WP1 - Lifestyle module documentation

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Short Description

This report details the calculation rational, data sources and lever assumption undertaken in the development of the Lifestyle module. It specifies the inputs and outputs of the Lifestyle module as well as its interfaces with the other modules in the EU calculator model. The scope of the module is explained and particular questions it allows to answer (in combination with the supply modules) are described. Importantly, this report contributes to the transparency of the EU calculator model as a whole.

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This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

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AC – Air conditioning

GHG – Greenhouse gas emissions

pkm – Passenger kilometres.

RoW – Rest of the World

RoFG – Remaining of the food groups

SSP – Shared Socio-economic Pathways

1 Introduction

It is suggested in the policy arena that behavioural changes are required in order to improve the chances to reach meaningful climate protection targets (European Commission, 2012). Such changes are often framed under the ambiguous, and elusive term, of “sustainable lifestyles” (Evans and Wokje, 2009). But while daily life and consumption will be central in addressing the global mitigation challenge (Edenhofer et al., 2014), the traditional focus of mitigation research has been on evaluating technological options (Leimbach et al., 2010; Luderer et al., 2013; Metz et al., 2007). Recently however, more efforts have been devoted to evaluate the mitigation potential of lifestyle-related dimensions such as residential energy use, mobility, waste and consumption (Bin and Dowlatabadi, 2005; Schanes et al., 2016). These studies often take a sectoral or regional perspective on mitigation implied in lifestyle changes but not a multi-sectoral and multi-country one.

The EU calculator model takes up this challenge by explicitly accounting for changes in lifestyles as direct or indirect drivers of demand for resources, products, energy and ultimately GHG at member-state level and across several sectors (e.g., buildings, transport, agriculture, industry or electricity). The explicit accounting of lifestyle changes in the EU calculator module allows for contextualizing the reductions in resource, energy and GHG emissions brought about changes in lifestyles, to those entailed in the advance of existing and deployment of new technologies. As one of the stakeholders consulted in the context of the module development bluntly puts *“we don't have a single clue about sustainable lifestyles since we are so busy trying less unsustainable options”* (see summary of lessons in Moreau et al., 2017, Del.1.6 - Exploring lifestyle changes in Europe). That said, we do not mean to convene the impression that lifestyle changes are a “silver bullet” to solving the mitigation challenge. Issues like limited individual agency (which is beyond the scope of this project) loom constantly in the horizon we speaking on the need to swiftly adopt a sustainable lifestyle. The EU calculator takes a holistic approach and accounts for multiple sectors, especially the most energy intensive ones such as buildings, transportation and food, as well as country specific issues and socio economic groups. In doing the module lends to latest developments and research projects in the field of sustainable lifestyles (e.g. UNEP, 2016; Akenji and Chen, 2016; Ivanova et al., 2017; Lorek and Spangenberg, 2017).

This report documents the rationale and assumption behind the selection of the levers and levels used in the Lifestyle module as drivers of demand and GHG emissions. Consequently, it also documents the main operations taking place within the module, its outputs and the interfaces to the supply modules. Finally, the data sources used in the Lifestyle module are listed.

2 Trends and evolution of European Lifestyles

The average environmental footprint per person in many European countries is about double the available bio-capacity of those countries (EEA, 2010). Especially food and drink, housing and infrastructure, and mobility are the areas with highest environmental impacts, including consumption-related material use, greenhouse gas emissions, acidifying emissions and ozone precursor emissions (Mont et al, 2014). Together, final consumption of food and drink, private transportation and housing are the source of 70-80% of Europe's environmental impacts (JRC, 2006). Individual everyday choices affecting resource and energy consumption are not static in time but evolve as society – as a whole - continuously iterates its values and preferences in the light of moral, technological and scientific progress. The preferences of one generation are not the same as the one before and much less the one that will come after (although a certain degree of continuity is certain). What might have appealed to us as wishful thinking one decade ago is slowly becoming the reality. In several European countries the demand for organic agricultural products outpaces the growth of organic food supply (Willer and Schaack, 2016). In the last decade the consumption of animal protein has barely nudged in Europe while bovine meat (a disproportionally high emitter of GHG) has plunged 14% [1] since 2000. In Germany about 75% of the population between 18 to 34 years lived in a household with a car, down from 85% in 1998. And while in 1998 about 73% of their traveling was done in a car, in 2013 it was barely 60% (Kuhnimhof 2017). In the affluent countries of United Kingdom, the Netherlands and Sweden the travel amount done by car has peaked and declined (Focas et al, 2017). At an aggregate level changes of final energy consumption in EU member states between 2007 and 2014 show that overall the EU-28 countries underwent a growth rate of -6.3%. Twelve Member States underwent higher reduction rates than the average European value, highest reduction rate was observed in Greece (-16.6%), followed by UK (-15.3%) and Portugal (-11.8%). Unfortunately, the recent (2017) pick up in GHG emissions for the transport and agricultural sector[2], highlight the fragility of decarbonisation trends. In the EU, the pace of lifestyle changes towards sustainability is paltry, geographically fragmented, and prone to reversal. Moreover, lifestyle choices and preferences are gendered. In an explorative study, researchers in Sweden interviewed single and multi-person households that participated in energy efficiency campaigns. They found that "extra workload induced by energy savings may at times be significant and fall upon women in a disproportional way" (Carlsson-Kanyama/Lindèn 2007). In

[1] https://www.eea.europa.eu/airs/2018/resource-efficiency-and-low-carbon-economy/food-consumption-animal-based

[2] EEA greenhouse gas - data viewer - https://www.eea.europa.eu/publications/data-and-maps/data/data-viewers/greenhouse-gases-viewer

order to get a better understanding of the gendered effects of energy saving measures for residential buildings it would be necessary to collect data (e.g. time surveys) at an individual level. Policy makers should also ensure that any energy saving initiatives do not un-intentionally exacerbate gender inequalities.

For a long time, the main strategy for addressing unsustainable consumption patterns and levels has relied on technological innovation; time is ripe for an equal consideration of the role of lifestyle changes as major contributor climate protection in the EU28.

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3 Questions addressed by the module

The Lifestyle module is placed at the very start of the modelling chain (setting directly or indirectly the demand for resources, energy and GHG emissions) in the EU calculator model. This means that que most interesting questions addressed by the module mostly emerge when combined with the supply modules. For example, the Lifestyle module alone computes the total travel demand of a country attending to differences in travel patterns across age and gender groups, which might be in itself and interesting outcome, but not one that would tell much about sustainability given that the GHG emissions from cars, trains, planes etc. needed to satisfy that demand are found in the transport module and the material resources needed for the manufacturing in the industry module.

In combination with supply, the Lifestyle module allows to answer several questions. An overarching one, that is cross sectoral, is to contextualize the reductions in resource, energy and GHG emissions brought about changes in lifestyles, to those entailed in the advance of existing and deployment of new technologies (see Table 1). Other questions are more specific and limited to one or two sectors only. For example, in combination with the Agricultural module, it allows to evaluate the impacts on resource demand (e.g., land, fertilizers, and water), energy and GHG of a lifestyle favouring the convergence to a healthy calorie amount sufficient to maintain the country-specific metabolic rate? In combination with the Employment module, it allows to assess the amount of jobs loss/gain of lifestyles favouring smaller living spaces and the acquisition of less appliances. Other questions that the Lifestyle module allows to answer in combination with a respective supply module are listed below.

Table 1 - Example of typical questions addressed using the Lifestyle module.

Theme	Information / Example analysis		Ambition[3]	Progress
What are the <u>types of impacts</u> we want to take into account in the model?	Impact of lifestyle changes (cross sector)	• Compare the reductions in resource, energy and GHG emissions due to changes in lifestyles and those achieved due to technologic progress.	Yes, in combination with the supply modules.	Implemented
	Impact of population changes (cross sector)	• Assessing the impact of population changes in material and energy demand, and associated GHG emissions.	Yes, in combination with the supply modules.	Implemented
	Impact of passenger travel (transport)	• Assessing the impacts on material demand (e.g., steel), energy and GHG in the manufacturing of (cars, trains, planes etc.) implied in the shifting to a lifestyle favouring less travel across all means of transportation.	Yes, in combination with the transport and industry	Implemented

[3] Does this module ambition to answer that question?

		• Assessing the impacts on energy and GHG in the operation of transport that are implied in the shifting to a lifestyle favouring less travel per person per year.	modules	
	Impact of floor area intensity in buildings or apartments and conscious appliance use (buildings)	• Assessing the impacts on material demand (e.g., cement, wood), energy and GHG implied in a shift towards the adoption of smaller residential buildings or apartments. • Assessing the implications on material demand (e.g., plastic, steel), energy and GHG implied in the fast/slower adoption and replacement of household appliances such as computers, TV's or dish dryers? • Assessing the implications on energy and GHG from a lifestyle favouring the moderate use of appliances in residential buildings or apartments. • Assessing the energy and GHG implications of excess cooling of the floor space. • Assessing the energy and GHG implications of changing rates of floor area cooled.	Yes, in combination with the buildings and industry modules	Implemented.
	Impact of dietary and food waste (agriculture)	• Assessing the impacts on resource demand (e.g., land, fertilizers, and water), energy and GHG of a lifestyle favouring the convergence to a healthy calorie amount sufficient to maintain the country-specific metabolic rate? • Assessing the impacts on resource demand (e.g., land, fertilizers or water), energy and GHG of a lifestyle favouring a healthy diet composition to supply the overall caloric demand of the population? • Assessing the impacts on resource demand (e.g., land, fertilizers or water), energy and GHG due to the reduction of food waste at the consumer level.	Yes, in combination with the agriculture, land use and water modules.	Implemented
	Impact of packaging and product replacement (Industry)	• Assessing the impacts on material production (e.g., plastic, pulp, paper, glass or aluminium) from lifestyles favouring the use of less intensive packaging and paper use. • Assessing the impacts on material production (e.g., plastic, minerals) from a lifestyle that favours the extension of appliance use beyond their typical lifetime.	Yes, in combination with the industry and buildings module.	Implemented
	Economic impacts of sustainable lifestyles (employment)	• Assessing the impacts on jobs loss/gain of lifestyles favouring less demand for products such as food, appliances and building materials.	Yes, in combination with the supply and employment modules.	Ongoing
What are the <u>existing solutions</u> to	Avoid	• Avoid time spent travelling by engaging on more teleworking and online access to services.	Yes, in combination with supply	Implemented

decarbonize the lifestyle?		• Avoid cooling the room to temperatures below the comfort temperature. • Avoid over consumption of food, defined in the sense of ingesting more calories than those necessary to sustain the metabolic rate. • Avoid the ingestion of food with large GHG intensities. • Avoid purchasing products with large quantities of packaging. • Avoid replacing home appliances before the end of their typical lifetime.	modules.	
	Shift	• Shift towards plant-based diets. • Shift towards less intense-packaging products. • Shift towards less usage of home appliances. • Shift from paper used for graphic printing to digital format.	Yes, in combination with supply modules.	Implemented
	Improve	• Improve the way we set the cooling temperatures of residential buildings.	Yes, in combination with the buildings module.	Implemented
What is the impact of potential breakthrough (technologies or societal change)?	Automation/ digitalization	• Automation can have an impact on transport demand as self-driving cars would unlock car mobility for older citizens. • Teleworking possibilities cut down the need for travelling to work and hence can reduce passenger demand. • Home-based access to services (e.g., doctor, shopping), can reduce the amount of time spent on travelling.	Partially reflected on some lever ambition definition.	Implemented
What are the impacts of Lifestyle on the other sectors?	Transport	• Leads to changes in total travel demand.	Yes	Implemented
	Buildings	• Leads to changes in number of households, floor area needed, appliance ownership and use, cooling area and cooling behaviour.	Yes	Implemented
	Agriculture	• Leads to changes in the amount of food production, type of food and waste availability for energy.	Yes	Implemented
	Industry	• Leads to changes in several type of material demand.	Yes	Implemented
What are the impacts of other sectors on lifestyle?	None	• The Lifestyle module sets the demand for material/land resources, energy and emissions but is not influenced by other modules.	–	–

4 Calculation logic and scope of module

4.1 Overall logic

Research shows how lifestyle choices and patterns can have significant implications on energy consumption and hence the need to account for the consumer perspective in modelling future energy consumption patterns. A sustainable lifestyle - in the context of the EU calculator - has been defined as "a cluster of habits and patterns of behaviour embedded in a society and facilitated by institutions, norms and infrastructures that frame individual choice, in order to minimize the use of natural resources and generation of wastes". Accordingly, in the EU calculator a lifestyle is best equated to a combination of future trajectories of activities, products and services at the individual level that have important implications in the amount of resources energy and emissions at the country-level.

The Lifestyle module is based on a bottom-up approach for determining the overall country-level demand for activity, products and services in the EU calculator. The model considers historical data from 1990 to 2015, and computes projections until 2050 based on four ambition levels of lifestyle change towards sustainability (ranging from current trends to transformational change). The measure of sustainability used (consistent across the modules in the EU Calculator) is emissions of CO_2. The four levels of ambition (definitions detailed in section 3.2) have been determined by stakeholder consultation and quantitative analysis of lifestyle drivers (e.g., income, demography) and their causal relationship with the outputs with material and service demand.

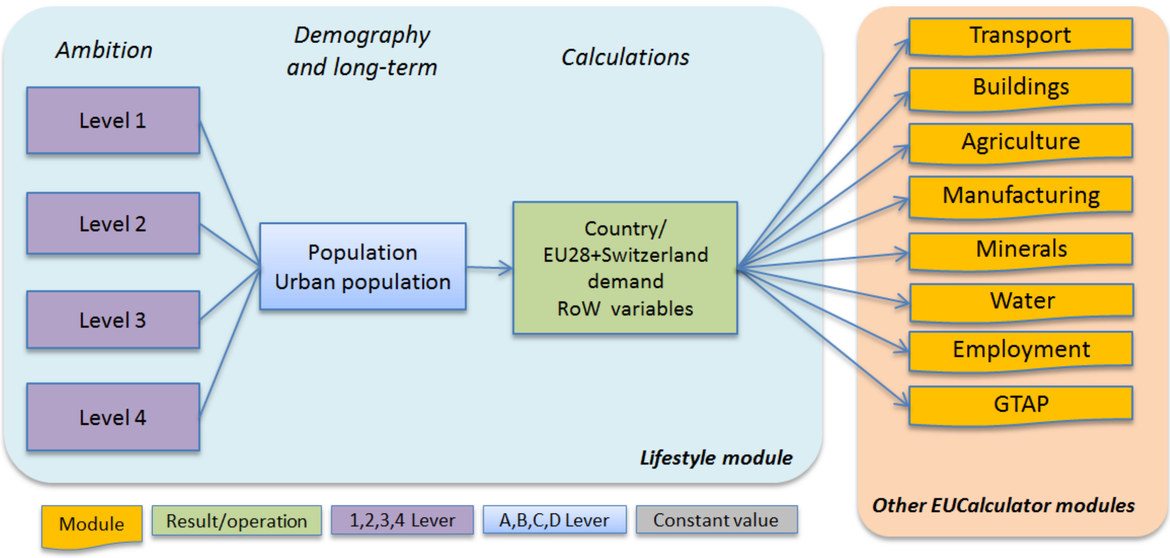

Figure 1 - Overall calculation logic of the Lifestyle module.

The overall simplified calculation logic of the Lifestyle module is presented in Figure 1. The four levels of ambition (Figure 1 left) inform of the per-capita level of a certain dimension of lifestyles (e.g., per capita calorie consumption or distance travelled). These are then scaled by the demography development (Figure 1 centre) of a country (which can be also defined by the user) and then integrated as country demand for a product or service (e.g., calories of poultry meat, travel demand in cities). In some cases the scaling can be done irrespectively of the age and gender differentiation of a country, for example the adoption of mobile phones has become ubiquitous across age classes. In other cases it is important to account for the age and gender stratification of the population (as in the case of demand for food) or the location (rural/urban) of the population within a country (as is the case of transport).

Because the level sustainability of population and "urbanity" developments cannot always be easily framed in terms of CO_2, the projections in these variables are reported as A, B, C and D (more details in section 3.2). Both for the cases of population and share of urban population, level A represent a scenario in which a generalized increase takes place until 2050. Concurrently, level D depicts a scenario where the total amount of population decreases. In regard to urban shares of population, level D delivers a small increase in the urban share of the population wile in level A more habitants move into cities.

The outputs of the module are then used as inputs in the subsequent modules of the EU Calculator through a variety of interfaces. In Table 2 the main outputs of the Lifestyle module are listed. The energy and emission associated with the outputs of the lifestyle module are addressed by other modules (e.g. Transport determines the energy entailed in the travelling demand; Buildings determines the electricity requirements of appliance use; Agriculture the resource use such as land and fossil fuels to supply the calorie demand; Industry determines the material use to supply the demand for paper and plastic).

