.01	0.05	Nylon 6 {GLO}
Nylon 6 granulate	0.02	0.00	0.00	0.03	Nylon 6, glass-filled {GLO}

Materials in the shoes	**Weight per Sport shoes [kg]**	**Weight per Leisure shoes [kg]**	**Weight per Fashion shoes [kg]**	**Weight per WW shoes [kg]**	**Ecoinvent dataset**
Nylon 6.6 fiber	0.05	-	-	-	Nylon 6-6 {GLO}
Nylon 6.6 granulate	-	-	0.00	-	Nylon 6-6, glass-filled {GLO}
Polycarbonate granulate	0.00	-	0.00	-	Polycarbonate {GLO}
Pentane	0.00	-	-	-	Pentane {GLO}
PET fabric	0.09	0.14	0.08	0.12	Textile, polyester {GLO}
PET fiber	0.10	0.03	0.01	0.03	Textile, polyester {GLO}
PET granulate	0.03	-	0.02	0.01	Polyethylene terephthalate, granulate, amorphous {GLO}
Polybutadiene	0.03	0.07	0.03	0.02	Polybutadiene {GLO}
PP fiber	0.00	-	-	-	Polypropylene, granulate {GLO}
PP gran	0.03	-	-	0.01	Polypropylene, granulate {GLO}
PU film	0.04	0.09	0.04	0.01	Polyurethane, flexible foam {GLO}
PU flex foam	0.08	-	0.07	0.33	Polyurethane, flexible foam {GLO}
Recy PET	-	-	-	0.01	Empty process
Recy rubber	-	0.03	-	0.00	Empty process
SBR	0.05	0.02	-	0.11	Styrene-acrylonitrile copolymer {GLO}
Silica sand	-	-	-	0.00	Silica sand {GLO}
Spandex	0.00	0.00	0.00	0.00	Synthetic rubber {RER}
TDI	-	-	-	-	Toluene diisocyanate {GLO}
TiO2	0.00	-	-	0.00	Titanium dioxide {RER}
TPU	0.07	0.09	0.11	0.01	Synthetic rubber {RER}
Wax / parrafins	-	-	-	-	Paraffin {GLO}
Wood pulp	0.00	-	-	-	Thermo-mechanical pulp {GLO}
Zinc oxide	0.00	0.01	0.00	0.01	Zinc oxide {GLO}
Weight of final product	*0.59 kg*	*0.90 kg*	*0.55 kg*	*0.97 kg*	*Referred to 1 pair of shoes*

Table 74. BoM of furniture pieces.

Materials in furniture pieces	**Amount per wardrobe [kg]**	**Amount per kitchen cabinet [kg]**	**Amount per wooden table [kg]**	**Amount per wooden seat [kg]**	**Amount per sofa [kg]**	**Ecoinvent dataset**
Medium density particleboard (MDP)	235	2.1	-	-	37.8	Particle board, for indoor use {GLO}
Solid timber	-	0.02	8.02	5.57	4.8	Sawnwood, hardwood, dried (u=20%), planed {RER}
Multilayered board	-	28.40	11.04	5.04		Glued laminated timber, for indoor use {GLO}
Aluminium	-	5.90	-	-		Aluminium, cast alloy {GLO}
Steel	15.70	5.90	0.25	0.28	4.8	Steel, unalloyed {GLO}
Glues and adhesives	0.72	0.72	-	-	-	Urea formaldehyde resin {GLO}
Paints and varnishes	4.82	0.72	1.70	1.00	-	Alkyd paint, white, without solvent, in 60% solution state {GLO}
Polypropylene	9.14	0.55	-	-	-	Polypropylene, granulate {GLO}
Textile, cotton	-	-	-	-	4.8	Textile, woven cotton {GLO}
Textile, polyester	-	-	-	-	2.4	Textile, polyester {GLO}
Polyurethane foam	-	-	-	-	5.4	Polyurethane, flexible foam {GLO}
Phosphorous (used in flame retardants)	-	-	-	-	0.6	Phosphorus, white, liquid {GLO}
Melamine	-	-	-	-	0.6	Melamine {GLO}
Weight of final product	*257 kg*	*39 kg*	*13.5 kg*	*7.5 kg*	*60 kg*	

Table 75. BoM of paper products.

Materials in paper products	Amount per newspaper [g]	Amount per book [g]	Amount per toilet paper [g]	Ecoinvent dataset
Thermo-mechanical pulp	22.62	86.13	-	Thermo-mechanical pulp production (EU)
Mechanical pulp	9.16	34.89	-	Stone groundwood pulp production (EU)
Chemical pulp	51.79	197.15	469.48	Sulfate pulp production (EU), elementary chlorine free bleached
De-inked (recycled) pulp	30.42	115.83	156.52	De-inked pulp (dataset compiled according to data in the screening study of the PEF pilot on Intermediate paper products
Urea (in wet strength agent)	0.02	0.09	-	Urea, as N {RER}
Fatty alcohols	0.05	0.26	-	Ethoxylated alcohol (AE3) {RER}, petrochemical
Biocides	0.06	0.29	-	Biocides, for paper production, unspecified, at plant/RER
Acrilic binder	0.07	0.35	-	Acrylic binder, without water, in 34% solution state {RER}
Retention aids	0.09	0.49	-	Retention aids, in paper production, at plant/RER
AKD sizer	0.10	0.51	-	AKD sizer, in paper production, at plant/RER
Pitch despergents	0.25	1.32	-	Pitch despergents, in paper production {RER}
Aluminium sulfate	0.41	2.13	-	Aluminium sulfate, powder {RER}
Latex	0.58	3.05	-	Latex {RER}
Potato starch	0.02	0.10	-	Potato starch {DE}
Maize starch	0.02	0.10	-	Maize starch {DE}
Starch	1.12	5.84	-	Polyester-complexed starch biopolymer {RER}
Kaolin (filler)	31.03	162.48	-	Kaolin {RER}
Weight of final product	*0.115 kg*	*0.600 kg*	*0.626 kg*[24]	

[24] 1 pack wiht four rolls

Table 76. BoM of clothes.

Materials in clothes	Amount per T-shirt [g]	Amount per Blouse [g]	Amount per pair of Jeans [g]	Amount per pair of Trousers [g]	Ecoinvent dataset
Textile, viscose	3.5	158.0	-	-	Viscose fibre {GLO}
Textile, polyamide	3.3	56.0	-	-	Nylon 6-6 {GLO}
Elastane	0.4	11.0	-	-	Synthetic rubber {RER}
Textile, cotton	153.8	-	684.3	-	Cotton fibre {GLO}
Polyester linings	29.4	-	43.3	-	Polyester resin, unsaturated {GLO}
Textile, polyester	0.6	-	0.6	458.0	Textile, polyester {GLO}
Aluminium (rivets, buttons or zips)	0.3	-	8.7	5.8	Aluminium, cast alloy {GLO}
Plastic (buttons)	0.0	-	-	0.4	Polyethylene, high density, granulate {GLO}
Wood (buttons)	0.0	-	-	-	Sawnwood, softwood, raw {GLO}
Textile, polypropylene	2.4	-	-	-	Polypropylene fibres (PP), crude oil based, production mix, at plant, PP granulate without additives EU-27 (from ELCD)
Acrylic	1.8	-	-	-	Polymethyl methacrylate, beads {GLO}
Wool	1.1	-	-	-	Wool, sheep, at farm/US
Chlorofibre	0.4	-	-	-	Polyvinylchloride, bulk polymerised {GLO}
Flax	0.1	-	-	-	Jute fibre {GLO}
Hemp	0.1	-	-	-	Kenaf fibre {GLO}
Weight of final product	*150 g*	*200 g*	*650 g*	*408 g*	

Annex 2. Datasets used to model packaging production and end of life

Production of materials and waste treatment (incineration and landfilling) are included in system S, whereas burdens and benefits from recycling are included in System R.