Table 2 - Main outputs of the Lifestyle module

Outputs to	Output
Transport	• Total EU28 + Switzerland population; • Total passenger distance travelled;
Buildings	• Residential floor area; • Residential floor area cooled; • Comfort temperature; • Number of appliances; • Hours of appliances use; • Product replacement rate;
Agriculture	• Total calorie requirements; • Calorie composition of diets; • Calories of food wasted at the consumer level;
Manufacturing	• Graphics and sanitary paper demand; • Paper, plastic, glass and aluminium packaging;
Minerals	• Upper and lower bounds of population in the RoW;
Water	• Total EU28 + Switzerland population;

Employment	• Active EU28 + Switzerland population; • Different aggregations of calorie demand; • Paper demand; • Sanitary and graphics paper;
GTAP	• Floor intensity per capita; • Passenger travel per capita; • Different aggregations of calorie demand; • Paper and plastic packaging; • Sanitary and graphics paper; • Aluminium and glass packaging; • Number of appliances;

4.2 Scope definition

The Lifestyle module enables the assessment of the fraction of material, energy demand and consequential GHG emissions that can be avoided by a shift from the current consumption trends to a generalized adoption of sustainable lifestyles. The module has identified four main sectors (Transport, Buildings, Agriculture and Manufacturing) in which a change in Lifestyle can bring about significant changes in the amount of materials, energy and GHG emission as the European level. Within these sectors, a shift towards sustainable Lifestyles can be reflected at the product/resource or service demand. In Table 3 a detailed breakdown of the lifestyle dimensions outputting from the Lifestyle module are listed.

Table 3 - Scope definition of the Lifestyle module and main outputs.

Product demand and use	**Service demand**
Number of washing machines [#] and use [h] Number of dishwashers [#] and use [h] Number of dryers [#] and use [h] Number of fridges [#] and use [h] Number of freezers [#] and use [h] Number of TV's [#] and use [h] Number of computers [#] and use [h] Number of phones [#] Plastic packaging [t] Paper packaging [t] Glass packaging [t] Aluminium packaging [t] Paper printing and graphic [t] Paper sanitary and household [t] Product replacement rate [%]	Comfort temperature [°C]
Space demand	**Transport demand**
Residential floor space [m2] Residential floor space cooled [m2] Number of households [#]	Urban travel [km] Non-urban travel [km] Non-shiftable travel [km]
Calorie demand	**Food waste**

Calories from wine [kcal] Calories from beer [kcal] Calories from fermented beverages [kcal] Calories from alcoholic beverages [kcal] Calories from cereals [kcal] Calories from rice [kcal] Calories from oil crops [kcal] Calories from pulses [kcal] Calories from starch [kcal] Calories from coffee [kcal] Calories from stimulants [kcal] Calories from sugars [kcal] Calories from sweeteners [kcal] Calories from vegetable oils [kcal] Calories from vegetables [kcal] Calories from pelagic fish [kcal] Calories from demersal fish [kcal] Calories from sea food [kcal] Calories from other aquatic animals [kcal] Calories from eggs [kcal] Calories from milk [kcal] Calories from offals [kcal] Calories from bovine [kcal] Calories from sheep [kcal] Calories from pigs [kcal] Calories from poultry [kcal] Calories from other animals [kcal]	Calories from wine [kcal] Calories from beer [kcal] Calories from fermented beverages [kcal] Calories from alcoholic beverages [kcal] Calories from cereals [kcal] Calories from rice [kcal] Calories from oil crops [kcal] Calories from pulses [kcal] Calories from starch [kcal] Calories from coffee [kcal] Calories from stimulants [kcal] Calories from sugars [kcal] Calories from sweeteners [kcal] Calories from vegetable oils [kcal] Calories from vegetables [kcal] Calories from pelagic fish [kcal] Calories from demersal fish [kcal] Calories from sea food [kcal] Calories from other aquatic animals [kcal] Calories from eggs [kcal] Calories from milk [kcal] Calories from offals [kcal] Calories from bovine [kcal] Calories from sheep [kcal] Calories from pigs [kcal] Calories from poultry [kcal] Calories from other animals [kcal]

4.3 Inputs and outputs of the module

The Lifestyle module sits the start of the modelling chain and hence it does not receive any inputs from the other modules. The Lifestyle module sets the overall country-level demand for products, resources and services (see Table 3) that is subsequently passed to other modules in which energy and GHG emission are derived.

4.4 Interactions with other modules

The main interactions of the Lifestyle module are with the transport, buildings, agriculture, industry, electricity, employment and minerals modules. An overall schematic of the interaction of the Lifestyle module with other modules, as well as the overview of outputs is shown in Figure 2.

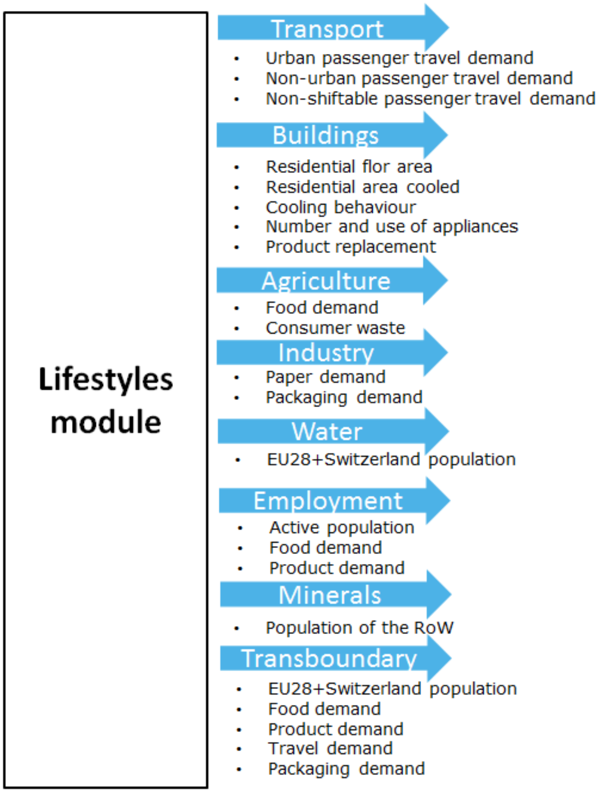

Figure 2 - Interactions of the Lifestyle module with the other modules

4.4.1 Outputs to other modules

4.4.1.1 Buildings

The lifestyle module provides the buildings module with the demand, at the country level, of the total residential floor space based on the individual preferences for the amount of floor space per person. Related to the total floor space, the module also computes the amount of the residential area that is allocated to cooling. In addition, the Lifestyle module also computes number and usage (in terms of hour used) of electrical appliances in buildings. Finally, the Lifestyle module also provides the Building sector with changes in the product replacement rate and the cooling behaviour of the population. The listing of the outputs considered is given below together with the details of units.

- Residential floor space [m2]
- Residential floor space cooled [m2]
- Product replacement rate [%]
- Number of washing machines [#] and use [h]
- Number of dishwashers [#] and use [h]
- Number of dryers [#] and use [h]
- Number of fridges [#] and use [h]
- Number of freezers [#] and use [h]
- Number of TV's [#] and use [h]
- Number of phones [#] and use [h]
- Number of computers [#] and use [h]
- Cool and heating behaviour [decrees C]

4.4.1.2 Transport

The Lifestyle module provides the transport module with the country-level passenger transport demand for a total of three sub-classes. The first two classes are the passenger transport demand taking place within the urban regions, the passenger travel demand taking place in non-urban regions. These classes are those that due to their typical distance (<1000km) are possible to shift from one mode of transportation to another.

- Urban travel [km]
- Non-urban travel [km]
- Non-shiftable travel [km]

The final category of passenger transport demand provided to the transport module is the non-shiftable demand. This demand is equated to that whose distances are typically above (1000km).

4.4.1.3 Agriculture

To the Agriculture module the Lifestyle module delivers total calorie requirements at the country level for a total of 26 food groups listed below. In addition, to each food group, the corresponding number of calories wasted as food waste is also supplied. Together, calories required plus the amount of calories wasted composes the total food demand of a country. Is it important to note that the fraction of food waste determined in the Lifestyle module refers only to the food waste taking place at the household level and not that the amount of agricultural waste taking place at the farm level. The latter is evaluated in the Agricultural module.

- Calories from wine [kcal]
- Calories from beer [kcal]
- Calories from fermented beverages [kcal]
- Calories from alcoholic beverages [kcal]
- Calories from cereals [kcal]
- Calories from rice [kcal]
- Calories from oil crops [kcal]
- Calories from pulses [kcal]
- Calories from starch [kcal]
- Calories from coffee [kcal]
- Calories from stimulants [kcal]
- Calories from sugars [kcal]
- Calories from sweeteners [kcal]
- Calories from vegetable oils [kcal]
- Calories from vegetables [kcal]
- Calories from pelagic fish [kcal]
- Calories from demersal fish [kcal]
- Calories from sea food [kcal]
- Calories from other aquatic animals [kcal]
- Calories from eggs [kcal]
- Calories from milk [kcal]
- Calories from offal [kcal]

- Calories from bovine [kcal]
- Calories from sheep [kcal]
- Calories from pigs [kcal]
- Calories from poultry [kcal]
- Calories from other animals [kcal]

4.4.1.4 Industry

The Lifestyle module provides directly the Industry module with the country aggregated demand for paper demand, both graphics and sanitary; and with the amount of packaging demand. Packaging demand is provided along four types of materials, namely plastic, paper, glass and aluminium.

- Plastic packaging [t]
- Paper packaging [t]
- Glass packaging [t]
- Aluminium packaging [t]
- Paper printing and graphic [t]
- Paper sanitary and household [t]

It is important to note that the interaction described above is a direct one in the sense that the outputs of the Lifestyle module are direct inputs to the Manufacturing module. In the EUCalc model many indirect interaction take place between he Lifestyles and the Manufacturing module mediated by for example the Transport and Buildings modules. A typical interaction is for example that the Lifestyle module supplies Buildings with the amount of residential floor area needed from which the model computes the additional floor area to be constructed. In turn, the need for construction materials such as cement and steel are requested from the Buildings model to Manufacturing. Indirectly the Lifestyles and Manufacturing are also linked via the outputs provided to Buildings. Similar rationale can be done for the Transport module in respect to cars or trains needed to supply the passenger travel demand.

4.4.1.5 Employment

The Lifestyle module provides the Employment module with the time development of the active population defined as the number of habitants in one country aged between 15 and 65. In addition, it also provides particular aggregations of the calories and waste delivered to the Agriculture module. The aggregations are done so that the outputs of the Lifestyles model better match the input-output model used in the Employment module to compute jobs and skills change.

- Active population in EU28+Switzerland [#]
- Paper printing and graphic [t]
- Total calories of beverages [kcal]
- Total calories of vegetables fruits and crops [kcal]
- Total calories of animals (non-fish) [kcal]
- Total calories of fish [kcal]

4.4.1.6 Water

The Lifestyle provides the Minerals module with trajectories of population of the EU28+Switzerland.

- Population in EU28+Switzerland [#]

4.4.1.7 Minerals

The lifestyle provides the Minerals module with trajectories of population of the EU28 + Switzerland and a trajectory of global population.

- World population [#]

4.4.1.8 Transboundary (GTAP)

The Lifestyle module also provides inputs to the GTAP model[4]. The latter makes the link of the activities taking place within the EU28+Switzerland with the global economy in the RoW. For a more detailed accounting how the GTAP model is linked to the outputs of the EUCalc model please refer to deliverable 7.2, Documentation of GTAP-EUcalculator interface and design of GTAP scenarios. The Lifestyle module provides GTAP with the following datasets:

- Plastic packaging [t]
- Paper packaging [t]
- Glass packaging [t]
- Aluminium packaging [t]
- Paper printing and graphic [t]
- Paper sanitary [t]
- Number of washing machines [#]
- Number of dishwashers [#]
- Number of dryers [#]
- Number of fridges [#]
- Number of freezers [#]
- Number of TV's [#]
- Number of phones [#]
- Number of computers [#]
- Population in EU+Switzerland [#]
- Residential floor space per person [m2/cap]
- Same calorie groups as in the Agriculture module

4.5 Detailed calculation trees

The Lifestyle module broadly operates according to the schematics in Figure 1 but depending on the output considered there are intermediate steps from determining the ambition level to providing the aggregated country output to the other modules of the EU Calculator. These are described within the lever specifications in section 5.3 Lever specification.

[4] https://www.gtap.agecon.purdue.edu/models/current.asp

4.5.1 Population in urban and non-urban areas

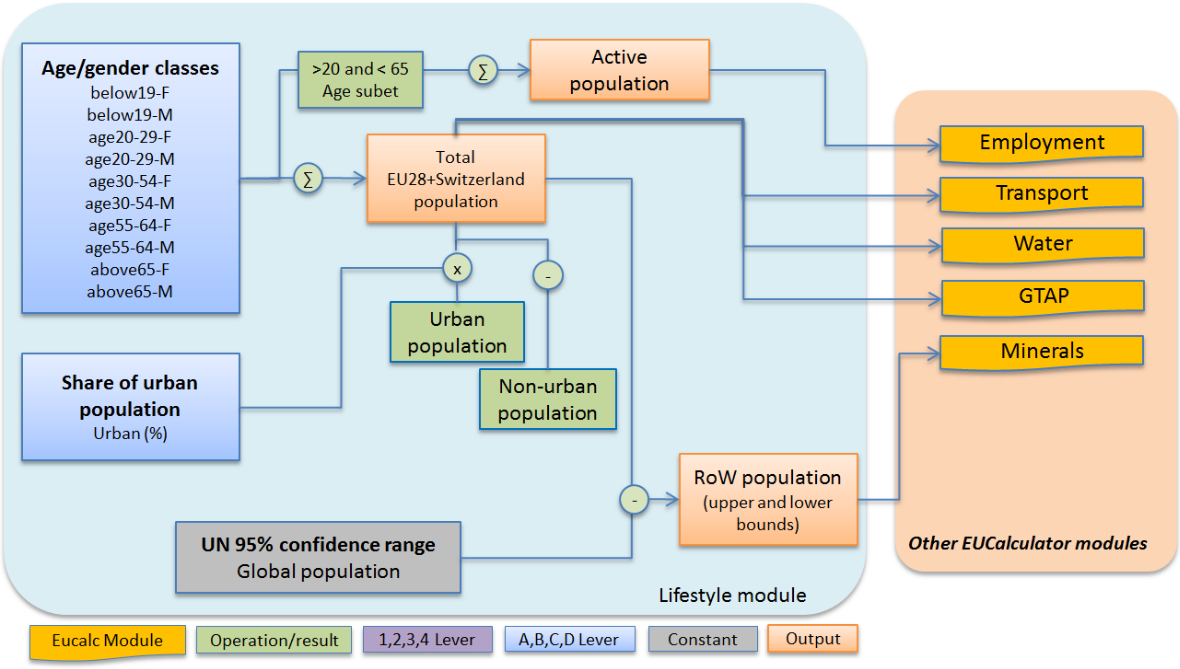

Figure 3 - Calculation tree determining total, active, urban and non-urban population.

Population numbers in their several aggregations (e.g., total, urban, active) are determined as shown in Figure 3. The population and urban population scenarios used are described in section 4.5.1. The minerals module requests a scenario of global population development. In this case, the SSP2 population scenario as in the IIASA SSP database is used[5].

4.5.2 Appliances ownership and use

Total number of appliances is requested by the Buildings module and has an input to GTAP. The number of appliances is determined by multiplying the lever setting the number of appliances in each household by the number of households, see Figure 4. In turn the number of households for each country is determined by multiplying the total number of inhabitants by the fixed, 2015, country-specific value of habitants per household taken from the EU LFS[6].

For the particular case of phones*, the lever ambition are not expressed in terms of the appliance per household but per capita. Hence, in the calculation tree ofFigure 4, phones per capita are multiplied directly by the total population.

[5] http://www.iiasa.ac.at/web/home/research/researchPrograms/Energy/SSP_Scenario_Database.html
[6] Version 1 released in July 2019 with data up to 2017 available at https://doi.org/10.2907/LFS1983-2018V.1

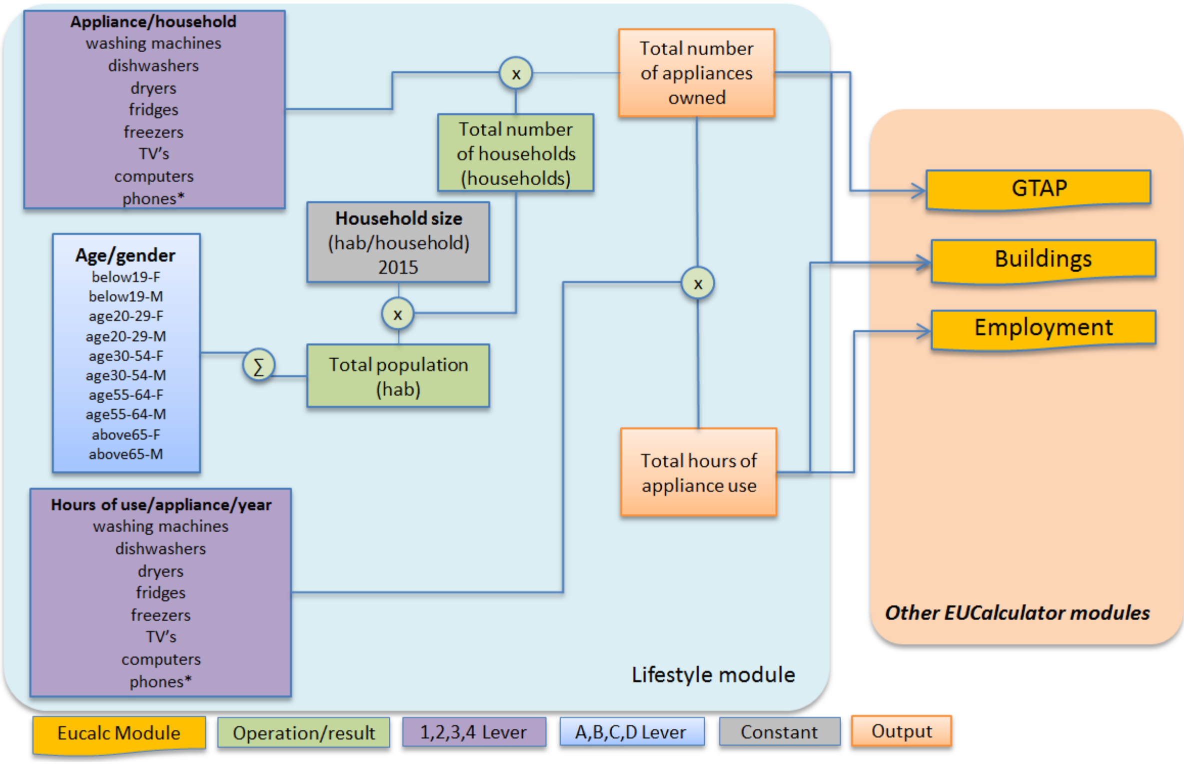

Figure 4 - Calculation tree determining country-demand of appliances.

For the case of determining the total use of appliances (in hours per year) the procedure is similar. The 1,2,3,4 lever informs on the amount of hours per year that the appliance is used. This information is then multiplied by the total number of appliances as described previously. The total number of appliances owned and use total hours of appliance are passed on to the Buildings module. To GTAP only the total number of appliances is provided and to the Employment module the total hours of appliance use, see Figure 4.

4.5.3 Floor use intensity and area cooled

The total m^2 of floor are and cooled floor are for the residential sector is determined as shown in Figure 5. Total population numbers are taken from the operation shown in Figure 3. Total population numbers are multiplied with the lever setting the amount of residential floor area per capita. The total floor area is the integration over a country of the population times the per-capita specification of residential floor space. This results in the country-demand of residential floor area, an output that is the passed to the Buildings module and GTAP. In addition to the total demand for residential floor area, the Lifestyles module provides the Buildings module with estimates of residential floor area subjected to cooling. For this purposes, the demand of residential floor area determined previously is multiplied by the lever setting the % of total residential floor are to be cooled.

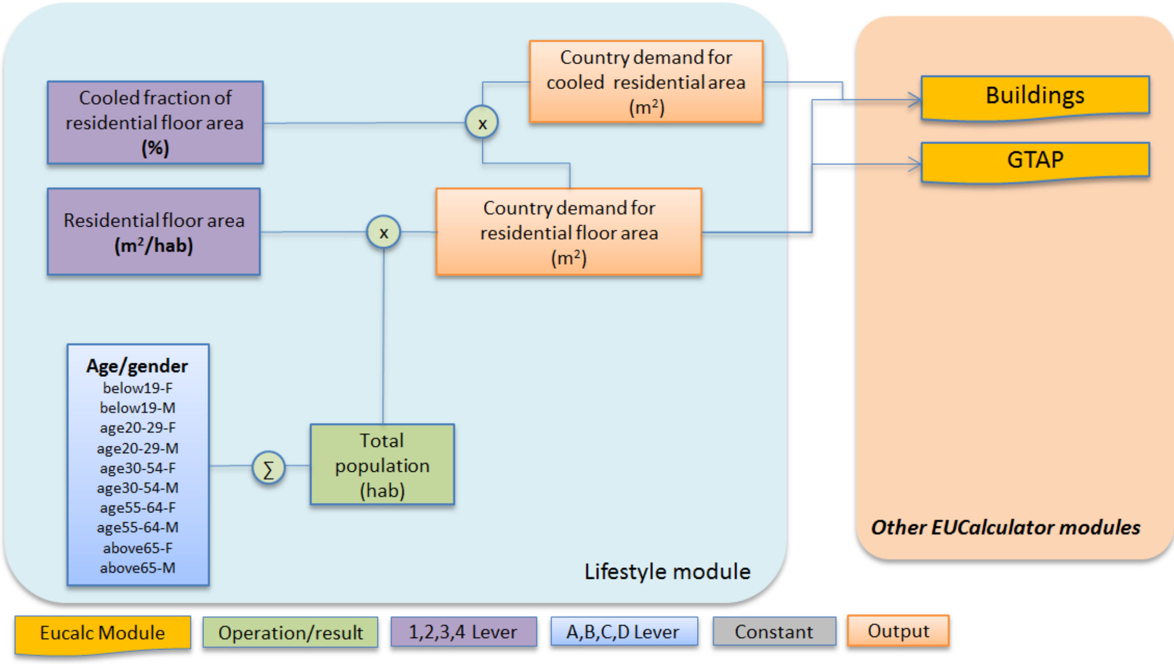

Figure 5 - Calculation tree determining the total demand of residential floor area, and residential area cooled.

4.5.4 Passenger travel distance

The total, urban, non-urban and non-shiftable travel demand (in passenger kilometres per year, pkm) of a country is determined following the calculation logic in Figure 6. The lever specifying the amount of travel demand by age class and gender is multiplied by the respective population class in order to obtain yearly distance travelled. The total distance is then multiplied by the fraction taking place outside the urban area. This is done by imputing the lever specification of the fraction of urban population in the "Urban %" term of the function shown in Figure 6. It is relevant to notice that the % of urban population is itself also a lever that the user can modify. The terms *a* and *b* are constant and country specific and are obtained by running a linear fit between the fraction of total pkm taking place outside the urban areas with the historical shares of urban population (see section 6 for the detailed parameters). The result of the function is the share of total pkm taking place outside the urban space. This share is multiplied by the total pkm determined previously. In this manner total non-urban travel distance is determined. Following, the non-urban travel distance is subtracted to the total; see remaining travel distance in Figure 6.

Finally, the remain travel distance is split into non-shiftable and urban travel by using the average 2010-2014 fractions of pkm distance above 1000km in the total urban travel taken from the Statistical Pocketbook 2016. All the outputs highlighted in Figure 6 are passed on to the Transport module. GTAP takes information on the per capita passenger travel distance directly for the lever setting.

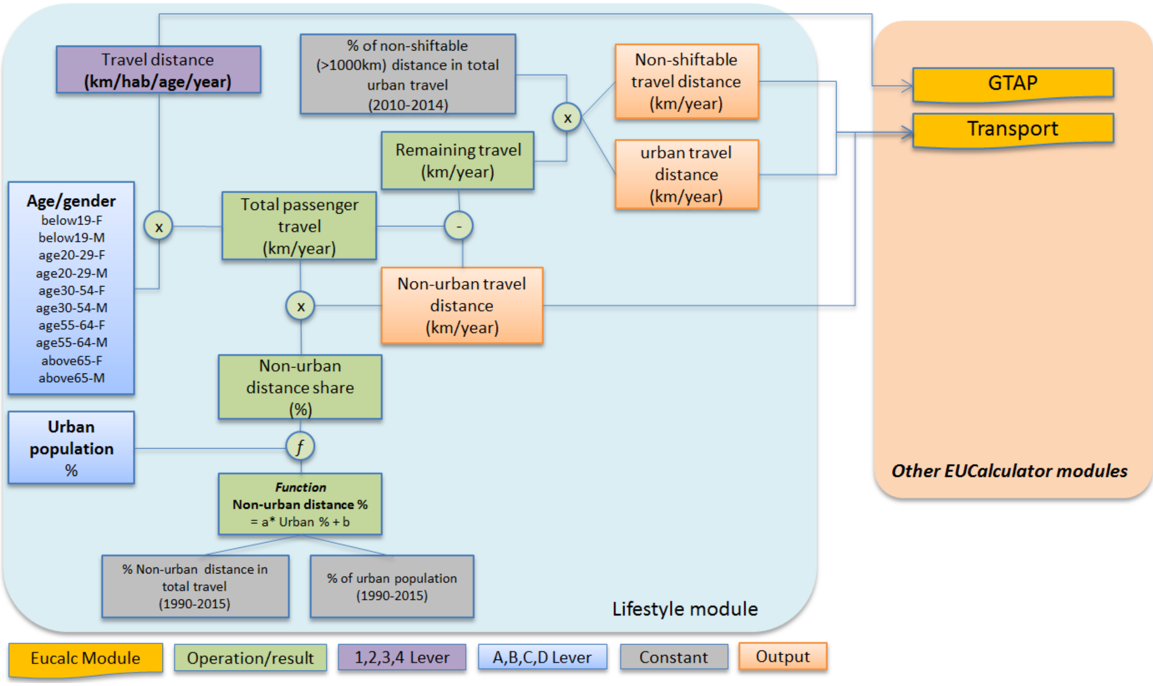

Figure 6 - Calculation tree determining the three-way passenger travel demand.

4.5.5 Food requirements and food waste

The total calorie consumption and food waste at the consumer level is determined following the calculation logic in Figure 7. The calories of food waste at consumer level are directly determined by multiplication of the per-capita calories of food wasted set by the corresponding lever with the user-defined population scenario. As for the calorie demand the calculation is sectioned into two parts. First the total amount of calories required to sustain the biophysical need of the population is determined by multiplication of the population numbers in the different age and gender classes with the corresponding per-capita calories needed (which vary according to different ambition levels).

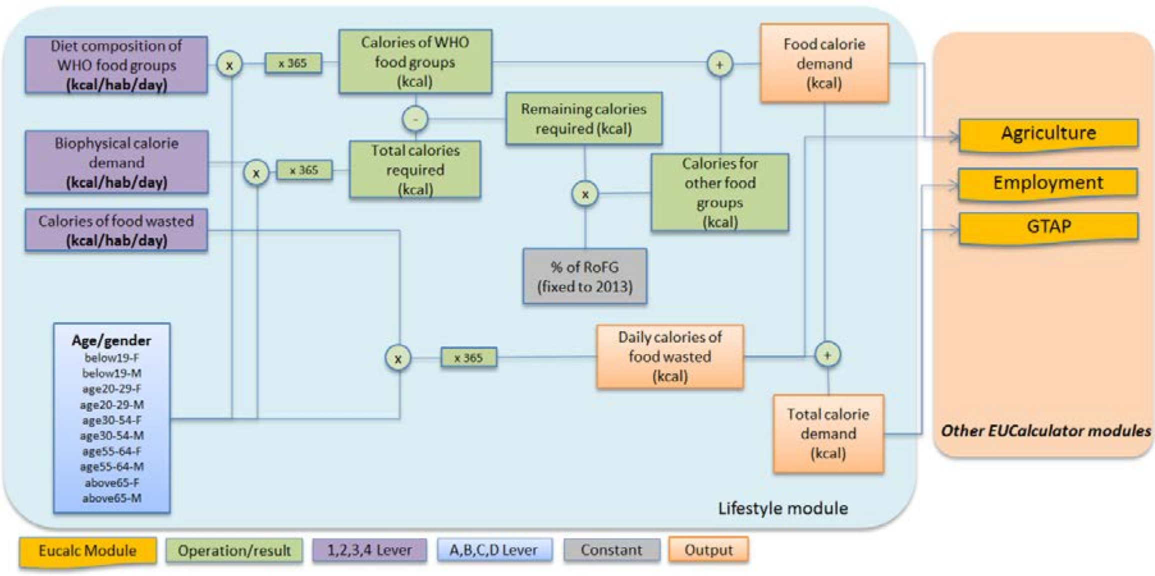

Figure 7 - Calculation tree determining total food demand and waste.

In parallel, the total amount of calories for the food groups reported on the dietary guidelines of WHO (2003) and WCRF (2007) are used are used, for a complete list of food groups and the respective modelling strategy, see Table 4. The calories for these groups are determined according to different ambitions, see "calories of WHO food groups" in Figure 7. By subtracting these calories to the total calories previously calculated we obtain the "Remaining calories required" to fulfil the biophysical need of the population. These are then distributed across the rest of the food groups considered by multiplying the total amount of calories available by the share of the remaining food groups in the total calories for the year 2013 (see "% of RoFG"). For example: if one has 2500 calories required and 500 of them are to fulfil the diet composition of the WHO food groups, then 2000 are still available to be distributed across the other food groups. Although the distribution is done using fix 2013 fractions extracted from the FAO food balance sheets [7], the absolute values are variable in time conditional to the lever combinations.

Table 4 - Food groups considered in the EUCal model and modelling strategy

Food group in the EU Calculator	Modelling strategy
Bovine Meat Demersal Fish Freshwater Fish Fruits - Excluding Wine Meat, Other Mutton and Goat Meat Offals Pelagic Fish Pigmeat Poultry Meat Sea food Sugar Sweeteners Vegetables	Affected by the WHO, WCRF and flexitarian dietary guidelines.
Beer Beverages, Alcoholic Beverages, Fermented Cereals - Excluding Beer Rice Coffee and products Eggs Fats, Animals, Raw Milk Oilcrops Pulses Starchy Roots Stimulants Vegetable Oils Wine	Balanced depending on the total calories and the sum of the calories on the food groups affected by the dietary guidelines of WHO and WCRF

4.5.6 Paper and packaging demand

The calculations of outputs regarding paper and packaging demand are straightforward, see Figure 8. Ambition level settings in terms of tons of paper and packaging per capita are multiplied by the total population. The result is total demand of paper and packaging consisting of paper, plastic, glass and

[7] http://www.fao.org/faostat/en/#data/FBS

aluminium materials, to the Manufacturing and Employment modules and also to GTAP.

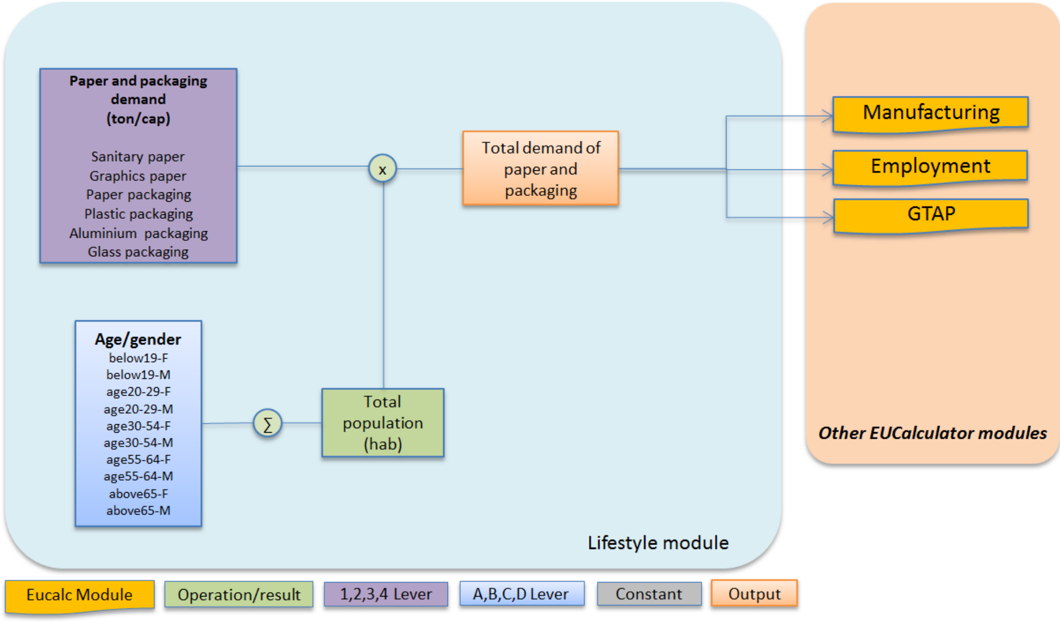

Figure 8 - Calculation tree determining total paper and packaging.

4.6 Calibration

Currently the Lifestyle module is undergoing calibration which due to its nature only concerns activities (e.g., country travel demand in kms), that is energy and GHG emissions are not determined in this module. At the rime of writing satisfactory has been achieved for the cases of total transport demand, total residential floor area, total calorie consumption and total calories wasted at the consumer level (in the case of calories the calibration takes place for 26 food groups). In the EU calculator calibration standards, a value of 100% represent that the observed historical values are perfectly reproduced by the module.

Outputs such as population and shares of urban population are not calibrated as there is no process in the Lifestyle module simulating the development of population in the past. For the case of appliance ownership, the patchiness of historical data (which often implies cross-country assumption of past development) hinders a meaningful calibration.

4.6.1 Sources

For the amount of calories consumed and wasted the food balance sheets provided by FAO are used[8]. The historical total residential floor area values are taken from the ODYSEE MURE database[9] and total passenger travel demand numbers for calibration are taken from the EU transport pocket book 2017 database[10].

[8] http://www.fao.org/faostat/en/#data/FBS
[9] http://www.odyssee-mure.eu/
[10] https://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2017_en

4.6.2 Model improvements through calibration

Currently the calibration of many activities (see next section) is already satisfactory. At the time of writing the overall calibration in the Lifestyle module, that is, averaging the calibration rates across all the activities and countries) is at circa 105% - see Table 5. That said, important discrepancies are detected for particular activities. Calibration of milk calories, both in their consumption (agr-milk) and waste (agr-wst-milk) variants is not satisfactory.

4.6.3 Current calibration rates

Table 5 details the current calibration rates in the Lifestyle module. Please note that only activities for the Agriculture, Transport and Buildings module are currently calibrated. Calibration on outputs for Industry will be done in the near future. For transport, while the calibration at the aggregated European level is good, for some countries the Lifestyle module overestimates demand by 70%.