	Production of material	Waste treatment (System S)				Recycling (System R)	
Material	**Ecoinvent process**	**Ecoinvent process (waste treatment)**	**% to landfill**	**% to incineration**	**% to recycling**	**Ecoinvent process (burdens)**	**Ecoinvent process Avoided products (benefits)**
Aluminium	Sheet rolling, aluminium {GLO}| market for | Alloc Def, U + Aluminium removed by milling, average {GLO}| market for | Alloc Def, U	Scrap aluminium {RoW}| treatment of, municipal incineration | Alloc Def, U + Waste aluminium {RoW}| treatment of, sanitary landfill | Alloc Def, U	20.1	10.7	69.2	Aluminium, wrought alloy {RoW}| treatment of aluminium scrap, post-consumer, prepared for recycling, at remelter | Alloc Def, U	Aluminium, primary, ingot {IAI Area, EU27 & EFTA}| market for | Alloc Def, U
	Aluminium removed by milling, average {GLO}| market for | Alloc Def, U						
Cardboard	Corrugated board box {GLO}| market for corrugated board box | Alloc Def, U	Waste paperboard {RoW}| treatment of, municipal incineration | Alloc Def, U + Waste paperboard {RoW}| treatment of, sanitary landfill | Alloc Def, U	11	0.58	83.2	Waste paperboard, sorted {GLO}| market for | Alloc Def, U	Sulfate pulp {GLO}| market for | Alloc Def, U
	Core board {GLO}| market for | Alloc Def, S		11	0.58	83.2		
Glass	Packaging glass, brown {GLO}| market for | Alloc Def, U	Waste glass {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Def, U + Waste glass {CH}| treatment of, inert material landfill | Alloc Def, U	21.2	11.2	67.6	Glass cullet, sorted {GLO}| market for | Alloc Def, U	Packaging glass, brown {GLO}| packaging glass production, brown, without cullet and melting | Alloc Def, U
	Packaging glass, white {GLO}| market for | Alloc Def, S		21.2	11.2	67.6		
PE	Polyethylene, high density, granulate {GLO}| market for | Alloc Def, U	Waste polyethylene {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Def, U + Waste polyethylene {CH}| treatment of, sanitary landfill | Alloc Def, U	44.5	23.6	31.9	Electricity, medium voltage {RoW}| market for | Alloc Def, U	Polyethylene, high density, granulate {RER}| production | Alloc Def, U
	Polyethylene, low density, granulate {GLO}| market for | Alloc Def, U						

	Production of material	Waste treatment (System S)				Recycling (System R)	
Material	**Ecoinvent process**	**Ecoinvent process (waste treatment)**	**% to landfill**	**% to incineration**	**% to recycling**	**Ecoinvent process (burdens)**	**Ecoinvent process Avoided products (benefits)**
PET	Polyethylene terephthalate, granulate, bottle grade {GLO}| market for | Alloc Def, U copia basket + Blow moulding {GLO}| market for | Alloc Def, U copia basket + Plastic processing factory {RER}| construction | Alloc Def, S	Waste polyethylene terephtalate {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Def, U + Waste polyethylene terephtalate {CH}| treatment of, sanitary landfill | Alloc Def, U	44.5	23.6	31.9	Electricity, medium voltage {RoW}| market for | Alloc Def, U	Polyethylene terephthalate, granulate, bottle grade {RER}| production | Alloc Def, U
PP	Polypropylene, granulate {GLO}| market for | Alloc Def, U	Waste polypropylene {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Def, U + Waste polypropylene {CH}| treatment of, sanitary landfill | Alloc Def, U	44.5	23.6	31.9	Electricity, medium voltage {RoW}| market for | Alloc Def, U	Polypropylene, granulate {RER}| production | Alloc Def, U
PS	Polystyrene, general purpose {GLO}| market for | Alloc Def, U	Waste polystyrene {CH}| treatment of, municipal incineration with fly ash extraction | Alloc Def, U + Waste polystyrene {CH}| treatment of, sanitary landfill | Alloc Def, U	44.5	23.6	31.9	Electricity, medium voltage {RoW}| market for | Alloc Def, U	Polystyrene, general purpose {RER}| production | Alloc Def, U

Annex 3. Global normalization factors for the Environmental Footprint method (EF 3.0)

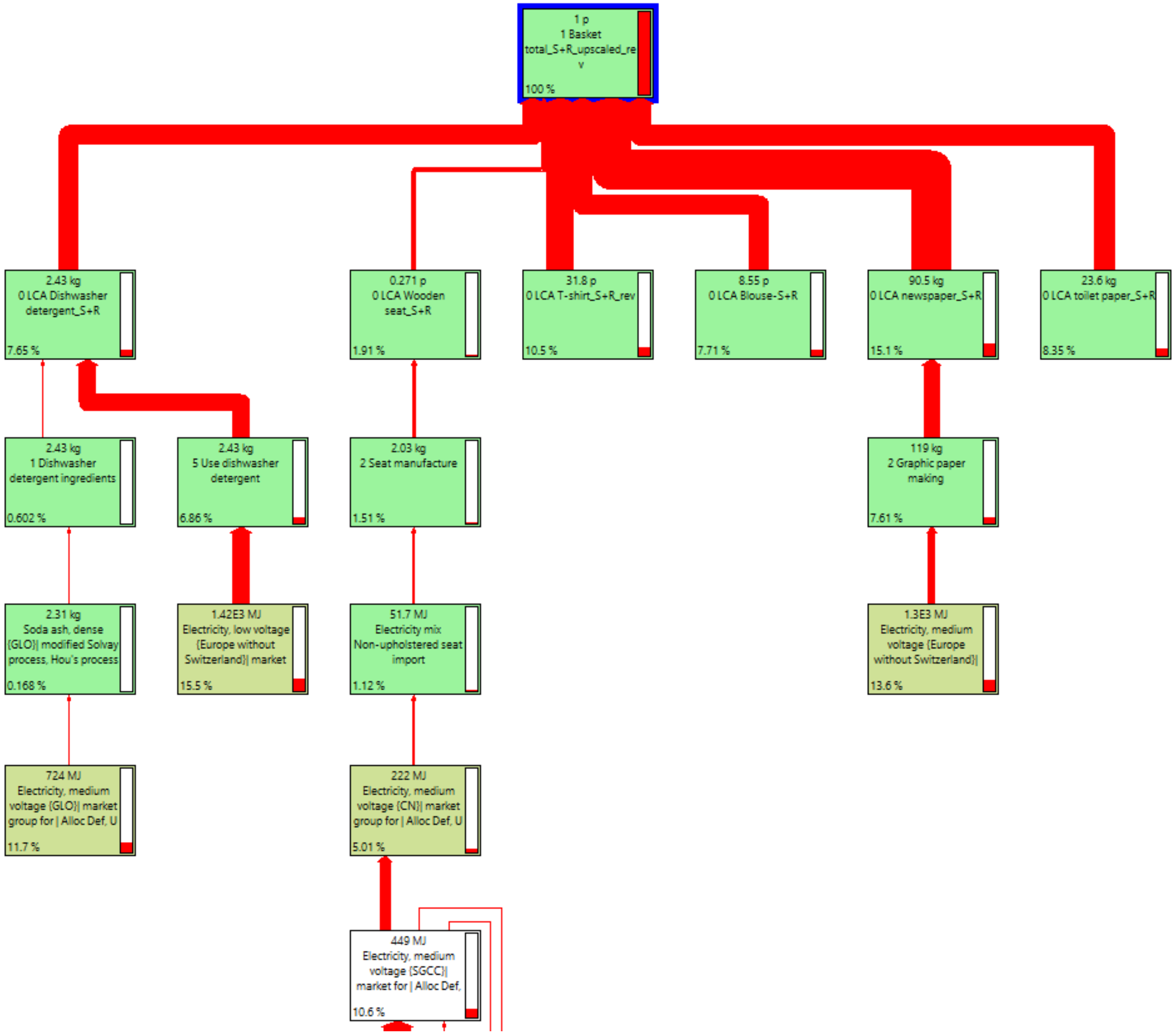
This annex reports the updated global normalization factors by impact category for the Environmental Footprint method version employed in this report (EF 3.0). The update includes modifications of specific inventory flows from Crenna et al. (2019).