Table 5 - Current calibration rates in the Lifestyle module

Activity	EU28 Mean	Country Min	Country Max
Calories for human consumption			
activity: agr-beer	118%	94%	133%
activity: agr-bev-alc	118%	94%	133%
activity: agr-bev-fer	110%	12%	156%
activity: agr-bov	100%	94%	135%
activity: agr-cereals	98%	75%	115%
activity: agr-coffee	119%	10%	133%
activity: agr-dfish	100%	94%	135%
activity: agr-egg	119%	94%	133%
activity: agr-ffish	100%	94%	135%
activity: agr-fruits	100%	94%	135%
activity: agr-milk	17%	14%	20%
activity: agr-offal	106%	85%	123%
activity: agr-oilcrops	119%	95%	135%
activity: agr-oth-animals	100%	94%	135%
activity: agr-pfish	100%	94%	135%
activity: agr-pigs	100%	94%	135%
activity: agr-poultry	100%	94%	135%
activity: agr-pulses	120%	95%	165%
activity: agr-seafood	100%	27%	135%
activity: agr-sheep	100%	94%	135%
activity: agr-starch	96%	76%	107%
activity: agr-stm	116%	95%	134%
activity: agr-sugar	100%	94%	135%
activity: agr-sweet	101%	94%	135%
activity: agr-veg	101%	94%	135%
activity: agr-voil	119%	94%	133%
activity: agr-wine	120%	94%	133%
Calories wasted at the consumer level			
activity: agr-wst-beer	101%	94%	135%
activity: agr-wst-bev-alc	101%	94%	135%
activity: agr-wst-bev-fer	87%	2%	253%
activity: agr-wst-bov	100%	94%	135%
activity: agr-wst-cereals	103%	96%	139%
activity: agr-wst-coffee	100%	8%	135%
activity: agr-wst-dfish	100%	94%	135%

activity: agr-wst-egg	200%	188%	269%
activity: agr-wst-ffish	100%	94%	135%
activity: agr-wst-fruits	100%	94%	135%
activity: agr-wst-milk	178%	160%	259%
activity: agr-wst-offal	100%	94%	135%
activity: agr-wst-oilcrops	100%	94%	135%
activity: agr-wst-oth-animals	100%	94%	135%
activity: agr-wst-pfish	100%	94%	135%
activity: agr-wst-pigs	100%	94%	135%
activity: agr-wst-poultry	100%	94%	135%
activity: agr-wst-pulses	101%	94%	152%
activity: agr-wst-seafood	98%	11%	135%
activity: agr-wst-sheep	100%	94%	135%
activity: agr-wst-starch	100%	94%	135%
activity: agr-wst-stm	100%	94%	135%
activity: agr-wst-sugar	100%	94%	135%
activity: agr-wst-sweet	101%	94%	135%
activity: agr-wst-veg	101%	94%	135%
activity: agr-wst-voil	100%	94%	135%
activity: agr-wst-wine	100%	94%	135%
Total residential floor area			
activity: bld-floor-space	101%	99%	122%
Total passenger travel demand			
activity: tra-total-demand	99%	67%	171%

5 Description of levers and ambition levels

5.1 Lever list and description

In the Lifestyle module saving on resource and energy are obtained by acting on the levers enumerated and described below. They basically fall into three broad categories; reduction on the demand for materials from manufacturing, reductions on the demand for services such as transport and energy and changes/reductions in the nature and amount of calorie intake. For each lever the magnitude of the change (ambition level) in each lever oscillate between minimal to transformational effort to tackle climate change.

Table 6 - List of levers considered in the Lifestyle module

	Lever	Brief description
1.	Population [#]	Number of inhabitants in EU28+Switzerland
2.	Share of urban population [%]	Fraction of the total population living in urban areas.
3.	Appliance ownership [#/household]	Total number of appliances in households.
4.	Appliance use [hours/app]	Yearly hours of use of each appliance.
5.	Product replacement rate [%]	How often appliances are replaced.
6.	Comfort temperature [ºC]	Indoor temperatures for residential buildings.
7.	Floor use intensity [m2/cap]	Per capita m2 of residential floor area.
8.	Share of residential floor cooled [%]	Amount of floor space cooled.
9.	Passenger travel distance [pkm/cap/year]	Yearly distance travelled by individuals.
10.	Calorie requirements [kcal/cap/day]	Daily calorie required by individuals to sustain their basal metabolism.
11.	Calorie wasted [kcal/cap/day]	Daily calories wasted by individuals.
12.	Calorie split [kcal/cap/day/food group]	Diet composition of individuals.
13.	Paper and packaging demand [kg/cap/year]	Amount of paper, plastic, aluminium and glass demand by individuals.

5.2 Definition of ambition levels

5.2.1 GHG focused levels: 1, 2, 3 and 4

The ambition levels 1-4 are expressing the range between a minimal (1) and maximum (4) ambition levels in terms of GHG emissions related with lifestyle choices. Table 7 shows the definition of levels used in the Lifestyle module and is consistent with the definitions used in the other modules of the EU Calculator.

Table 7 - Definition of ambition levers in the lifestyle module

Level	Definition
1	**Past trends of lifestyle change:** This level reflects a Europe in which the lifestyle evolves until 2050 follows the 1990-2014 trends. This does not always translate into an increase demand for energy or resources. For example, some countries have been reducing certain types of meat consumption throughout time, while others have seen stagnation is road transport demand. Nevertheless, at an aggregated European scale, this level results in higher emission and resource consumption.
2	**Ambitious change:** This level is more ambitious than a projection of historical trends but falling short from a generalized shift towards the adoption of sustainable lifestyles.
3	**Very ambitious change:** This level is considered as very ambitious but realistic scenario, given the evolution of lifestyles change observed in some geographical areas. In this level, rather than being a niche, sustainable lifestyle practices are the norm across all European countries.
4	**Transformational change:** This level is considered as transformational and requires major societal changes. This level is considered a transformational change in European lifestyles that goes beyond the best examples observed today and is only possible by means of a breakthrough on the lifestyle choices made by individuals.

It is important to underline that the magnitude of energy and GHG emissions implied in the ambition levels of lifestyles defined above are always conditional to choices and development of particular technologies and processes taking place in the other modules. While the magnitude of resource and energy saving may differ conditional to the choices of levers taking place in the other modules, the gradient of the potential savings entailed in the lever choice taking place in the Lifestyle module remain unchanged, that is, level 1 returns the lower savings or even increase) while level 4 returns the highest savings.

5.2.2 Alternative levels A, B, C and D

Depending on the lever setting, i.e. on the context, some ambition levels could be either best or worse in terms of GHG emissions. In addition, some of the levers required to determine the overall amount of resource and energy consumption are subjected to ethical considerations that are at some extent outside the scope of our module. An iconic case of the latter is the amount of population living in Eu28 + Switzerland. For these types of levers rather than the 1-4 gradients of emissions saving as detailed in the section before, the EU Calculator team opted for an A to D classification.

The levers classified in this manner portrait trajectories of particular variables that may, or may not lead to a saving of emissions. For example more people in a country does not necessarily equates to more transport emissions in case the per capita demand for transport falls and there is a strong shift towards clean mobility modes.

5.3 Lever specification

In the following sections we specify both the lever specification as well as details of the analytical steps done in order to obtain the respective demand to be passed on to the other modules in the EU calculator. This complements the overall simplified structure of the Lifestyle modules presented in section 2.2.

5.3.1 Population

5.3.1.1 Lever description

This lever sets the trajectories of population in 10 age/gender classes in EU28+Switzerand until the year 2050. This level follows an A to D classification as discussed in Section 5.2.2.

5.3.1.2 Rational for lever and level choices

Current situation

Between 1960 and 2018, the population of the EU grew from 407 million to 513 million, an increase of 106 million people. In the year 2018 the population of the European Union (EU) was estimated at 512.6 Million, 1.2 Million more than in 2017. In that year more deaths than births were recorded meaning that the natural change of population was negative. The rise in overall population was therefore due to net migration.

Various scenarios for 2050

In Europe fertility and mortality, two of the three main drivers of population change are expected to decline. In the World Population Prospects: The 2012 Revision provided by United Nations Department of Economic and Social Affairs (UN 20013) most of the scenarios for the EU28 space result in a decline of population by 2050 in the range of 500-453 Million range. In the same report, the upper range of population for the EU tops at circa 550 Million by 2050 (UN 2012). The population scenarios for Europe entailed in the SSP exercise (Riahi et al., 2017) point for larger ranges of variation. By 2050 population in the EU is projected to range between a maximum of circa 618 and 460 Million in SSP5 and 3 respectively.

Disaggregation methodology rational

No disaggregation, see section 5.3.1.3

5.3.1.3 Ambition level and disaggregation method

EU-Levels

The Lifestyle module makes use of the projection[11] of population by age, sex and year ranging from 2015 up to 2050 made available by the Eurostat (Eurostat 2017). The Eurostat projections were find to capture the possibility space of development of future population numbers entailed in the scenarios previously described.

Level A is determined as half-way between the High Migration scenario variant in the Eurostat projections. Following this scenarios, European population and Switzerland rises to circa 542 Million by 2050. This is in line with the maximum in UN (2013) projections but considerably lower than the SSP5. We justify this choice because in order for the SSP5 to be a close representation of the near future, the population of Europe would have to grow at 3.6 million per year in order to the projections by mid-century. Furthermore, this growth would have to be fuelled by migration and internal fertility in order to be consistent with the assumptions. Even at the high of the migration surge observed in Europe in the year 2015, asylum applicants mounted up to 1.3 and million respectively[12]. Even assuming that a 2015 year could repeat itself until 2020, migration numbers would not suffice to get close to SSP5 numbers. In addition, a stagnating average fertility has been observed across EU28 countries since 2008 at circa 1.6 children per woman[13]. With an increase of about 1.1 Million per year referenced to 2015, the A level is very much aligned with the past trends of decadal population growth of 1.3 million/year between 1994 and 2014.

Level B is aligned with the baseline population projection in Eurostat and with those the 2015 Ageing Report (2015) and the SSP2. This represents a scenario of moderate population growth in which by 2050 EU28+Swizerland population tops at 533 million. This level is below the past trends of decadal population growth, see above. Level D is aligned with the low fertility variant of the Eurostat projections. Under this scenario the European population falls to 516 Million by 2050. Level C is set as the average between the Level B and D representing therefore an intermediate scenario between the baseline and that of low fertility.

Table 8 – EU28+Switzerland levels for lever population

EU + Switzerland	A	B	C	D
Population [Milllions]	542	533	516	499

Disaggregation by country

There is disaggregation necessary. The Eurostat projections are available at the country level and for the 10 age/gender classes considered in the EUCal model.

[11] https://ec.europa.eu/eurostat/cache/metadata/en/proj_esms.htm
[12] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=migr_asyappctzaandlang=en
[13] http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Fertility_indicators,_EU-28,_2001%E2%80%932015_YB17.png

5.3.1.4 Sources and references

Eurostat 2017, Technical Note: Summary methodology of the 2015-based population projections, EUROPEAN COMMISSION EUROSTAT Directorate F: Social statistics Unit F-2: Population and migration, Luxembourg, 2017

UN 2013, World population prospects: the 2012 revision. *Population division of the department of economic and social affairs of the United Nations Secretariat, New York*, *18*.

Riahi, Keywan, et al., "The shared socioeconomic pathways and their energy, land use, and greenhouse gas emissions implications: an overview." *Global Environmental Change* 42 (2017): 153-168.

The 2015 Ageing Report: Economic and budgetary projections for the 28 EU Member States (2013-2060), ISSN 2443-8014 (online)

5.3.2 Share of urban population

5.3.2.1 Lever description

This lever controls the amount of the population in the EU calculator that lives in urban areas.

5.3.2.2 Rational for lever and level choices

The rational for this lever is twofold. First there is a growing body of literature exploring the relation between city size, energy and GHG emissions. For the US, a super-linear scaling behaviour, expressed by a power-law, between CO_2 emissions and city population has been determined. This suggests that the high productivity characteristic of large cities is done at the expense of a proportionally larger amount of emissions compared to smaller ones (Oliveira et al., 2014). Secondly, the Transport module differentiates different types of modal shift scenarios depending if the passenger transport demand is to take place in cities or in rural areas. Hence this lever will serve to inform the Transport module on the total distance available in urban and rural areas. Furthermore, passenger car use was found to scale inversely with population density, which in turn influences transport CO_2 emissions (Baur et al., 2014).

<u>Current situation</u>

According to the Eurostat (Eurostat 2015), urban areas - defined as cities, towns and suburbs - provide a home to 72% of the EU-28's population; 41% live cities and 31% in towns and suburbs in 2014. Over the past 50 years, the urban population has continued to grow with considerable differences in the size and spatial distribution of urban developments between member states. More compact cities favour less need for transport and were demonstrated to have a significant impact on transport emissions

<u>Various scenarios for 2050</u>

Unlike for the case of population, long-term urbanization projections on a country scale are harder to come by for Europe, not to mention consistently for all EU member states. That said, we investigate urbanization estimates from two consistent global studies we could source, the projection entailed in the SSP database and the UN urbanization prospects (UN 2015). To date, the urbanization projections in the SSPs constitute the only consistent set of global urbanization projections at the country level that extend over the whole 21st century. None of the scenarios evaluated anticipates a decline in urbanization across either in Europe, in the case of UN (2015), see Figure 9, nor at member state level, as is the case in Riahi et al., (2017).

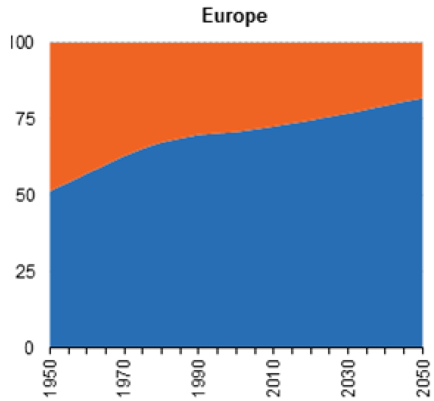

Figure 9 - Share of urban and rural populations, 1950–2050 in UN (2015)

Accordingly, the continuation of the global megatrend of more people moving into cities appears to be a robust assumption. Since the temporal focus of the EU calculator unfolds only over a few decades (2020-2050) and the inertia of the urbanization trends, no level depicting a decline of population living in urban agglomerations is therefore considered. The pace of change in Europe will likely be slower, with the share of the population living in urban areas projected to rise to about 80 % by 2050 (Eurostat 2015). The range of urban population shares is more substantial if one examines the results implied in SSPs. For the EU28, the interval of potential change range between 87% an 73% for SSP's 1 and 3 respectively.

<u>Disaggregation methodology rational</u>

No disaggregation, see section 5.3.2.3

<u>Feedback from the stakeholder consultations</u>

No specific feedback from the stakeholder consultation.

5.3.2.3 Ambition level and disaggregation method

<u>EU-Levels</u>

Considering the literature above it is very unlikely that the urban share of population in the EU28+Switzerland will decline. The future evolution seems therefore to be a question of fast versus slow increase. In order to reflect the full spectrum of ranges found in the literature the level A for this lever is linked to the strong urbanization scenario of SSP1 in which the urban share of European population grows to 87%. At circa 0.48% growth a year of urban population, this level is the highest of those investigated. Level B anticipates a constant growth in urban population of about 0.35% a year, reaching a total of about 80% by 2050. Level B is linked to the SSP2 scenario delivering an average fraction of population living in urban areas of 80%, an annual growth of about 0.35% a year. This is also aligned with the choice done for the lever population. Level D is linked to the SSP3 scenario by which the fraction of urban population in Europe practically stagnates between 2015 and 2050 reaching 78% at the end of the simulation period. Level C is constructed as an intermediate level between B and D and results in a urban share of population by 2050 of 76%

Table 9 – EU28+Switzerland levels for lever fraction of urban population

EU + Switzerland	A	B	C	D
Urban population [%]	83%	80%	78%	76%

<u>Disaggregation by country</u>

There is disaggregation necessary. The SSP database (Riahi et al., 2017) contains projections of the urban share of the population at the country level.

5.3.2.4 Source references

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5.3.3 Appliance ownership

5.3.3.1 Lever description

This lever describes the amount of white and black appliances found in each household and comes expressed as appliance/cap. A reduction of the average number of appliances found in households, all other things kept constant, leads to a reduction in carbon emissions.

5.3.3.2 Rationale for lever and level choices

Global energy use for lighting, appliances and equipment in buildings grew steadily at 1% per year since 2010 (IEA 2017). Appliances (including lighting and cooking) use more than a third of the global energy consumed in buildings (IEA

2017). Their part in electricity demand has been driven by the growth in several types of goods: large appliances increasing 50% since 1990; lighting, growing on average 2% annually since 2005; and networked devices and other small consumer electronics increasing 3.5% annually since 2010 (IEA 2017). Despite significant progress on labelling and mandatory minimum energy performance standards (MEPS), resulting in energy consumption growth of over 50% from 2000 to 2012 (IEA ETP 2015). Finally having fewer appliances in households can be achieved by sharing or leasing and this strategy was found to result in important energy savings. Intlekofer et al., (2010) showed that energy could effectively be saved by on average by 30% with leasing of dishwashers, clothes washers and refrigerators; while the potential for energy savings for renting out computers was between 20-30%, if the leasing extended the production of computers.

Current situation

In Europe there is a lack of published data based on the study of appliance penetration or ownership comparing different countries trends and assessing different appliances families (Cabeza et al., 2017). This is still and hindering reality allowing for a more in depth understanding of the drivers behind household appliance ownership patterns. That said, it is not that information is completely missing. The ODISSEE database provides an entry point, though fragmented, to the current European pattern of household ownership. Figure 10 shows the 2014 situation of dishwasher ownership per household in European countries and highlights the broad trend of increasing household penetration of dishwashers as countries become more affluent.

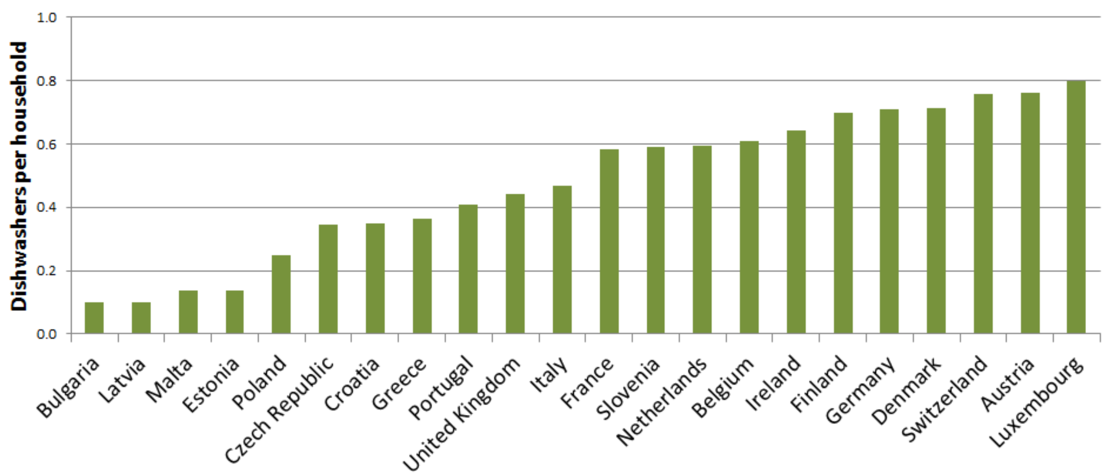

Figure 10 - Number of dishwashers per household in 2014 for selected European countries. Source: ODISSEE database, year 2014

In Luxembourg and Switzerland the penetration of dishwashers is nearly complete at around 0.8 per household. For countries like Bulgaria and Latvia penetration in 2014 hovered around 0.1. This evidence is further quantified in by means of a regression analysis in see Figure 11 where number of dishwashers per household are correlated with per-capita GDP at country-level (see Figure 11 right panel) and computer ownership (see Figure 11 left panel). The scaling of appliance ownership with income is in line with the evidence found in the literature where, in general, after a rapid uptake of appliance ownership in lower income levels, the penetration tends to saturate (Rao and Ummel 2017).

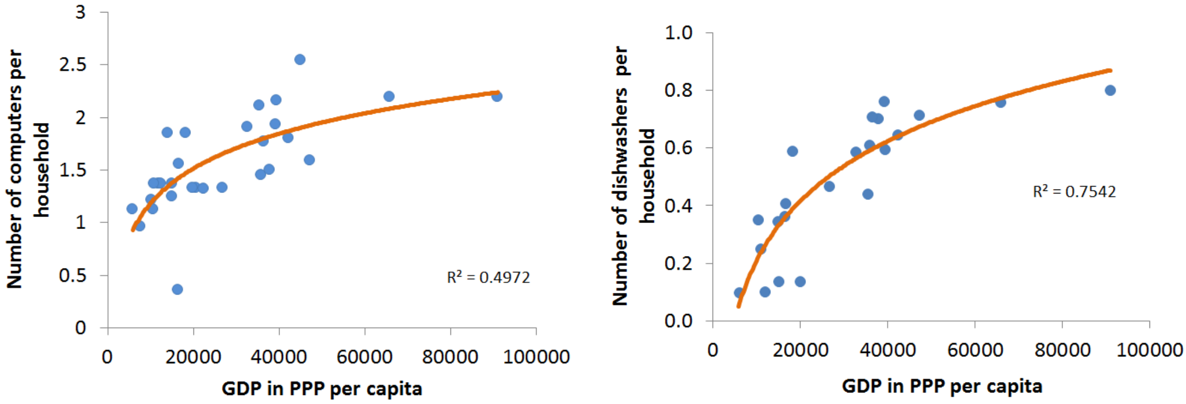

Figure 11 - Relation between income per capita and ownership of computer and dishwashers in households. Source: ODISSEE database, year 2014.

Similar curves were found for the cases of mobile phone and dryer (not shown). For television, fridge and freezer no significant correlation with income was found, likely reflecting the already high levels of penetration of these appliances. Finally, the case of washing machines (Figure 12), an inverted U curve was observed meaning that after a given income level the number of washing machines per household decreases after achieving a maximum, at circa 25000€/capita in the year 2014.

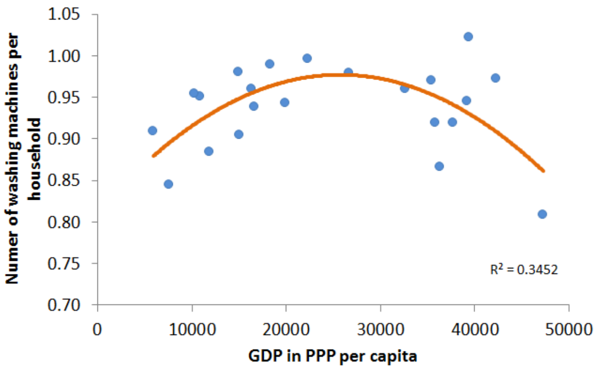

Figure 12 - Relation between income per capita and ownership of washing machines in households. Source: ODISSEE database.

When buying household appliances, studies point to important differences in purchasing choices of household appliances between women and men. A study carried out in seven EU countries indicates that "women considered environmental issues in general and energy and water consumption aspects in particular, more than men. Moreover, women searched more for information regarding energy efficiency class" (Gaspar & Antunes 2011).

Various scenarios for 2050

Reflecting the general empirical relation between appliance penetration and income, previous scenarios have suggested a generalized increase of appliance ownership (Grubler et al., 2018, EU reference scenario 2016). In the global North, which includes Europe, Grubler (2018) and colleagues suggest an increase in consumer goods by a factor of 2 by 2050. The upwards trend in appliance ownership is expressed in the EU reference scenario (Capros et al., 2016) and implicitly in IEA's projection of energy use (IEA 2017) where appliances and other equipment are said to double their electricity consumption by 2030 (more energy than any other final good or service category in buildings).

No scenario proposing a reduction of appliance ownership has been found and by large the reductions in energy consumption from appliances are equated in studies to the increase of appliance efficiency rather than reduction of their number. Given that the vast majority of appliances operating in 2050 have yet been manufactured, there is a significant opportunity to implement efficiency standards now to further reduce consumption, particularly in rich countries (Cabeza et al., 2014). On the other hand, rebound effects both in user behaviour and preference highlight that a curtailing of appliances number might be needed in order to lower the final energy consumption of appliances. For China for example, it was found that although flat-screen televisions have proven to be more energy efficient than the cathode ray tube technology they replace. But sales have quickly shifted to much larger screens, cancelling efficiency benefits (Zhou et al., 2011).

Disaggregation methodology rational

In terms of disaggregation rational it is assumed that as countries grow more affluent the barriers to the acquisition of home appliances is reduced although not eliminated. If the country starts from a low penetration level for a given appliance, literature says that it should converge rather rapidly to middle/high levels of income. The aspects from gender in the purchase and used of appliances (see section 5.3.4) were not considered in the disaggregation of ambition levels by country. The reason for such is that the model does not make any consideration of which gender occupies single-person households.

According to Eurostat (2019) there were more single person households in 2016 (32 %) than two-person households, and 18 per cent of women were living in single households compared to 14 per cent of men. Explanations for this asymmetry might be due to elderly women outliving their partners and young women leaving their family homes at a younger age compared to their male counterparts (Eurostat 2019). In the EUCalc model the average size of households is kept constant throughout the time frame of analysis (at the country-level) and there is no considerations made about the gender composition of households. That said, the absolute number of households changes in time driven by changes in the total amount of population explained in section 5.3.1.

5.3.3.3 Ambition levels and disaggregation method

EU-Levels

For level 1, we assume countries converge to levels of appliance ownership typical found in European countries with high income levels, typical beyond 40k € per year in 2014. For example, for the adoption of fridge's this would imply a convergence to 1.1, similar to the penetration found in Germany in the year 2015. For computers, a 2 value per household is assumed, a typical value found in affluent countries such as Switzerland. For dishwashers, countries are set to converge to vales of 0.7, a value typically found in EU countries with incomes beyond 40k.

For level 4 countries converge in general to appliance ownership of countries with middle incomes, typical between 20 and 30k in the year 2014. This is a level of income that largely eliminates the monetary barrier of individuals buying an appliance. For the case of dishwashers, countries converge to 0.5 per household (the same of Italy at an income level of approximately 25k in 2014); computers to 1.3 (the same of Spain at an income level of approximately 22k in 2014); TV's to 1.1 (similar to the level of Slovenia at an income level of approximately 20k in 2014). For the case of washing machines, a convergence to 0.8 is assumed reflecting the levels found in Switzerland. Although Switzerland is classified as an affluent country, we take this level of washing machine penetration to show what is possible to achieve lower levels of appliance penetration via device sharing. Levels 2 to 3 are calculated as intermediate levels.

Table 10 – EU28+Switzerland levels for appliance ownership

Name / Unit	1	2	3	4
Number of washing machines per household [#]	1	0.9	0.85	0.8
Number of dishwashers per household [#]	0.7	0.65	0.55	0.5
Number of dryers per household [#]	0.45	0.43	0.42	0.4
Number of fridges per household [#]	1.1	1.05	1.02	1
Number of freezers per household [#]	0.8	0.7	0.6	0.5
Number of TV's per household [#]	1.4	1.3	1.2	1.1
Number of computers per household [#]	2.5	2.1	1.7	1.3
Number of phones per person [#]	1.5	1.2	1.1	1

Disaggregation by country

Countries converge to the average European value by 2050.

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5.3.4 Appliance use

5.3.4.1 Lever description

This lever controls the amount of yearly hours and appliance is used.

5.3.4.2 Rational for lever

In combination with the lever setting the number of appliances owned, this lever will allow the user to additionally evaluate the energy implications of a moderate use of appliances.

Current situation

Between 2002 and 2010, TV viewing decreased slightly in most of European countries among both boys and girls (exceptions are Greece and The Netherlands for girls and Greece for boys). The decrease was more than offset by a sharp increase in computer use (see Figure 13), which was consistent across all countries with boys reporting overall more hours of screen time (Bucksch et al., 2016).

Variable	Age	Weekdays					
		Year of survey			Trend		
		2002	2006	2010	2002/2006	2006/2010	2002/2010
Boys							
TV viewing	11	2.61	2.34	2.24	–	–	–
	13	2.83	2.60	2.38	–	–	–
	15	2.69	2.51	2.31	–	–	–
Nongaming computer use	11	n.a.	1.03	1.31	n.a.	+	n.a.
	13	n.a.	1.39	1.70	n.a.	+	n.a.
	15	n.a.	1.69	2.11	n.a.	+	n.a.
Computer use for gaming	11	n.a.	1.71	1.77	n.a.	+	n.a.
	13	n.a.	1.92	2.04	n.a.	+	n.a.
	15	n.a.	1.80	2.04	n.a.	+	n.a.
Computer use (combining gaming and nongaming purposes)	11	1.32	2.74	3.08	+	+	+
	13	1.55	3.31	3.74	+	+	+
	15	1.62	3.49	4.15	+	+	+
Total screen time	11	3.93	5.09	5.33	+	+	+
	13	4.38	5.92	6.13	+	+	+
	15	4.31	6.01	6.47	+	+	+
Girls							
TV viewing	11	2.36	2.21	2.08	–	–	–
	13	2.67	2.55	2.31	–	–	–
	15	2.48	2.39	2.21	–	–	–
Nongaming computer use	11	n.a.	.95	1.27	n.a.	+	n.a.
	13	n.a.	1.42	1.95	n.a.	+	n.a.
	15	n.a.	1.58	2.27	n.a.	+	n.a.
Computer use for gaming	11	n.a.	.93	1.05	n.a.	+	n.a.
	13	n.a.	.91	1.11	n.a.	+	n.a.
	15	n.a.	.67	.90	n.a.	+	n.a.
Computer use (combining gaming and nongaming purposes)	11	.73	1.88	2.32	+	+	+
	13	.85	2.33	3.06	+	+	+
	15	.79	2.25	3.17	+	+	+
Total screen time	11	3.09	4.10	4.41	+	+	+
	13	3.52	4.89	5.38	+	+	+
	15	3.27	4.65	5.38	+	+	+

Figure 13 - Trends in screen-time behaviors from 2002 to 2010 for all countries and regions combined by age and gender (mean hour per day). From Bucksch et al., 2016.

In terms of white appliances use that are not permanently in use (e.g, fridge), different regions in Europe exhibit different behaviors. While Scandinavia, Southern and Western Europe have higher penetrations of dishwashers that UK and Ireland, the usage per week is lower. Broadly while households in UK and Ireland use the dishwasher 5 times a week, the other regions use it about 4 times a week. Similar differences can be found in the habits of washing clothes. In Scandinavian countries average usage of 2.75 times a week while in Southern Europe an average use of 3.15 times a week is reported (see Figure 14).

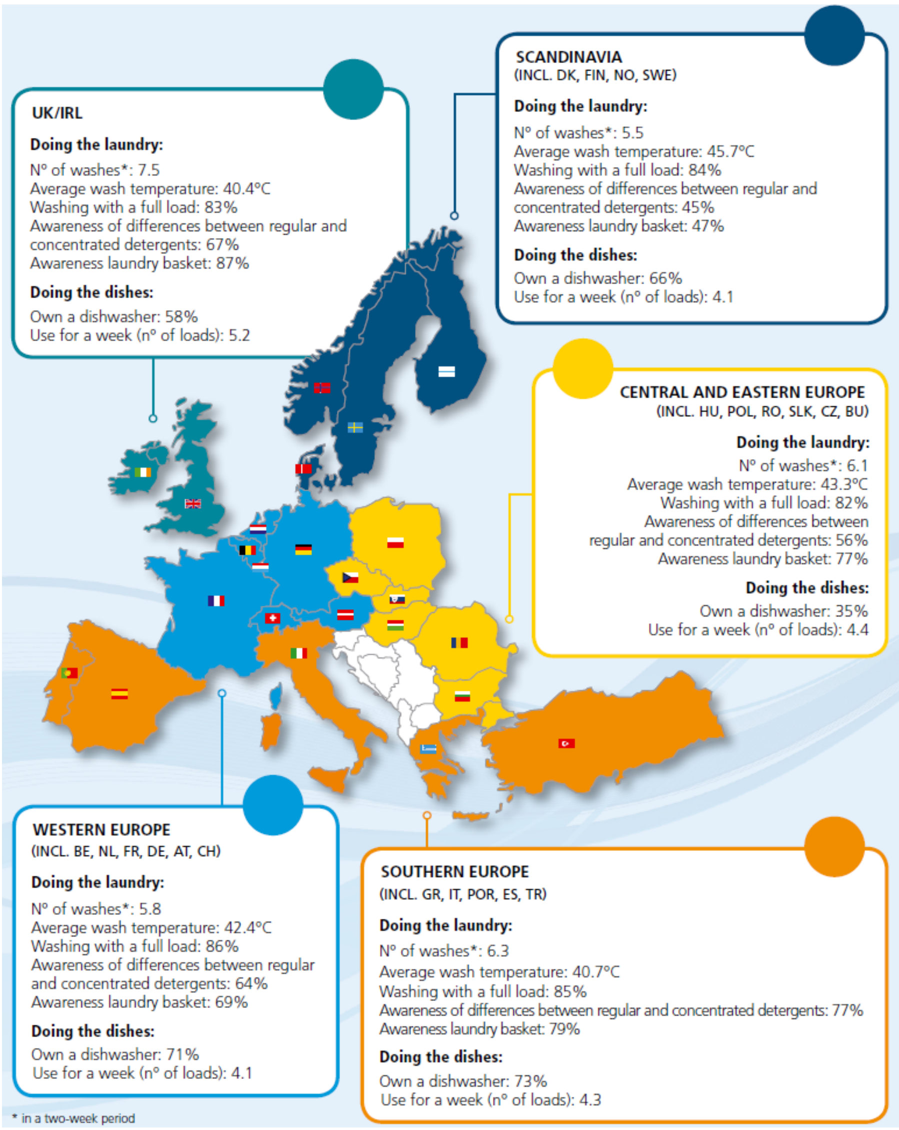

Figure 14 - Overview as to how washing and dishwashing habits differ across Europe. Source: PAN-EUROPEAN CONSUMER SURVEYON SUSTAINABILITY AND WASHING HABITS [SUMMARY OF FINDINGS, 2014]

Various scenarios for 2050

In the lack of concrete scenarios regarding the use of appliances, the Lifestyle module borrows from the reference targets of healthy screen time found in World Health Organization, 2019. For the other appliances the future scenarios are constructed to take into account the best current geographic practices in regard to appliance use.