Impact category	Per person	Global NFs
Climate change	8.10E+03	5.58E+13
Ozone depletion	5.36E-02	3.70E+08
Particulate matter	5.95E-04	4.11E+06
Ionising radiation	4.22E+03	2.91E+13
Photochemical ozone formation	4.06E+01	2.80E+11
Acidification	5.56E+01	3.83E+11
Terrestrial eutrophication	1.77E+02	1.22E+12
Freshwater eutrophication	1.61E+00	1.11E+10
Marine Eutrophication	1.95E+01	1.35E+11
Water use	1.14E+04	7.89E+13
Land use	1.04E+06	7.19E+15
Resource depletion, fossils	6.50E+04	4.48E+14
Resource depletion, minerals and metals	6.36E-02	4.39E+08
Human toxicity, cancer	1.69E-05	1.17E+05
Human toxicity, non-cancer	2.30E-04	1.58E+06
Ecotoxicity freshwater	4.27E+04	2.94E+14

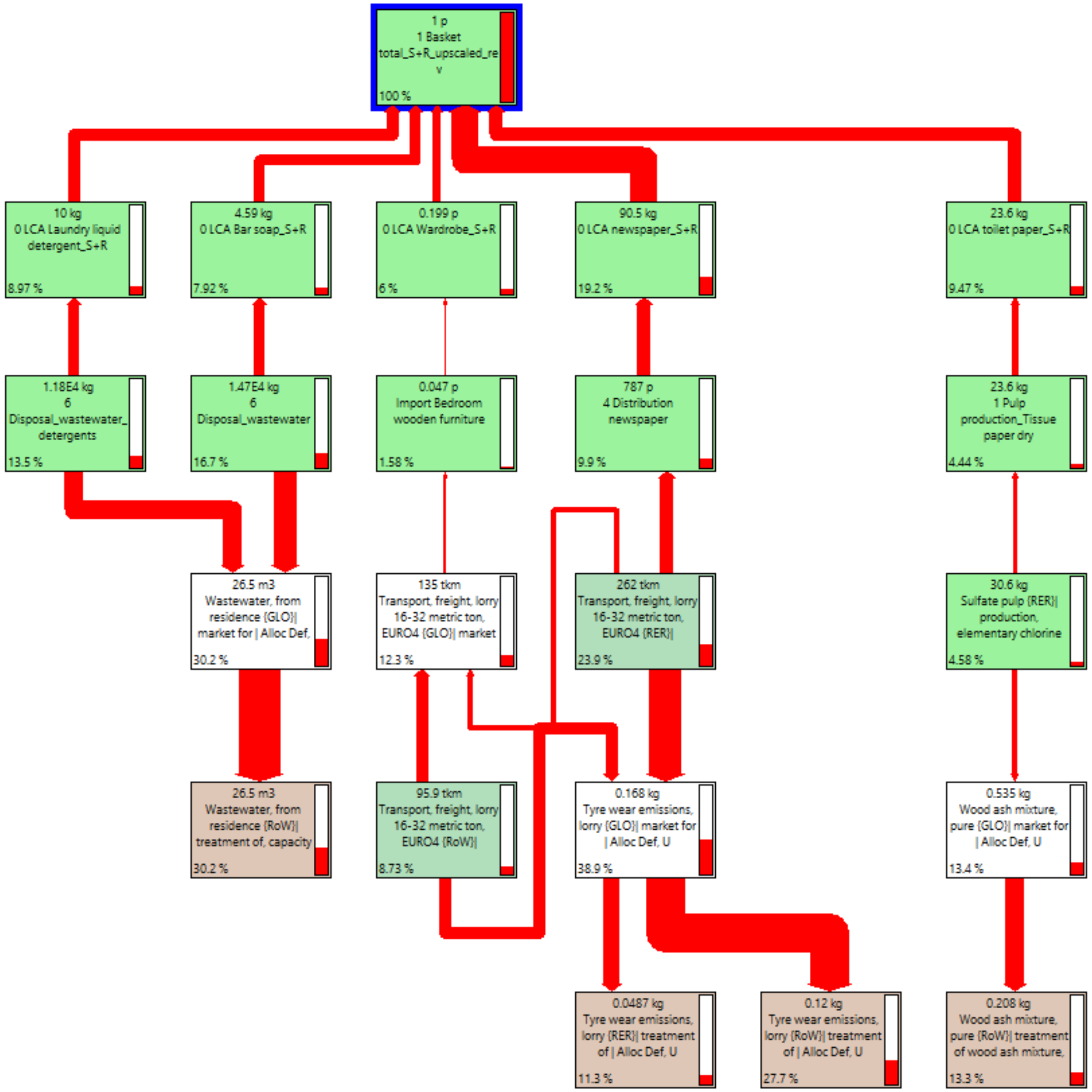
Annex 4. Network graphs of the inventory of most contributing elementary flows

The inventory networks of the most important flow(s) (most contributing to impact categories, considering ILCD methods) (Table 19) are reported below. The larger the depth of the red arrow going from one process to the related one(s), the larger the contribution of that process to the total amount of the analysed flow in the inventory (e.g., which are the activities that entail higher emissions of carbon dioxide to air).

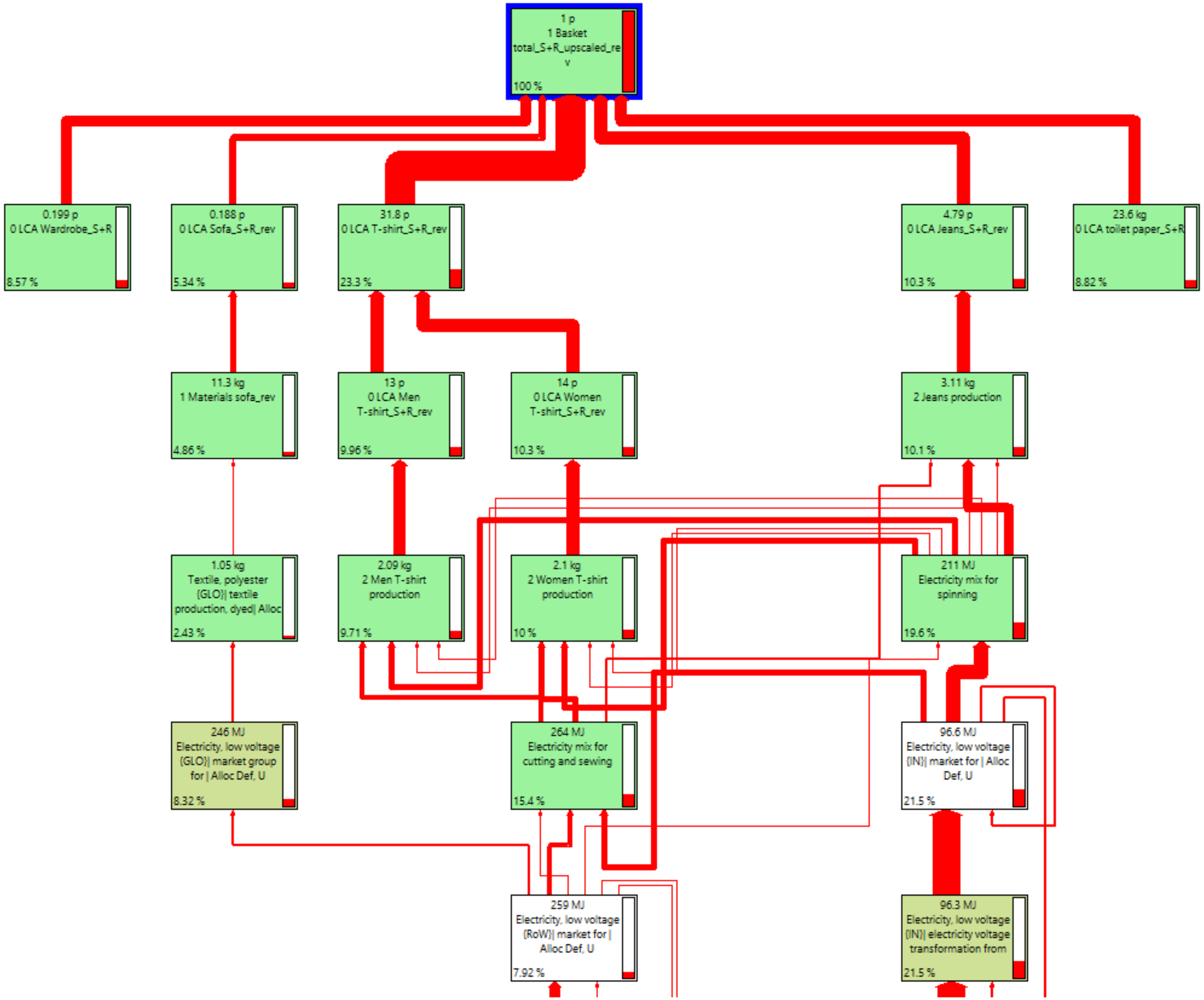
Carbon dioxide, fossil (83.6% of climate change)