Disaggregation methodology rational

No disaggregation method considered.

Feedback from the stakeholder consultations

This lever was not discussed with stakeholders.

5.3.4.3 Ambition levels and disaggregation method

EU-Levels

Level 4 for the use of computer and TV in households is equated to 2h of use per day combined (or 1h each). The World Health Organization (2019) recommendation suggests a maximum of total screen time of 1h for children less than 5 years of age. We extend this value to 1h of TV and computer each in order to encompass the entire population. Level 1 assumes a drop of 20% in viewing time for TV following past trends by 2050 and a rise in time spent in front of a computer by 50%, also reflecting the empirical trend in Bucksch et al., 2016. Levels 2 and 3 are constructed as intermediate scenarios. For dishwashers, driers and washing machines level 3 is equated to the operation time found in Scandinavian countries and taken from the Pan-European Consumer Survey PECS (2014) and level 4 a reduction of further 20%. Level 1 is assumed that countries increase in 10% their appliance use from the levels observed current. Level 2 is set as an intermediate scenario between level 1 and 3. Fridges and freezers maintain a 24h operation across lever settings.

Table 11 - EU28+Switzerland levels of appliance use

Name / Unit	1	2	3	4
Use of washing machine per household [h/day]	0.45	0.4	0.36	0.3
Use of dishwasher per household [h/day]	1	0.93	0.87	0.7
Use of dryer per household [h/day]	0.45	0.4	0.36	0.3
Use of fridge per household [h/day]	24	24	24	24
Use of freezer per household [h/day]	24	24	24	24
Use TV per household [h/day]	2	1.5	1.2	1
Use of computer per household [h/day]	4.3	3.2	2.2	1
Use of phone per person [h/day]	24	24	24	24

Disaggregation by country

Countries converge to the European level set by the lever by 2050.

5.3.4.4 Source references

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5.3.5 Floor use intensity

5.3.5.1 Lever description

This lever describes the amount of residential floor space per person and comes expressed as m2/cap. The energy and material needs of residential buildings are correlated with its size. A reduction on average floor space per person, all other things kept constant, leads to a reduction in carbon emissions.

5.3.5.2 Rationale for lever

The amount of floor space is a very common reference value to determine the energy use intensity of buildings. It is widely used in architecture and real estate economy. Independent of technology-dominant system used to heat buildings, the gross floor area shows a linear correlation (see Figure 15) with total energy consumption. This has been investigated for the case of British Columbia's low-rise and multi residential building stock (Finch et al., 2010).

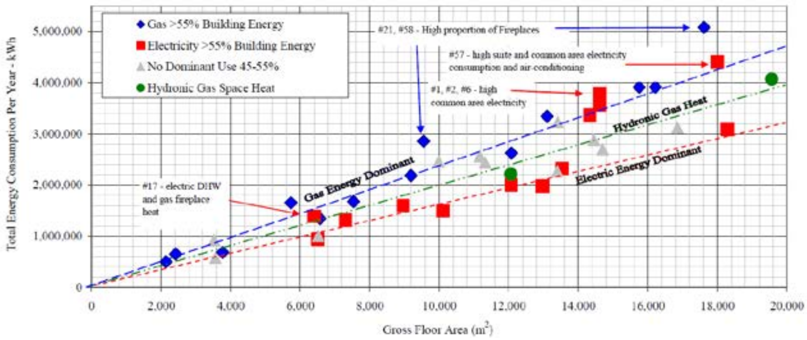

Figure 15 - Total Energy versus Gross Floor Area, Split between Gas and Electric Energy Dominated Buildings

A decrease in the intensity (that is, less floor space per person) would therefore yield reductions on the total amount of energy requirements for heating of buildings. Given that 50% of annual energy consumption [14] in buildings is associated with heating and cooling, this lever becomes an important determinant of emissions.

<u>Current situation</u>

In 2012 Eurostat placed the average size of a dwelling in the EU28 member states at circa 96m^2. The variability across member states was bounded between a maximum of 141.2m^2 in Cyprus and a minimum of 43.9m^2 in Romania. Demographic changes towards smaller household sizes and individual aspirations for more living space are suggested to push the average size of a dwelling upwards. In order to quantify this phenomenon, we gather data on the total floor area of dwellings from the ODYSSEE MURE database[15] and country population to determine per capita floor area of dwellings for EU28 Member states between the years 2000 and 2014. The evolution in time of the mean is characterized by an

[14] https://ec.europa.eu/energy/sites/ener/files/DG_Energy_Infographic_heatingandcolling2016.jpg

[15] http://www.odyssee-mure.eu/

increase from 36 to 45.5 m^2 between the years 2000 and 2014, see Figure 16 top panel.

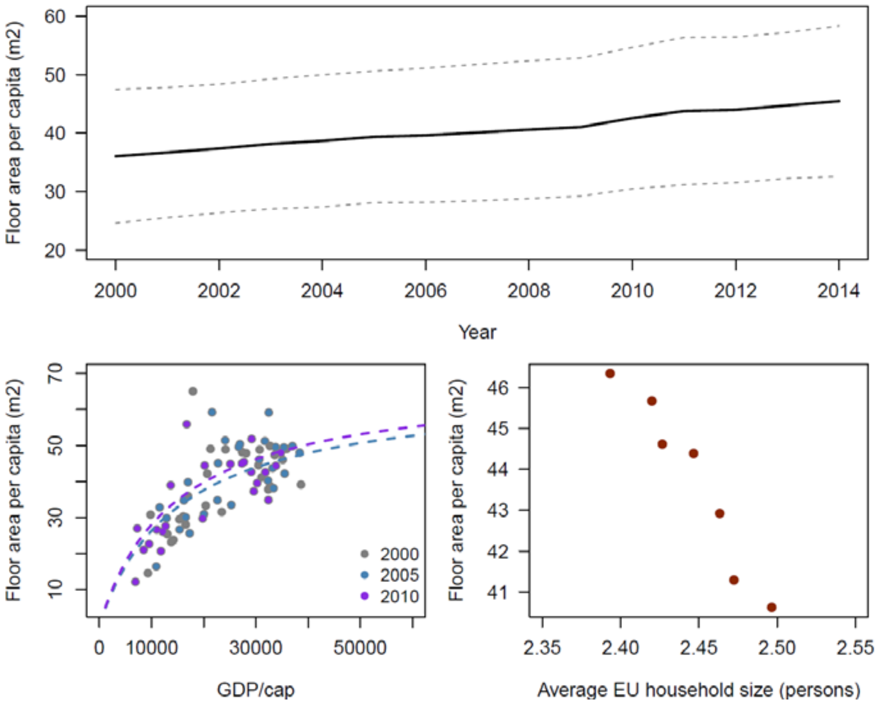

Figure 16 - Evolution of residential floor space per capita in EU countries between 2000 and 2014 (top panel), country-level GPD vs floor area/cap relation (bottom left panel) and EU-level household size vs floor area/cap (208-2014).

The evolution of per-capita floor area and income levels for European countries for the years 2000, 2005 and 2010 is shown in Figure 16 bottom left panel. It is observed that the relation between these two quantities is one of supra-linear growth until income levels of about 30k and of stabilization to sub-linear growth thereafter. From 2005 to 2010, the functional relationship between income level and floor are per capita has remained unchanged but the saturation level of floor are (that for income levels >30k) has moved upwards. Finally, at the European level, the average floor area per capita has also been observed to scale linearly with the size of the household (see Figure 16 bottom right panel).

<u>Various scenarios for 2050</u>

Güneralp et al., (2017) uses empirical multiple linear regression models to predict residential area using a panel dataset for 32 regions in 1990 and 2000. Explanatory variables used are GDP per capita and urban population density. Using the fitted parameter values of the regression model, three scenarios of low, medium and high residential floor area per capita are determined by 2050 for each region urban population density change rate and GDP/cap from the forecasts exercises (Clarke et al., 2007, UNPD 2013). When measured as percentage change between 2015 and 2050, the results of the exercise deliver a generalized increase in floor area ranging between 10 to 15% for Central and Eastern Europe and between 13 and 20% for Western Europe, see Figure 17.

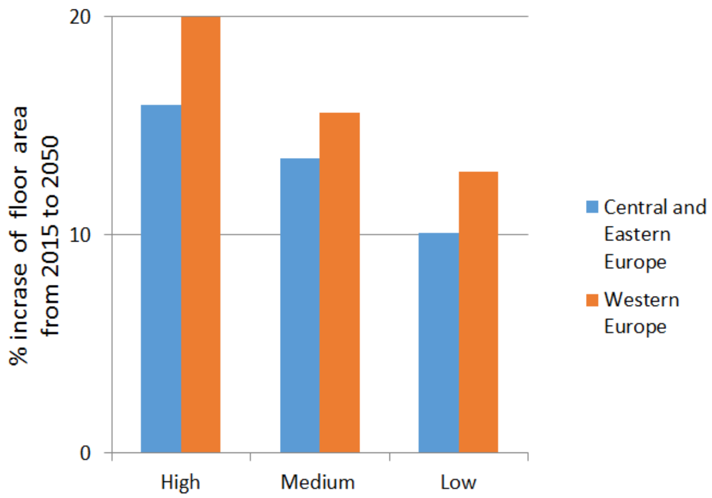

Figure 17 - Percentage increase of total floor area for Central and Eastern Europe and Western Europe between 2050 and 2015 taken from Dataset S1 in Güneralp et al., (2017).

Disaggregation methodology rational

The non-linear relationship between GDP and floor area per capita observed for the past is used to disaggregate the future floor intensity values for each country. The 2005 and 2010 fits of per capita floor area in Figure 16 bottom left panel are obtained via the function *a*GDP/(b+GDP)*, in which GDP is the country-specific GDP per capita; *a* is the asymptotical maximum of the function and *b* the speed to which per capita floor area converges to the maximum. The maximum is then manipulated so that the average EU floor area per capita matches that of the ambition levels. The countries then converge to the EU level following the past income-floor area trajectory. Accordingly, countries with relative lower incomes raise their per-capita floor area proportionally faster than those with higher incomes.

Feedback from the stakeholder consultations

During the stakeholder consultation the interest of including a lever changing the preferences for smaller living spaces was fully supported. In deed it was pointed out that "Square meters matter. We are still in favor of single standing houses with a room for every person, each with all the electric equipment possible. Results from efficiency pathways show that it is very unlikely that we will reach EU efficiency targets through efficiency gains alone". Indeed it was pointed out that in successful experiments systematically reduce surface area per capita such as vertical cities with small private units and plenty of common space already exist, for example in Cologne. The tiny house movement is also an example of sufficiency and de-growth. Housing cooperatives invest/crowdfund to buy and renovate space so that people can live a different lifestyle in a more collective and communal way.

5.3.5.3 Ambition levels and disaggregation method

EU-Levels

Given that the scenario in Güneralp et al., (2017) reflects the current observed trends and dependencies of floor area with income and urbanization dynamics, the projections are taken as reference to establish ambition Level 1. Accordingly, floor are in Europe is to increase by 20%, which would imply a 2050 floor space per capita of about 55m2 (currently 45.5m2, see Figure 16).

Level 4 should represent a transformational change towards sustainability. In regard to floor area per capita (all things kept the same) such transformational should be to achieve hard to conceive values from today's cultural standpoint but that are common in other places of the world. For example, in Korea, an affluent country with living standards on par with rich European countries, the minimum standard for living space is 12 m^2 for one person (Rao and Min 2018). Showing that in some geographic contexts a very low floor-space per person is possible, even when the country is affluent.

In a European context previous literature pointed for a target value of 20m^2 per capita, see Mont et al., (2014). This level has been proposed as indicative of a sustainable lifestyle and taken also in Del 4.1[16] of the SPREAD[17] Sustainable Lifestyles 2050 (a 7th Framework project.) Romania, with a 2014 floor space of 18 m^2/person, is the European country closest to the 20m^2 per capita proposed in the literature. We assume that such radical transformation would not be feasible in Europe in the sense that would imply to more than half the current per capita average of floor space. Accordingly, we align level 4 to Rao and Min (2018) suggest the value of 37 m^2/cap (that of China's average home size in urban areas) as the benchmark for decent living in affluent countries. In the same study, the floor area value is justified to be compatible with the current demographic trends in Europe towards small families. Levels 2 and 3 are intermediate levels between level 4 and level 1.

Table 12 - EU28+Switzerland levels of residential floor use

Name / Unit	1	2	3	4
Floor intensity (m2/cap)	55	50	43	37

Disaggregation methodology rational

Rich countries maintain their relative distance to the mean as in the year 2014. Countries that are currently below the average are allowed to converge faster than the average for levels 1, 2 and 3. For level 4 all countries converge to the European average.

16 www.sustainable-lifestyles.eu/fileadmin/images/content/D4.1_FourFutureScenarios.pdf

17 https://www.sustainable-lifestyles.eu/

5.3.5.4 Source references

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5.3.6 Share of residential floor cooled

5.3.6.1 Lever description

This lever determines the fraction of the residential floor space described in section 5.3.5 is subjected to cooling.

5.3.6.2 Rational for lever

For large parts of Europe and increases in cooling energy demand due to global warming is said to outweigh the expected reductions in energy for heating. Depending on the generation mix in particular countries, the net effect on CO_2 emissions may be an increase even where overall demand for delivered energy is reduced (Aebischer et al., 2007).

<u>Current situation</u>

Currently, that is for the year 2015, the amount of cooled area as share of a country's total residential area varies between values of more than 50% in Malta and Cyprus to less than 0.5% in countries such as Finland or Germany (see Figure 18 left panel). The variation reflects the main driving variable for cooled floor area is climatic although it is also noted that income levels to play a role.

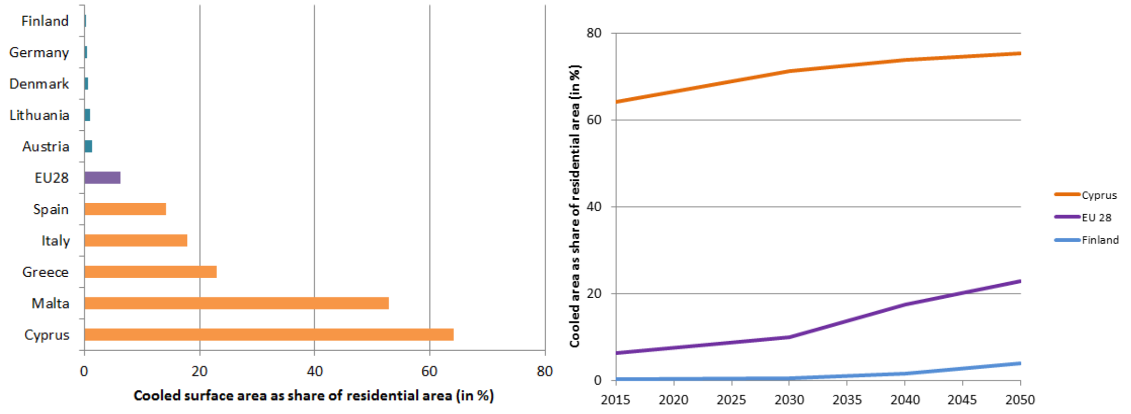

Figure 18 - Surface cooled area as share of total residential are in selected countries for the year 2015 (left panel) and projections until 2050 (right panel). Source: Space Cooling Technology in Europe, Technology Data and Demand Modelling. Deliverable 3.2: Cooling technology datasheets in the 14 MSs in the EU28

Various scenarios for 2050

The Lifestyle module makes use of the scenarios until the year 2050 developed in the context of the Heat Roadmap Europe[18] project, regarding the penetration of cooled floor area (Heat Roadmap Europe 2016). Deliverable 3.2 of the Heat roadmap project archives this relating % of residential cooled area as a function of CDD (cooling degree days) and income for Europe. It is also assumed that the limit to penetration (about 80% of residential floor area) is only limited by climate and not by income (Heat Roadmap Europe 2016). Under the assumption of RCP 4.5, shares of cooled are in Europe are estimated to grow from 6.3% to circa 23%. For countries that are currently located in relative cold climates, the increase in cooled area is expected to be dramatic. Finland is estimated to see its share of cooled surface area in residential buildings increase by a factor of 10 to about 4% of the residential floor area.

Given the inertia of the climate system, a certain degree of warming is unavoidable until 2050 even in the case of stringent mitigation efforts. Accordingly, no scenario in which the share of cooled are is reduced or even maintained constant is considered. This is justified by two evidences. The first is that countries are expected to continue becoming more affluent and hence the financial burden of acquiring new cooling systems is progressively lowered. Secondly the fraction of elderly population in Europe, who are disproportionately affected by heat impacts (Hajat et al., 2007), is expected to increase pretty much independently of the demographic scenario considered. When combined, these robust trends are expected to drive the increase of cooled surface area in Europe.

[18] https://heatroadmap.eu/

Disaggregation methodology rational

The disaggregation follows the differences between countries implied in the projections of % of cooled area for residential buildings proposed in Heat Roadmaps 2016.

Feedback from the stakeholder consultations

This lever was previously presented as number of AC appliances per household. In the development of the project it was discussed with the Buildings module it was decided to use the share of residential area subjected to cooling.

5.3.6.3 Ambition levels and disaggregation method

EU-Levels

Ambition Level 1 is equated to the shares of cooled area developed in Heat Roadmap Europe 2016. Level 4 of ambition reflects a scenario in which the rise in which the rise of cooled area follows the average developments of population aging in accommodate the growing fraction of vulnerable population. In average the population share the elderly in the total population of the EU-28 is projected to increase from 19.2 % at the start of 2016 to 29.1 % by 2080. This implies that the share of the elderly is projected to rise by about 10%[19]. In order to reflect the fact that the projections of the EUCalc model only run until 2050, level 4 bounds the increase of cooled area to 8% of the total residential. Levels 2 and 3 are constructed as intermediate scenarios.

Table 13 - EU28+Switzerland levels of residential floor area fraction cooled

Name / Unit	1	2	3	4
Share of residential area cooled (%)	21.8	15.1	12.3	5.5

Disaggregation by country

The disaggregation follows the differences between countries implied in the projections of % of cooled area for residential buildings proposed in Heat Roadmaps 2016.

5.3.6.4 Source references

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Heat Roadmap Europe 2016, Space Cooling Technology in Europe, Technology Data and Demand Modelling. Deliverable 3.2: Cooling technology datasheets in the 14 MSs in the EU28

[19] https://bit.ly/2ElmGWB

5.3.7 Comfort temperature

5.3.7.1 Lever description

This level describes to what temperature the inhabitant of a building sets the room temperature.

5.3.7.2 Rational for lever

The inclusion of this lever introduces the cooling behavior aspect in the Lifestyle module complementing the levers on floor intensity and growing shares of cooled area. Hoyt *et al.,* (2005) explored a simulation model of air-conditioning systems and reviewed case studies that suggest energy savings of 7-15% per each degree of increase or decrease temperature. Furthermore, the inclusion of this lever will allow the user to investigate the relative energy implications between this lever and those controlling the floor use intensity and the share of residential area subjected to cooling.

Current situation

Current apparent comfort temperature range from 14 °C in central Europe to 25 °C in southern Spain, and they are significantly higher than annual mean apparent temperatures (Ballester et al., 2011).

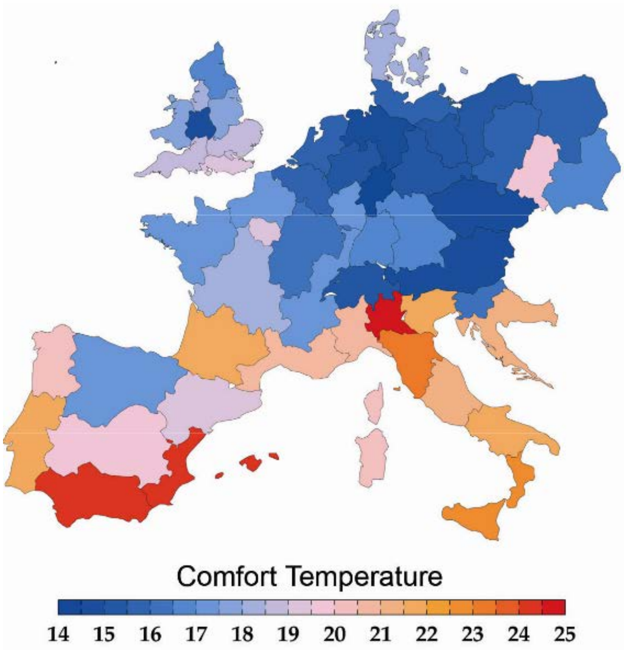

Figure 19 - Observed comfort temperatures in °C for the 1998-2003 time frame.

In addition to the geographic differences regarding comfort temperature there are also gender differences. A meta-analysis of scientific studies indicates that women “are more sensitive to deviations from an optimal thermal environment, and less satisfied than men, especially in cooler conditions” and thus women have a higher need for individual temperature controls (Karjalainen 2012). This has two implications for heating/cooling energy saving initiatives. First, in terms of data on energy saving behaviour data needs to be collected at an individual and not a household level. Second, when designing homes with fixed temperatures, or low adaptability, gendered differences need to be considered.

Various scenarios for 2050

We could not source scenarios regarding the evolution of comfort temperatures.

Disaggregation methodology rational

The different scenarios of European change are translated directly to the country level by removing the assumed European change to the country's current comfort temperatures.

Feedback from the stakeholder consultations

This lever was not presented at the stakeholder consultation.

5.3.7.3 Ambition levels and disaggregation method

EU-Levels

Level 4 is assumed to be that in which dwellers set their room temperatures to that equivalent to the conform temperature determined in Ballester et al., 2011 at the country level. The estimates of comfort temperature in Ballester et al., 2011 are determined empirically using mortality data at NUTS2 level between 1998 and 2003, and refer to the temperature at which the cases of excess mortality due to heat are at the lowest. At the European level the comfort temperature was set at about 20ºC of mean daily temperature. Levels 3 to 1 are sequential reductions/increases from most ambitious level. This reflects incremental scenarios in which the inhabitants of dwellings cool/heat their rooms further/lower than the comfort temperature.

Table 14 - EU28+Switzerland levels of comfort temperature

Name / Unit	1	2	3	4
Comfort temperature cold	18	19	19.5	20
Comfort temperature heat	20	21	21.1	22

Disaggregation by country

The different scenarios of European change are translated directly to the country level by removing the assumed European change to the country's current comfort temperatures.

5.3.7.4 Source references

Ballester, J., Robine, J.M., Herrmann, F.R. and Rodó, X., 2011. Long-term projections and acclimatization scenarios of temperature-related mortality in Europe. *Nature Communications*, *2*, p.358.

Karjalainen, S. “Thermal Comfort and Gender: A Literature Review.” Indoor Air, vol. 22, no. 2, Apr. 2012, p. 96-109.

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5.3.8 Product replacement rate

5.3.8.1 Lever description

This lever controls the amount of time a consumer wishes to extend the use of appliances she or he owns beyond their usual lifetime.

5.3.8.2 Rational for lever

Traditionally, much more attention has been placed on the amount of energy used by product than the amount of energy it took to produce it. But not all appliances are created equal. White appliances, including refrigerators, clothes washers, and dishwashers, require a significant amount of energy to produce but their overall (full life cycle) energy expenditure takes place during operation. Manufacturing accounts for about 4 to 12% of the total lifetime energy use; see Figure 20 from Gonzalez et al., 2012.

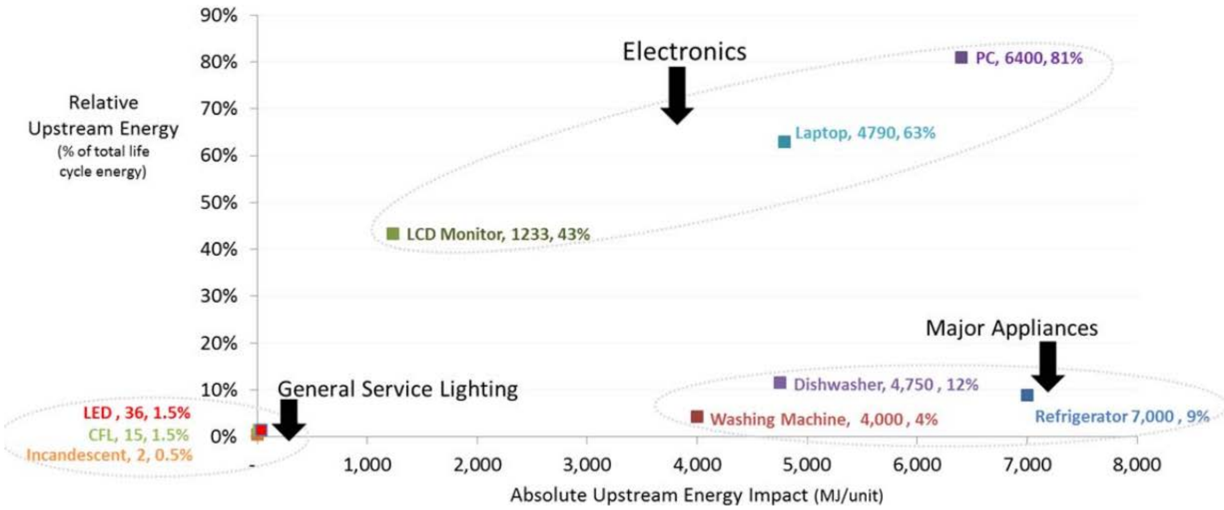

Figure 20 - Upstream energy impacts by category of appliances. Source: Energy Solutions analysis adapted from Deng, Babbit, and Williams (2011); Kirchain et al., (2011); Boustani, Sahni, and Gutowski (2010); OSRAM (2009)

On the other hand, products with shorter useful lives as well as those with semiconductor manufacturing (e.g., electronics) tend to have much higher relative embedded energy and GHG emissions contribution compared to products with motors, pumps, or compressors (Weber 2011). Products such as computers have a higher proportion of their overall energy use tied to their production in the range of 40 to 80% of their total life cycle energy use. Wang *et al.,* (2011) show with a dynamic model that energy savings with extended lifetime of electronics could be profitable and also reduce energy demand at use. Guvendik (2014) performed an LCA of the fairphone and showed how material and energy savings are dependent on the years of extended use and the components that need to be replaced.

Women in Sweden tend to buy “basic essentials in the form of less expensive but recurring consumer goods for the whole family, such as food, clothing and household articles, while [men] are more likely to buy expensive capital goods and own things like homes, cars and home electronics.” (Johnsson-Latham 2007:38). According to OECD findings, setting women’s behavior and consumption patterns as the norm would lead to an overall smaller impact on the environment and promote sustainable patterns that would be beneficial for economy and society (OECD 2008a).

Current situation

Building on a data-rich case of was of waste flows in Electrical and Electronic Equipment (EEE) of the Netherlands, Huisman et al., (2012) concluded that basically all appliances investigated shown decreasing residence times of equipment putted in the marked in 2000 versus that introduced in 2010.

Table 15 - Shorter lifespans of Electrical and Electronic Equipment (EEE)

Equipment	Residence time (2000 vs 2010)
Screens	17%
IT	10%
Small tools	12%
Dishwashers, oven and drier	7%
Freezers and fridge’s	4%

A similar conclusion regarding the increasing frequency of product replacement was reached by Prakash et al., 2016 (in German). The study acknowledges that there are material, functional, psychological and economic obsolescence considerations driving the replacement of products but that in general useful service life of most of the analysed product groups has decreased over the last years. In particular that an increasing shares of appliances are replaced or disposed of before they reach an average first useful service life or age of 5 years (Prakash et al., 2016).

Various scenarios for 2050

Consistent and quantitative scenarios of product replacement rates for the future were not found within the scope of the appliances considered (see section 5.3.3). It was assumed therefore that one plausible scenario is the prolongation of the trend regarding shorter residence time of appliances noted in the studies referenced above until 2050. This is also supported by Hischier et al., (2005), who reported that the annual growth of E-waste (a proxy for discarded appliances) in Europe is increasing at a rate of 3–5%, compared to an average (2005–2008).

Studies on products such as notebooks show that a long-lasting appliance is generally more eco-friendly – despite advances in energy efficiency. Even if the new notebook uses around 10 per cent less energy than the old one, it would have to remain in service for around 80 years in order to compensate for the energy consumed in its manufacture (Oeko-Institut, 2018). From an environmental perspective, it also makes sense to keep other electronic devices, such as TVs and smartphones, in service for as long as possible (Oeko-Institut, 2018). Quantitative estimates show that technically, it could be possible to reduce the purchase frequency of new appliances by 30% (i.e. instead of buying a new TV every 3 years, buy every 4.3 years (Moran et al., 2018, based on (Robinson, 2009)).

Disaggregation methodology rational

There is no disaggregation rational applied in this lever. The current and future state of the technical lifetime of appliances is determined in the Buildings and Technology matrix modules. The lever proposed informs on extending or shortening the technical lifetime of the appliance. It is assumed that this is not conditional to a particular country in the same measure that the availability of technologies in countries is not constrained in the technology matrix.

Feedback from the stakeholder consultations

This lever was not presented during the consultation workshop and emerged from internal discussions within the project regarding the need to allow users to see the effect of conscious purchasing decisions.

5.3.8.3 Ambition levels and disaggregation method

EU-Levels

In ambition level 1 the replacement of appliances follows the evidence of shorter residence times suggested in and Prakash et al., (2016) and Huisman et al., (2012). This means that for example for fridges and freezers a decrease in residence time of 4% is assumed which in turn is equated to the lifetime of the appliance in the technology matrix to be reduced to 96% of its technical lifetime. For TV's and IT the decrease in technical lifetime is equated to 83 and 90% respectively. Regarding level 4, a reduction of purchase frequency of new appliances by 30% proposed in Moran et al., (2018) is achieved for IT, and TV's. This reduction was the most ambition level we found in the literature.

For the other appliances level 4 ambition is reduced to 10% in order to avoid rebound effects of potentially old appliances with low energy standards in service. In level 2 it is assumed that households or individuals only replace their appliances once these reach their technical lifetime. Level 3 is an intermediate level between 2 and 4.

Table 16 - EU28+Switzerland levels for product replacement rate lever

Name / Unit	1	2	3	4
Replacement of washing machines [factor]	96	100	105	110
Replacement of dishwashers per household [factor]	93	100	105	110

Replacement of dryers per household [factor]	93	100	105	110
Replacement of fridges per household [factor]	96	100	105	110
Replacement of freezers per household [factor]	96	100	105	110
Replacement of TV's per household [factor]	83	100	115	130
Replacement of computers per household [factor]	90	100	115	130
Replacement of phones per person [factor]	90	100	115	130

Disaggregation by country

There is no disaggregation rational applied in this lever.

Feedback from the stakeholder consultations

This lever was not presented during the consultation workshop and emerged from internal discussions within the project.

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5.3.9 Passenger travel distance

5.3.9.1 Lever description

This lever describes the amount of yearly passenger travel per capita in each country and expressed in pkm/cap. A reduction on passenger travel, all other things kept constant, leads to a reduction in carbon emissions.

5.3.9.2 Rationale for lever

The transport sector represents circa 33% of primary energy needs in Europe in 2015 [20] and contributed 25.8% of total EU-28 greenhouse gas emissions in 2015[21]. Without aggressive and sustained mitigation policies being implemented, transport emissions could increase at a faster rate than emissions from the other energy end-use sectors and reach around 12 Gt CO2eq/year by 2050 (Sims et al., 2014). On the other hand, the transport sector is recognized as particularly difficult to decarbonize given the investment costs needed to build low-emissions transport systems, the slow turnover of stock and infrastructure, and the limited impact of a carbon price on petroleum fuels already heavily taxed (Sims et al., 2014). Accordingly, a shift towards demand-side solutions for mitigating climate change is now gaining traction (Creutzig et al., 2018).

<u>Current situation</u>

Passenger travel distance in EU28+Switzerland (given in pkm/year/person), has increased from about 9000 in 1995 to about 11200 in the year 2014; an annual growth of 1.3%, see Figure 21). Although traffic congestion and the alternatives offered by public transport, walking and cycling are contributing to a saturation of passenger road transport (Focas et al., 2016), as city-centre congestion increases, people are willing to pay more for space and amenities, so they travel

[20] https://ec.europa.eu/eurostat/statistics-explained/index.php/Consumption_of_energy

[21] https://www.eea.europa.eu/data-and-maps/indicators/transport-emissions-of-greenhouse-gases/transport-emissions-of-greenhouse-gases-10

farther to live where land is less expensive and home-based movement easier (Gwilliam, 2002).

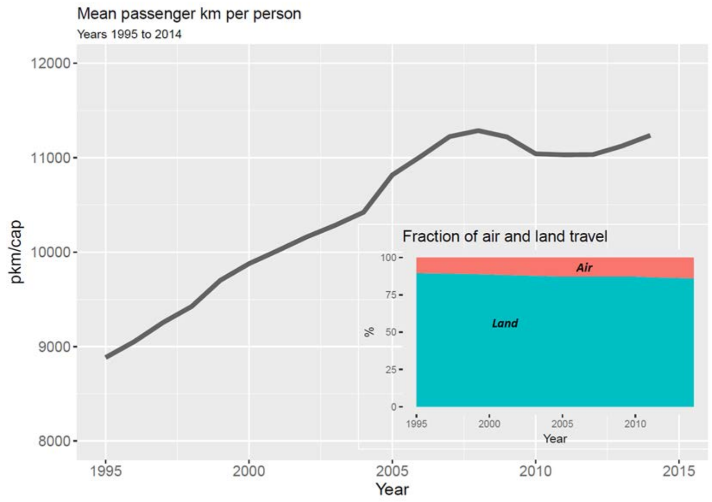

Figure 21 - Average pkm/cap (total travel) in the EU28+Switzerland (1995-2014). Fraction of air and land pkm (inset). Data: EU Transport Figures, Statistical pocketbook 2016.

Importantly, the rise of air passenger transport is pushing total volumes of passenger km's traveled. In the EU28, air passenger transport increased by 37% between 2000 and 2014, a 2% year on year increase (Statistical Pocketbook, 2016). Furthermore, air traffic is projected to grow in the long-term, driven by global GDP growth and pkm are forecast to grow over the period 2016 - 2035 at a rate of 4.5 to 4.8 % pa (DGMOVE, 2017).