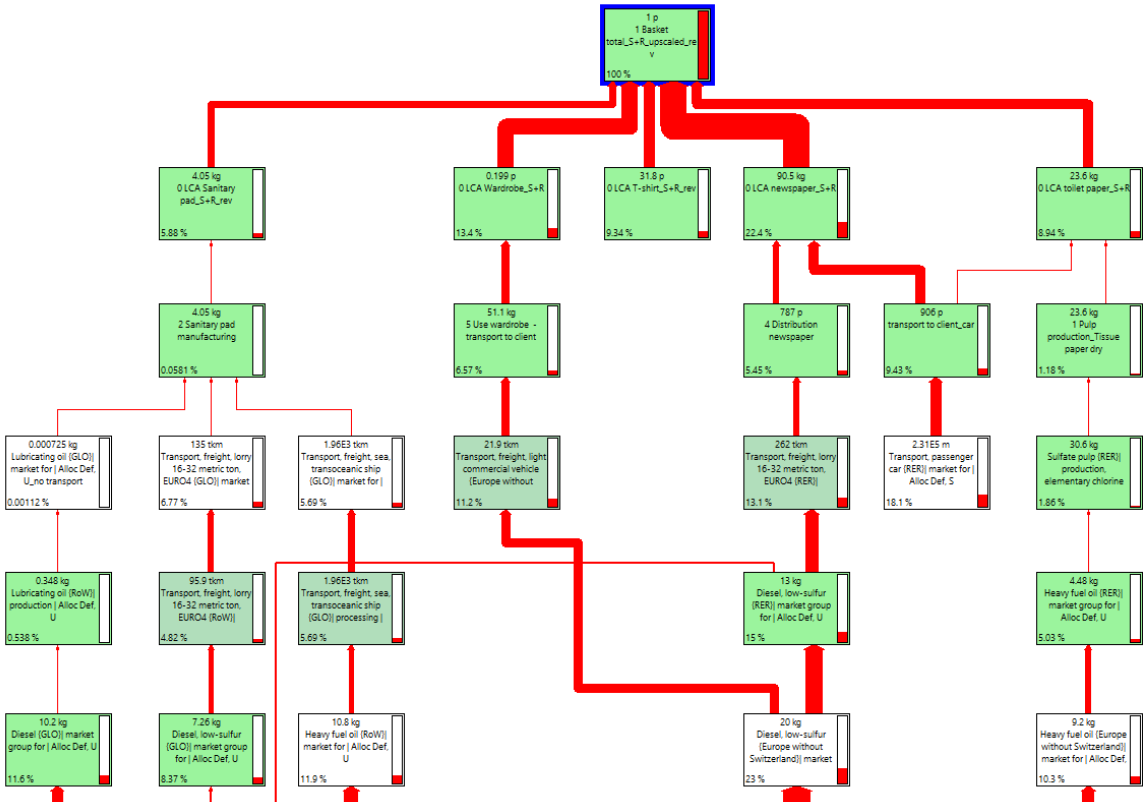
Zinc to soil (32.2% of human toxicity, non-cancer)



Particulates ≤ 2.5 (74.9% of particulate matter)



Methane, bromotrifluoro-, Halon 1301 (52.7% of ozone depletion)



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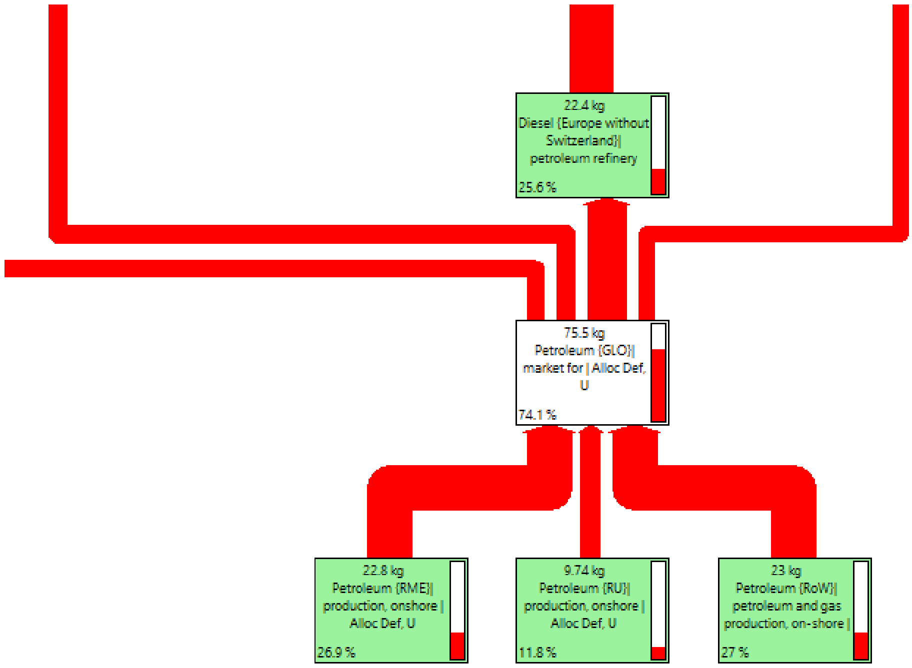
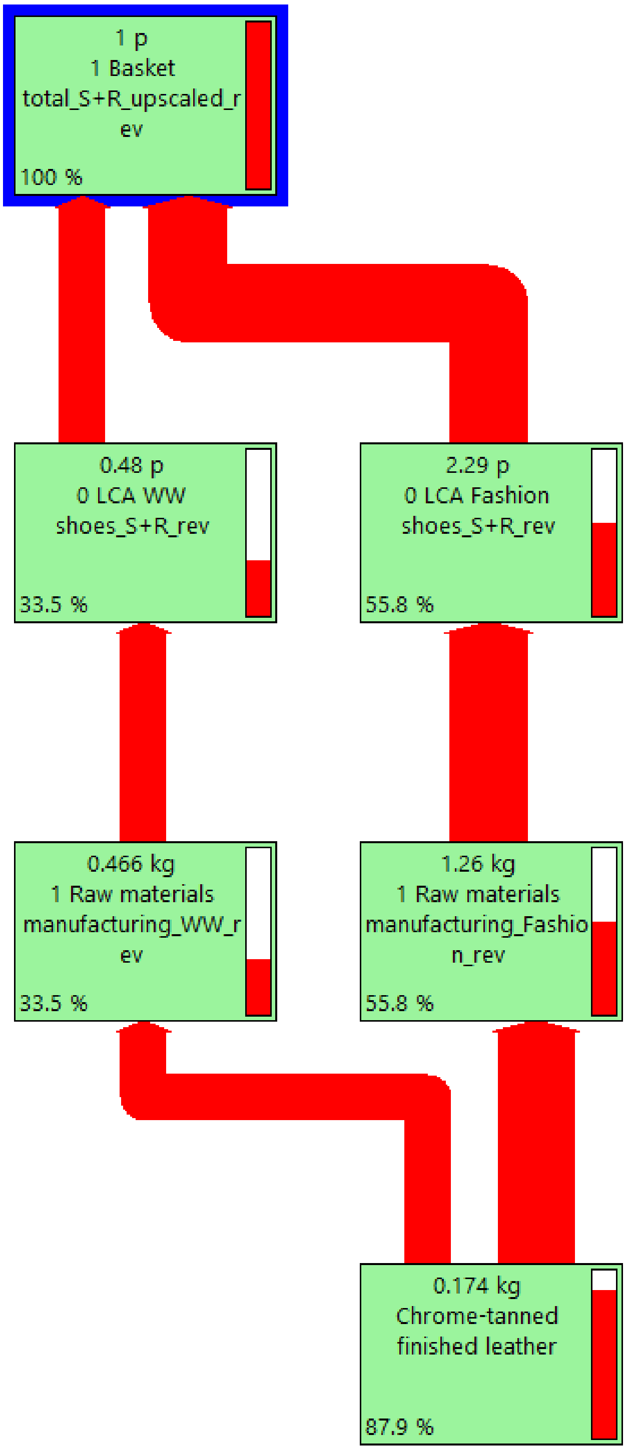
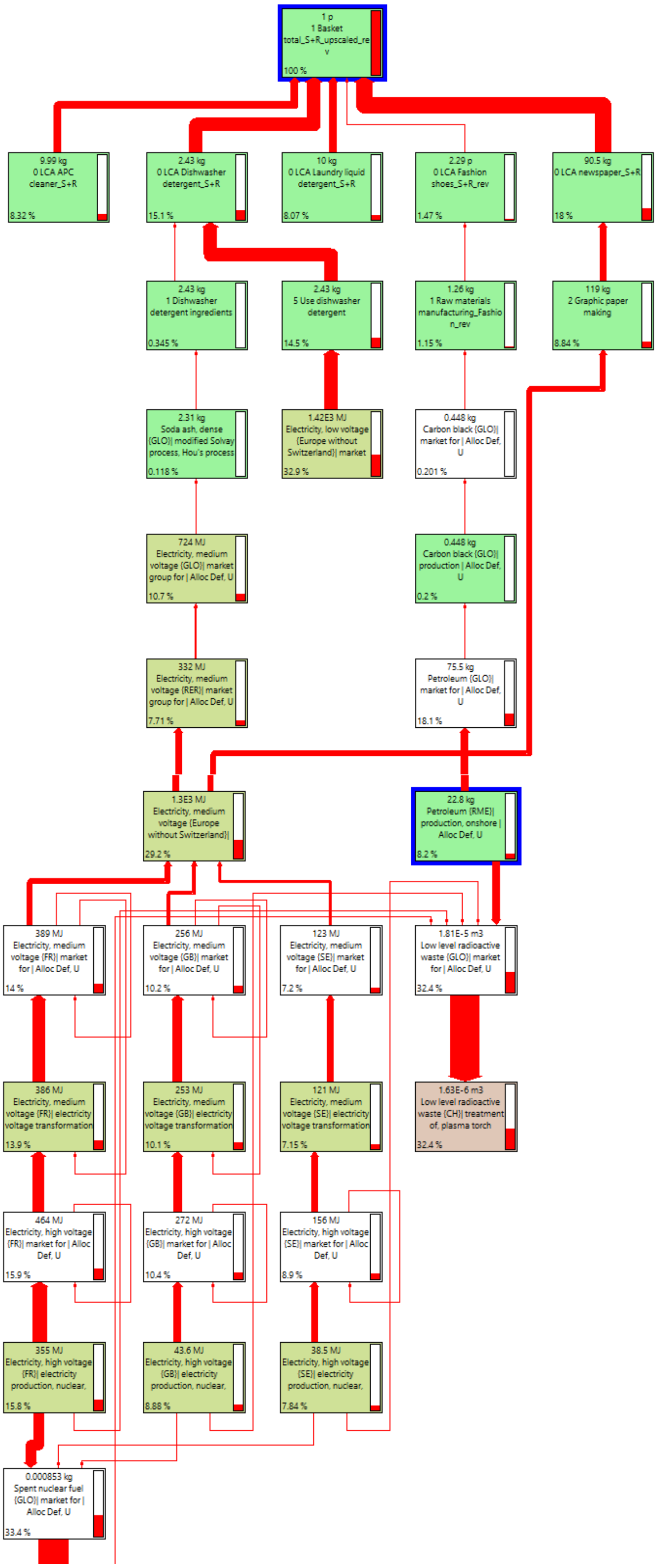


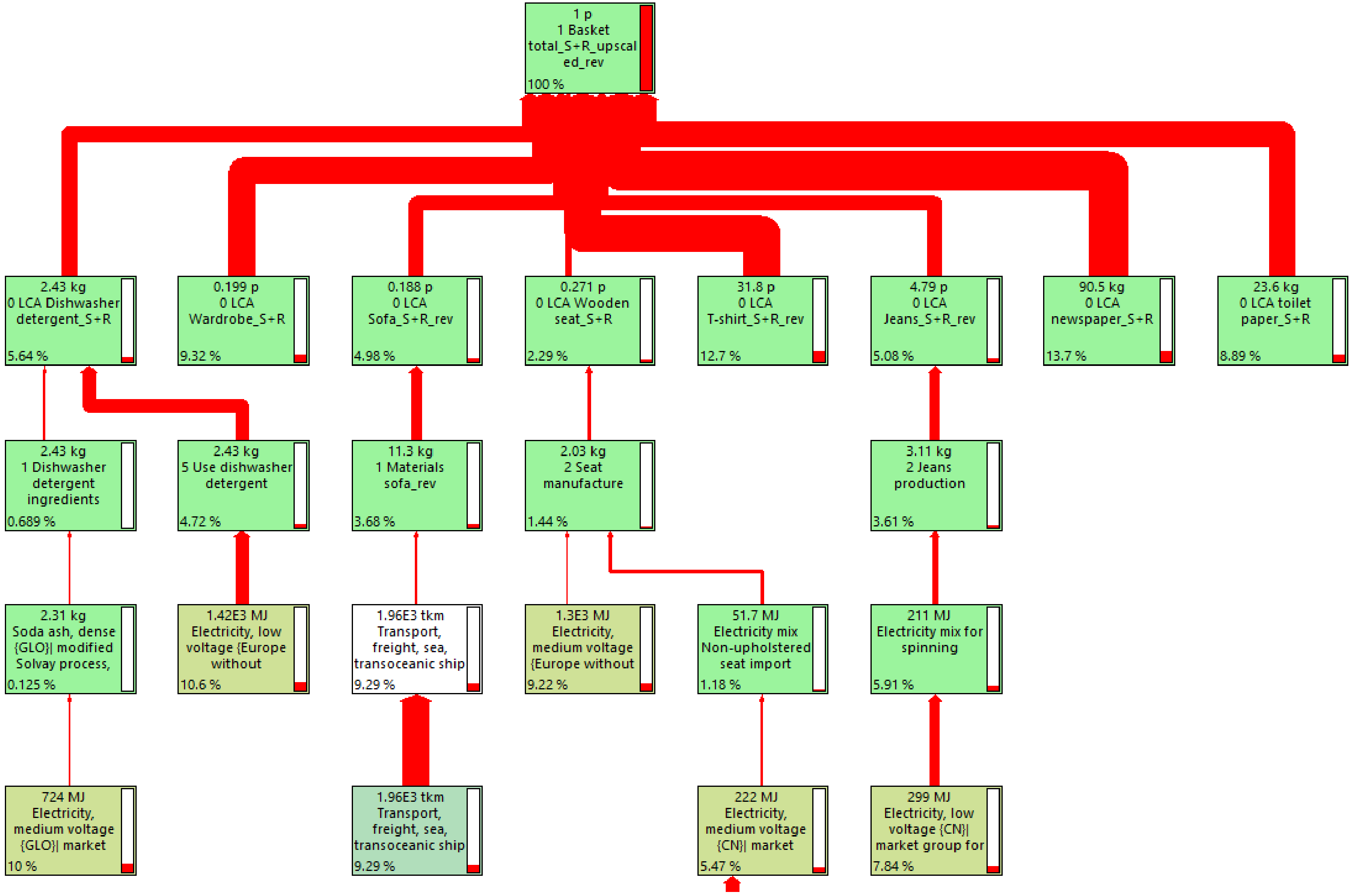
Chromium to water (54.3% of human toxicity, cancer and 17.6% of freshwater ecotoxicity)



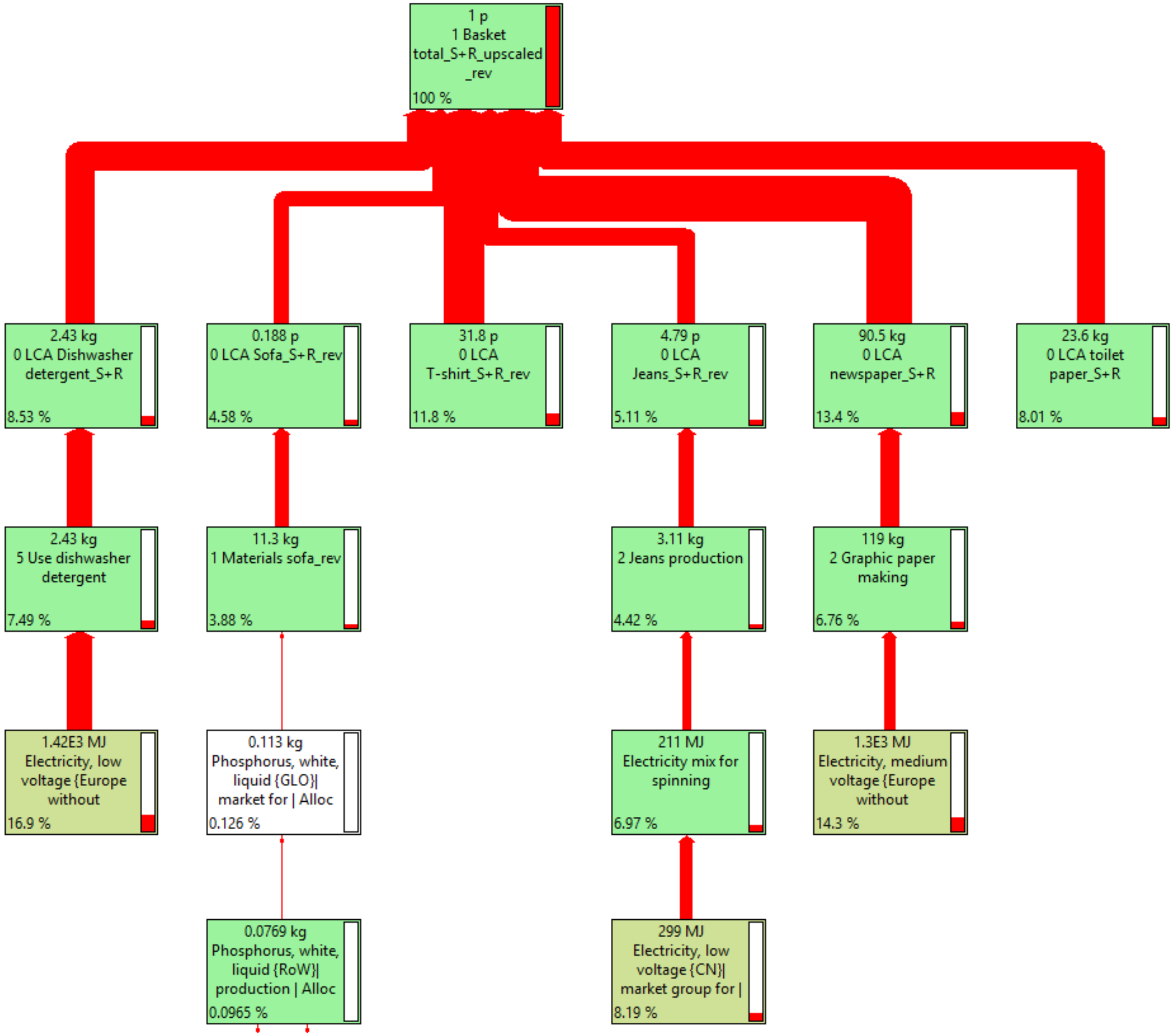
Carbon-14 to air (94.4% of ionising radiation HH)



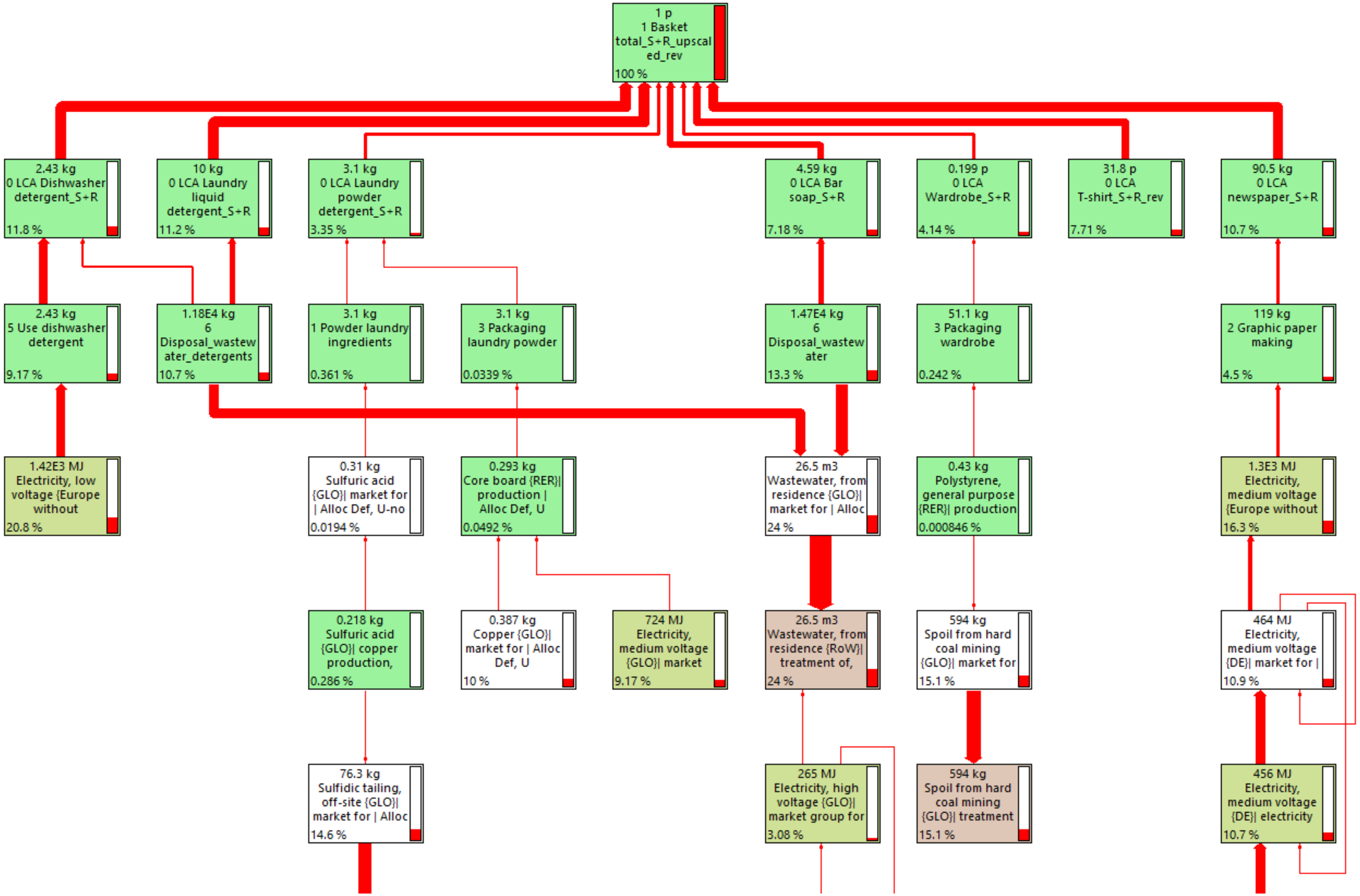
Nitrogen oxides (73.8% of photochemical ozone formation, 79.9% of terrestrial eutrophication and 52.1% of marine eutrophication)



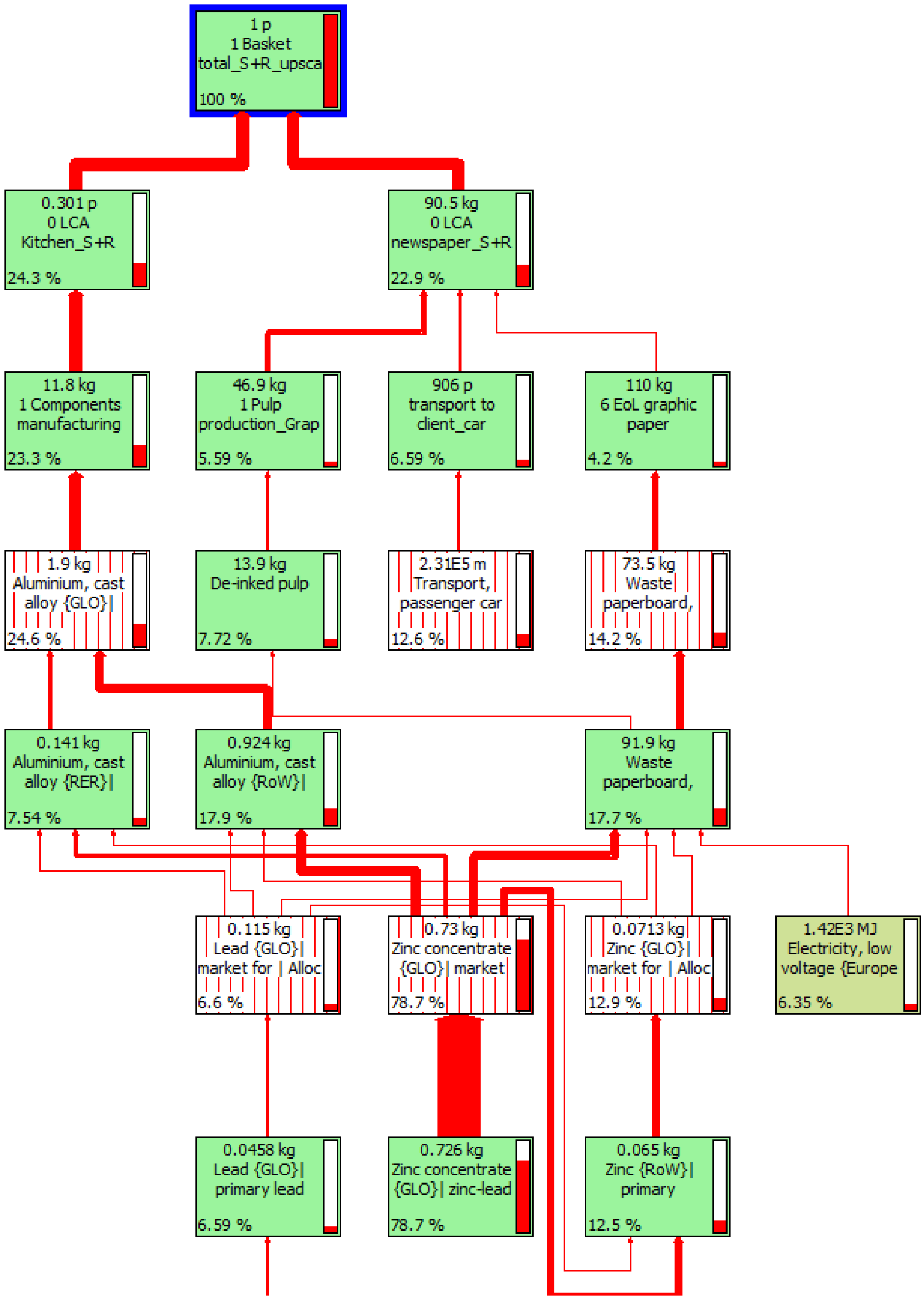
Sulphur dioxide (63.4% of acidification)



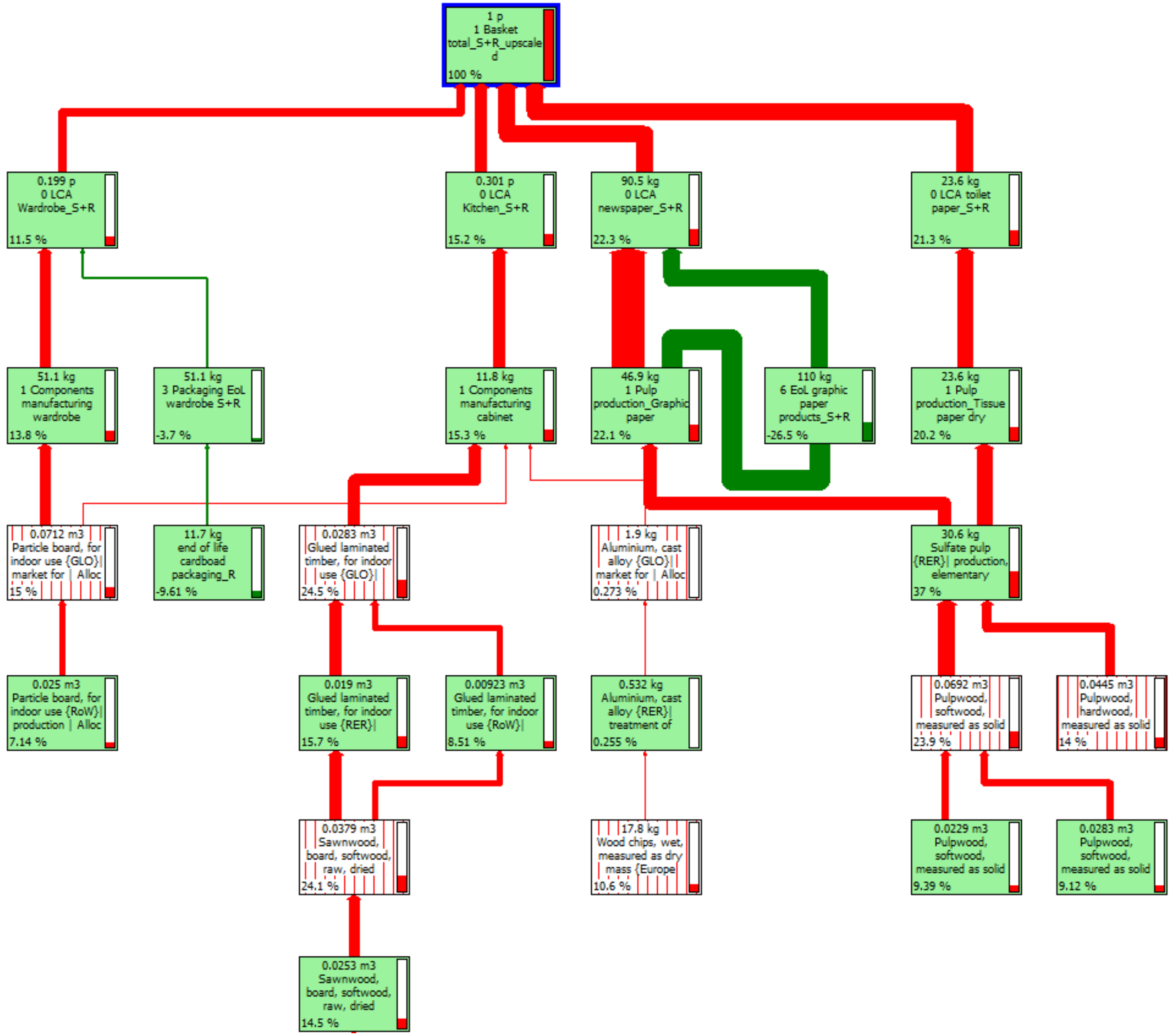
Phosphate to water (91.0% of freshwater eutrophication)



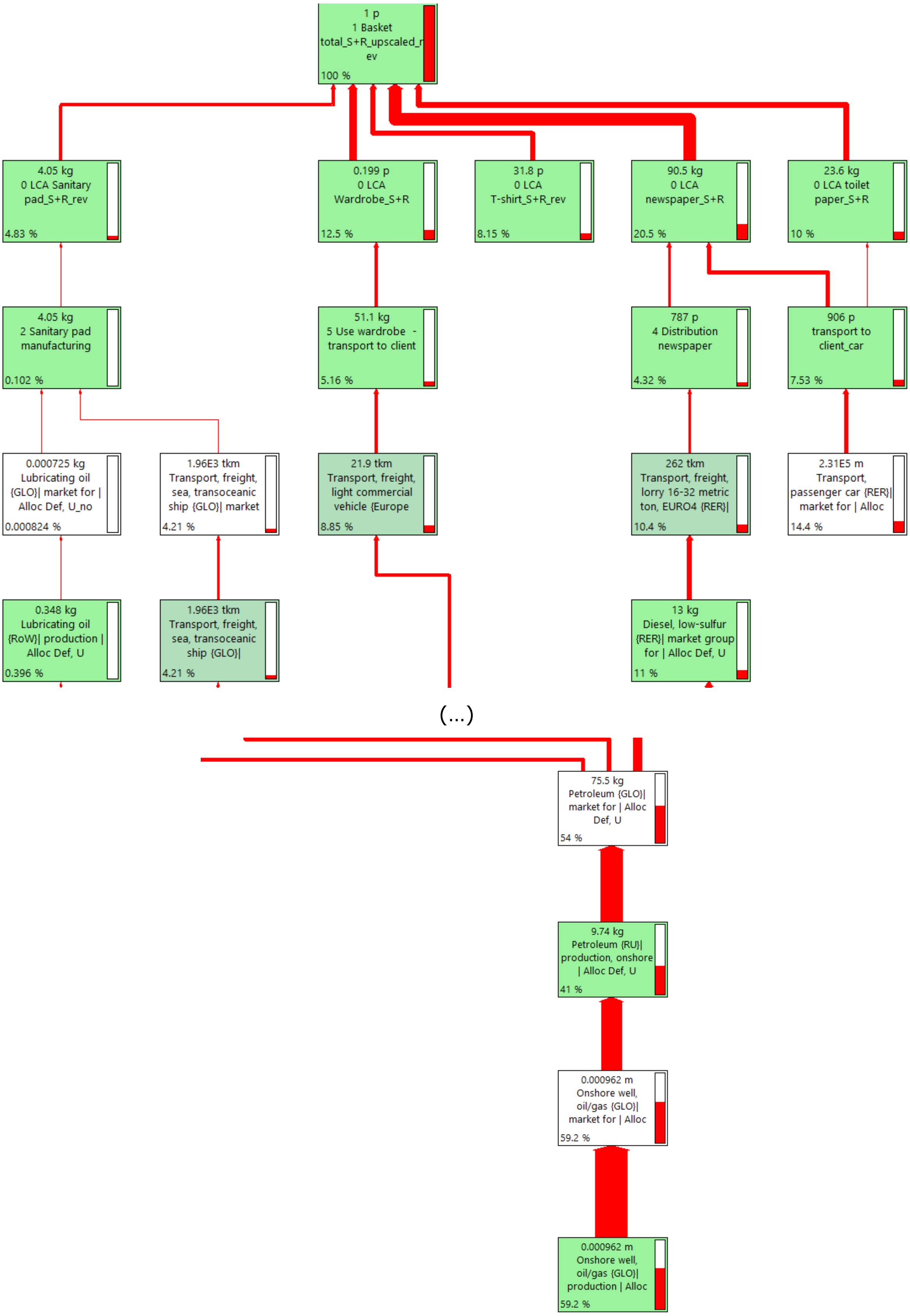
Indium (75.2% of resource depletion)



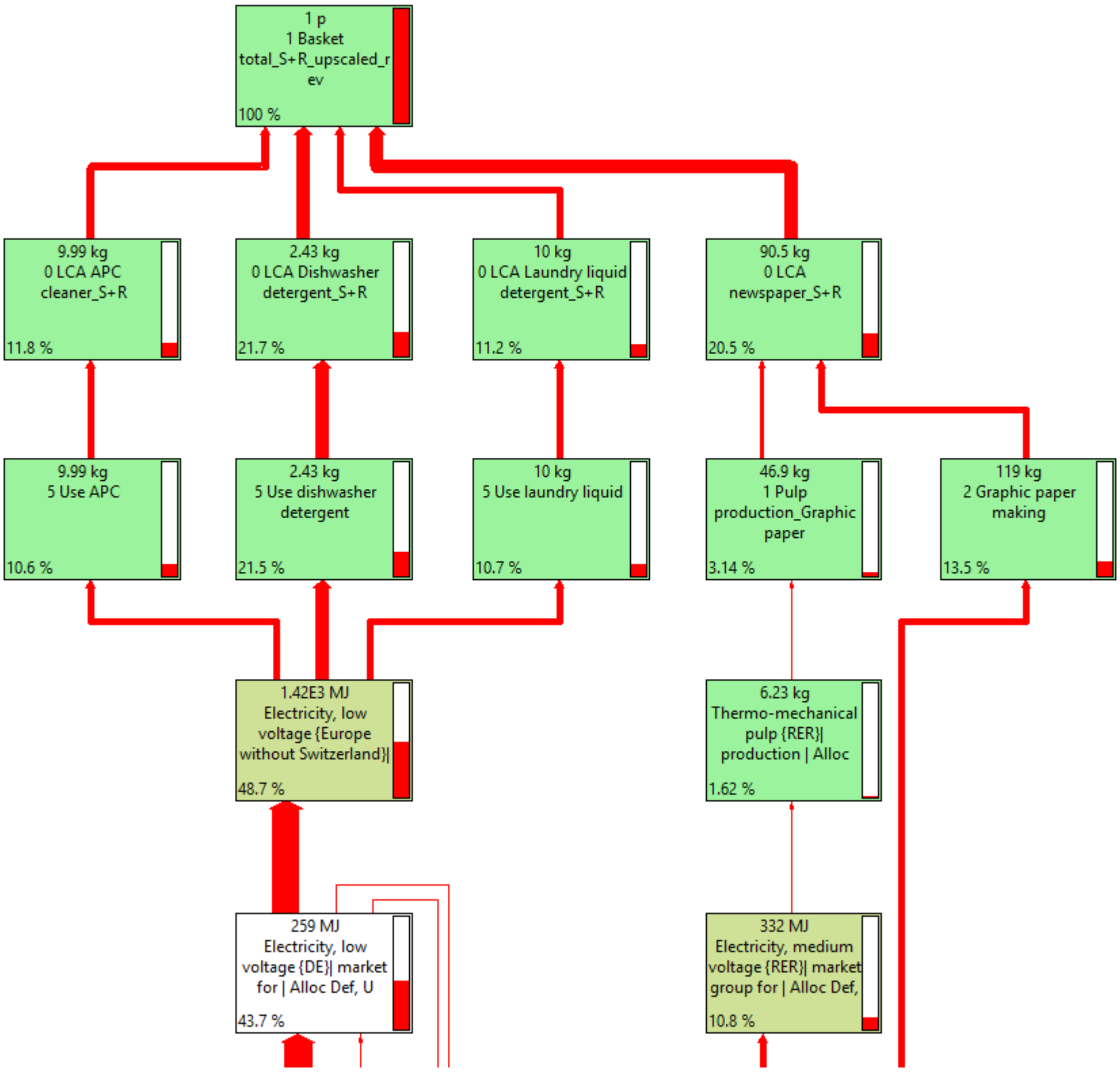
Occupation, forest, intensive (39.8% of land use occupation)



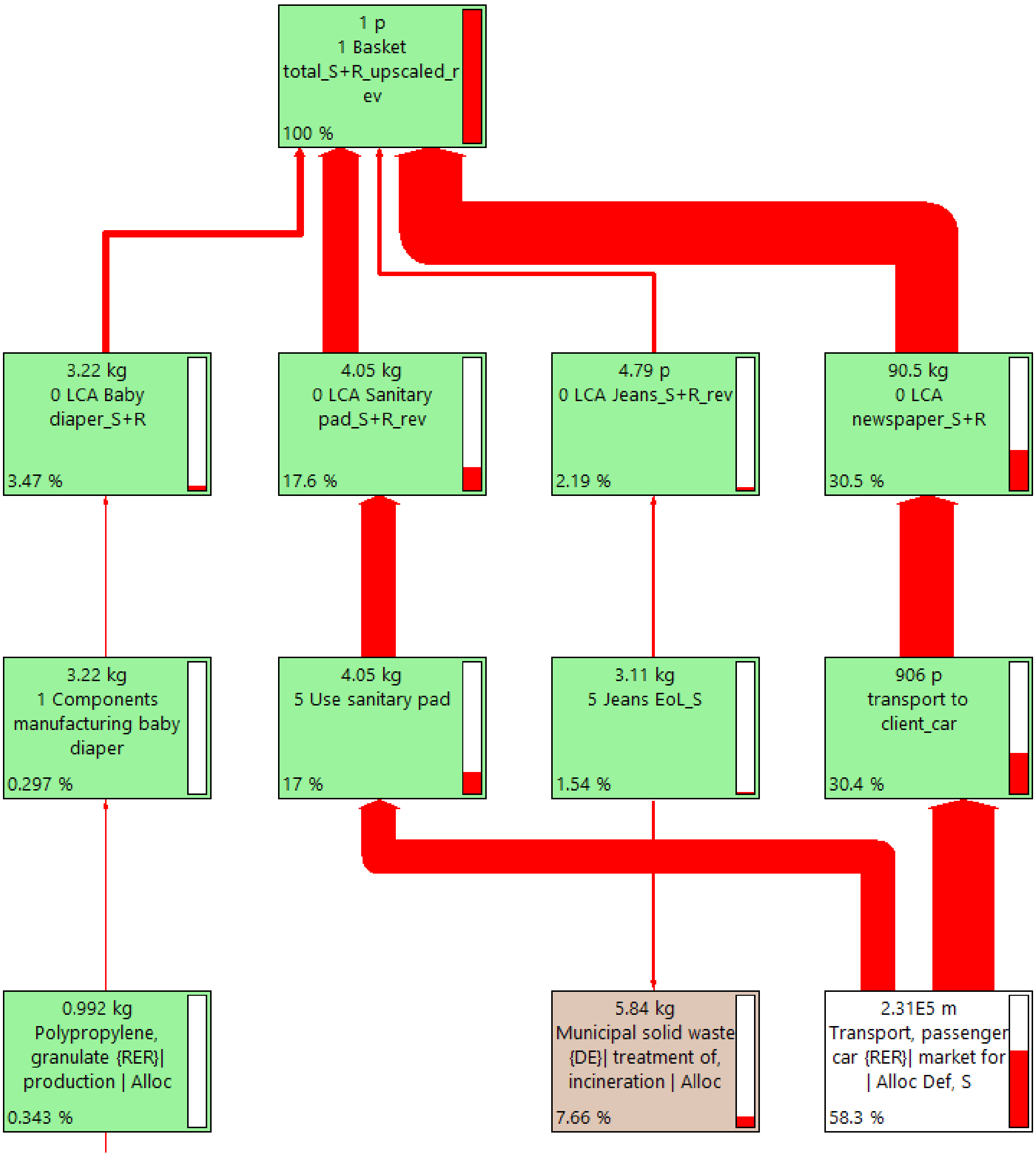
Transformation, to mineral extraction site (32.2% of land use transformation)



Water, cooling, DE (11.1% of water resource depletion)



Chromium to water (14.9% of freshwater ecotoxicity)



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