Various scenarios for 2050

Transport activity shows significant growth, with the highest increase during 2010-2030, driven by developments in economic activity (Capros et al., 2016). Average european pkm/cap values for the totality of passenger transport (including road, rail, air and water) are suggested to be of circa 17000 by 2050 mostly driven by rise of passenger activity in the aviation sector (Capros et al., 2016). Slightly higher growth is proposed by Petersen et al., 2009. In a scenario of average economic growth of 2% in Europe the study proposes an average EU-wide value of pkm/cap in the order of 17900 by 2030. In a comprehensive review of over 20 transport scenarios by 2050, Skinner et al., 2010 points that projected passenger demand was found to increase by up to 200% in total and possibly more. If no actions are taken then there will be little decoupling between demand and emissions. In addition, more than half of the vision scenarios assume that technology improves faster than demand increases, resulting a net emission decrease. Scenarios of demand seem biased towards relying on technology improvements to curb emissions.

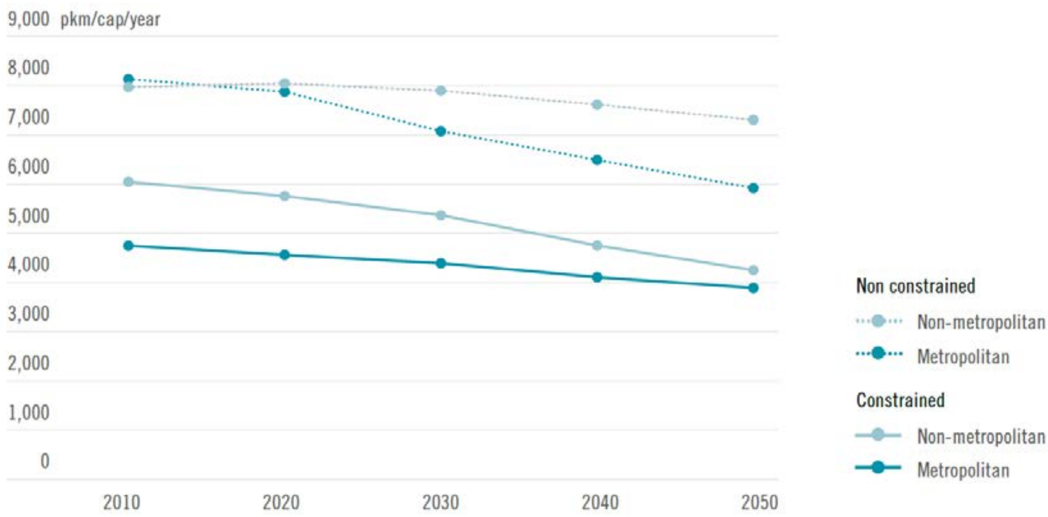

Figure 22 - Annual individual distance travelled for constrained and non-constrained mobility from Briand et al., 2017.

Scenarios proposing a net reduction in passenger demand by 2050 exist but are rare. A deed decarbonisation scenario of the transport sector developed for France (Briand et al., 2017) suggests a future of in which people will aim to reduce their constrained mobility. This is brought about infrastructural but also lifestyle change like that of teleworking affecting a large part of employees in 2050 of one day per week and that e-commerce could replace the need for one third of shopping trips to hypermarkets. For France, these changes result in a reduction of travel demand in the order of 27% for both metropolitan and non-metropolitan areas (see Figure 22). For France this would translate into an 8% reduction in total mobility, from 840 Gpkm to 772 Gpkm, due to a 19% reduction in mobility demand.

The International Transport Forum recently found that “gender is a more robust determinant of mode choice than age or income” (Ng & Acker 2018). This shows that travel behaviour is deeply gendered and that travel choice is not made in social vacuum. Swedish research shows that if travel behaviour of women was the norm, climate goals for the transport sector could be met (Kronsell 2016). Challenging prevailing gender norms therefore does not only foster gender equality but also sustainability, thus offering a low-cost readily available approach for CO_2 reduction. In the EUCalc model the choice of transport mode is carried on in the Transport module. In the lifestyles module only the total amount of travel distance is calculated.

<u>Disaggregation methodology rational</u>

Passenger transport demand is mediated by the amount of daily time dedicated to travel and the average daily speed (Schäfer et al., 2019). From a lifestyle perspective, the daily travel time is dominated by the time spent on traveling to/from work or study; traveling for leisure; and travelling for shopping and access to services (see Figure 23, left panel).

Our empirical analysis revealed that only travel time dedicated to leisure was found to be sensitive to changes in GDP/cap (see Figure 23, right panel) and that the other activities have no significant correlations with income. Level 1 on passenger travel distance reflects this finding by preserving the statistical link between travel time for leisure activities and income for all countries until 2050. The amount s of travel for work/study and shopping and access to services is kept constant to present values. The average speed is left constant between 2015 and 2050, meaning in practice that future travel demand is driven by changes in travel time alone.

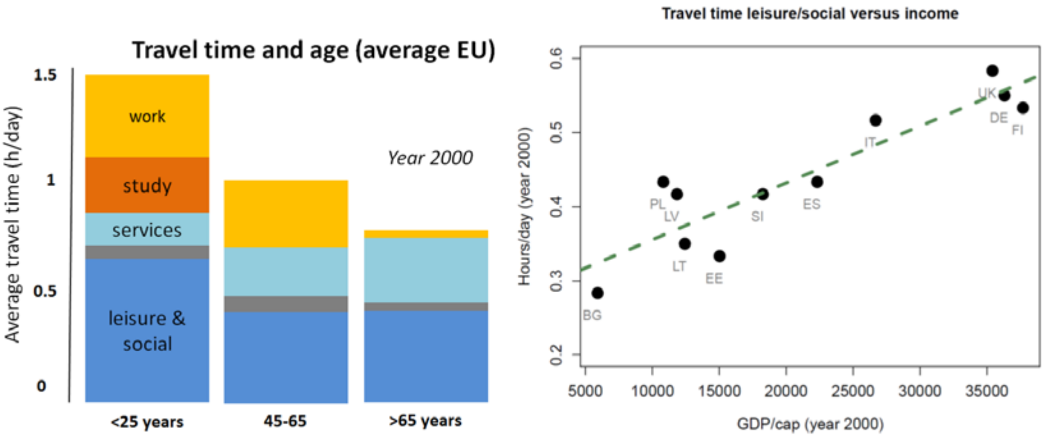

Figure 23 – Travel-time by activity and age for European countries (felt panel, Eurostat 2003), Linear correlation between travel time for leisure/social activities and GDP for the year 2000 (right panel, Eurostat 2003).

<u>Feedback from the stakeholder consultation</u>

During the consultation workshop it was proposed to split both the passenger and the freight modules into urban and rural transport so as to be much more refined in terms of the potential for modal shift or even reducing transport demand. It was also suggested to better reflect non-motorized transport, particularly in terms of the urban context where bikes have the potential to both reduce GHG emissions but also to increase the quality of life in urban centres, see also Del 2.3. In order to account for these suggestions the total travel demand obtained for each country from the disaggregation procedure explained beforehand is decomposed into three sub-components, namely:

- Air passenger travel demand that cannot be shiftable to land (assumed that the demand for air trips superior to 1000km).
- Passenger travel demand taking place within urban areas.
- Non-urban passenger travel demand; defined at the difference between the total travel demand and the sum of the non-shiftable and urban travel demand.

The schematic calculations of passenger travel distance in the Lifestyle module is presented in Figure 6. The starting point for the three-way split is the total passenger travel distance obtained by the multiplication of each ambition lever with a population projection. Using past observations of % of urban population and % on non-urban distance total travel a linear function is derived (see Section 6 for the estimated parameters).

In the lifestyle module this function uses the ABCD lever specification of % of urban population to estimate the % of non-urban travel. This fraction is multiplied with the previously estimated total passenger travel in order to obtain the non-urban travel distance to be passed on to the transportation module. Non-urban travel distance is then subtracted from the total passenger travel. The amount of travel distance remaining from this procedure is finally disaggregated between that taking place within the urban areas and that that cannot be shifted. This is done by using the observed proportion of non-shiftable travel distance in urban travel distance in total urban travel distance in the year 2010 (the last year we had observation for).

5.3.9.3 Ambition levels and disaggregation method

EU-Levels

In Level 1 travel time for leisure is set to converge by 2050 to levels of 0.7 hours/day, a level slightly higher than that of current affluent EU. The time spent for work/study and for access to services remains constant to year 2000 values (approximately 0.3 and 0.2 h/day). Average travel speeds remain constant for all the levers settings to 2014 values. Under this assumption average passenger travel distance in EU28+Switzerland reaches circa 15120 pkm per person per year, a 21.3% increase from 2015 levels.

For level 3, current travel time dedicated for leisure is equal to that of level 1 and by 2050 travel spent on travelling to work/study drops by 25% from current values. This reflects the situation in the Czech Republic where 15% of the working population (the driving force behind travel for work) is involved in telework at least “a quarter of the time” or more (International Labour Office, 2016). Time spent for shopping and access to services is reduced by 20%, reflecting the reductions of time spend traveling for shopping in England (Francke & Visser 2015). As results, by 2050, average passenger travel distance in EU28+Switzerland reaches 13714 pkm per person, a 10% increase from 2015 levels. In Level 4 the travel time for leisure activities leisure is equal to that of level 1. Time spent on travelling to work/study is reduced by 50% reflecting the opportunities of full teleworking potential and a doubling of the situation of level 3. Time spent for shopping and services is reduced by 40%, a doubling of the situation in level3. As result, by 2050, average passenger travel distance EU28+Switzerland reaches 12254 pkm per person, a 1.7 % decrease from 2015. Level 2 is set as an intermediate level between level 1 and 3.

Table 17 - EU28+Switzerland levels for the passenger transport demand lever

Name / Unit	1	2	3	4
Passenger travel distance (pkm/cap)	15120	14424	13714	12254

Disaggregation by country

In level 1 country evolve in accordance with their individual growth in travel time allocated to leisure. In levels 2 to 4 countries converge from their current position to the distance implied in the reductions of travel time.

5.3.9.4 Source references

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5.3.10 Calorie requirements

5.3.10.1 Lever description

This lever describes the amount of daily calories demand for an individual to maintain its metabolic rates and comes expressed in kcal/cap/day. An overall reduction in daily calories, all other things kept constant, leads to a reduction in carbon emissions from the agricultural sector.

5.3.10.2 Rationale for lever

Global demand for agricultural crops is increasing, and may continue to do so for decades, propelled by a 2.3 billion person increase in global population and greater per capita incomes anticipated through mid-century (Tilman et al., 2011). Income growth and human development, particularly in low- and middle-income countries, is suggested to accelerate dietary transitions towards high and very high caloric intake (Pradhan et al., 2013). This prospect will put more pressure in already strained agricultural systems and potentially lead to an increase of emissions in the agricultural sector. Tubiello et al., 2014, estimates that greenhouse gas emissions from agriculture, forestry and fisheries have nearly doubled over the past fifty years and could increase an additional 30 percent by 2050, without greater efforts to reduce them. These efforts should be made both on the side of making agriculture production more efficient but also on the demand side.

Over the last 50 years food surplus - the amount of calories in excess of the theoretical food requirements for the population - grew from 310 to 510 kcal/cap/day. Similarly, GHG emissions related to the food surplus increased from 130 Mt CO2eq/yr to 530 Mt CO2eq/yr, an increase of more than 300% (Hiç et al., 2017). In case of increasing stagnation of agricultural-systems efficiency in delivering more food per ton of CO2, a reduction (particularly in the rich world) of food demand is a viable option to reduce GHG emissions. For example, studies have shown that eating less food in general could lower GHG emissions by reducing food demand, which could be lowered by up to 20% in some countries (Vieux *et al.,* 2012).

<u>Current situation</u>

Current (2013) average calories available in Europe stands at and average of 3316 kcal/cap/day (see Figure 24), an increase from 3281 Kcal/cap/day in the year 1990. The distribution of calorie availability in the EU+Switzerland is heterogeneous. It ranges between countries with typical calorie availability in the neighbourhood of 3200 Kcal (e.g., Sweden) to countries with 3600 Kcal/cap/day (e.g., Ireland). Most of the countries (~ 60%) are characterized by calorie availability of in the range between 3200 and 3600 Kcal/cap/day.

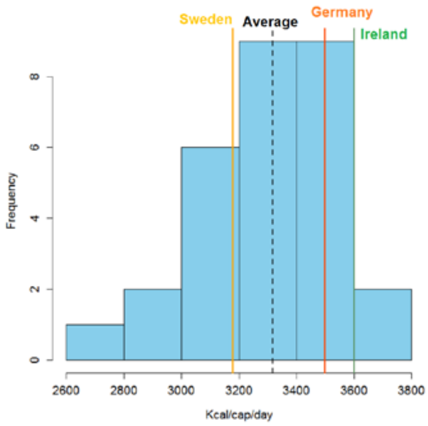

Figure 24 - Distribution of calorie demand in kcal/cap/day for EU28+Switzerland in the year 2013. Data source: Grand total item in FAO food balance sheets.

Various scenarios for 2050

Bruinsma 2012, estimated and increase for European union of food demand in the order of 3531 Kcal/cap/day in 2030 and 3572 by 2050, a shy increase of circa 6% over today's (see above) demand. Bodirsky et al., 2015 and Kruse 2010 deliver projections for Europe that are somehow higher. For 2030 and 2050 Bodirsky et al., 2015 suggests respectively and increase of calorie demand for Europe of 3704 and 3808 Kcal/cap/day. Values in Kruse 2010 for the same time periods are respectively 3833 and 3917 Kcal/cap/day. A common trait in demand scenarios is the use of income as leading explanatory variable. Accordingly, the values reported in Bodirsky et al., 2015 refer to a world in which countries follow a income trajectory implied by the B2 scenario of the 2005 IPCC Special Report on Emissions Scenarios (SRES) (Nakicenovic et al., 2000).

It is important to refer that while the exercises above are often characterized of food demand scenarios, in reality they should be better understood as calorie availability scenarios. The reason for such is that the proxy used to estimate food availability is in reality the amount of calories available at the market place within one country. To these calories it is necessary to subtract those lost in waste at the household level and those incurred in the transport and distribution of the calories.

Furthermore, in the Lifestyle module we are interested in investigating how lifestyle changes can affect the amount of calories consumed. This cannot be done by using the traditional numbers of "food demand" because they hide mask aspects such as body weight of the population as well as their physical activity levels. Accordingly, the estimates of calorie requirements in the Lifestyle module are based in bottom-up projections of Basal Metabolic Rates[22], Body Mass

[22] Basal metabolic rate (BMR) is the rate of energy expenditure per unit time by endothermic animals

Index[23] and Physical Activity Levels[24] determining a person's body weight for different age groups in a given country. This approach has been used and detailed in Hiç et al., 2017.

Disaggregation methodology rational

Level 1 of calorie requirements in the EUCal is determined by extending the country-specific linear trends of BMI in time observed between 1990 and 2013 extracted from NCD-RisC 2016. From the future BMI a new BMR is derived assuming and average PAL equal to that in Hiç et al., 2017. Calorie requirements for Levels 3 and 4 are assumed to be those resulting from a decline in BMI so that overweight levels of a country are, respectively, a quarter of that observed in 2015 and half of that observed in 2015.

Feedback from the stakeholder consultations

It was voiced in the lifestyles consultation that demographic change and gender aspects influence many of the lifestyle dimensions. In the case of calorie requirements lever this feedback was integrated by taking into account the age and gender profile of the population within a given country. The rationale for this rests on the evidence that calorie requirements between younger and older population, as well as between genders, are rather distinct; being higher in younger age classes for males and lower for female age class above 65[25]. Accordingly, calorie requirements defined in levels 1 to 4 are determined for a total of 10 age/gender classes, namely: below 19, age20-29, age30-54, age 55-64, and above 65, both for the male and female sides. This was done by adapting the age-specific BMR's and PLA's in table of Hiç et al., 2017 to the specific age classes used in the EU calculator.

5.3.10.3 Ambition levels and disaggregation method

EU-Levels

Our estimates of calorie requirements are based on the methodology put forward in (Hiç et al., 2016). Calorie requirements are a function of demography, BMI (Body Mass Index) and Physical Activity Levels (PALs). Demography is included in order to account for the fact that calorie requirements between younger and older population are rather distinct, being higher in younger age classes for males and lower for female age classes above 65[26]. The energy requirements are separately calculated for four age groups, infants, children, and adolescents, adults, (iii) elders, and pregnant and lactating women. Historically, BMI has been increasing at a slow pace in several European countries (see Figure 31 in section 6). This highlights the potential to now reverse the trends and start pushing for a generalized distribution of normal weight BMI's across the population. WHO

[23] Body Mass Index (BMI) is a person's weight in kilograms divided by the square of height in meters.

[24] Physical activity level (PAL) is a way to express a person's daily physical activity as a number and is used to estimate a person's total energy expenditure.

[25] http://www.fao.org/3/a-y5686e.pdf

[26] http://www.fao.org/3/a-y5686e.pdf

suggests a BMI of between 18.5–24.9 as normal weight and BMI's above 30 as indicator of obesity[27]. Examining the current (2015) fraction of population with BMI>30 across European countries makes clear the untapped potential for the health argument proposed in (Stoll-Kleemann and Schmidt, 2017). According to (Abarca-Gómez et al., 2017), the fraction of population with BMI>30 in European countries ranges between 20 and 30%, with Malta championing Great Britain to first place. Worryingly, the decadal trends of obesity prevalence have been increasing across Europe at rates as high as 0.5% a year (see Figure 31 in section 6) underlying the potential for height reduction, diminution of the BMI and by extent a decrease in dietary requirements in European countries seems substantial.

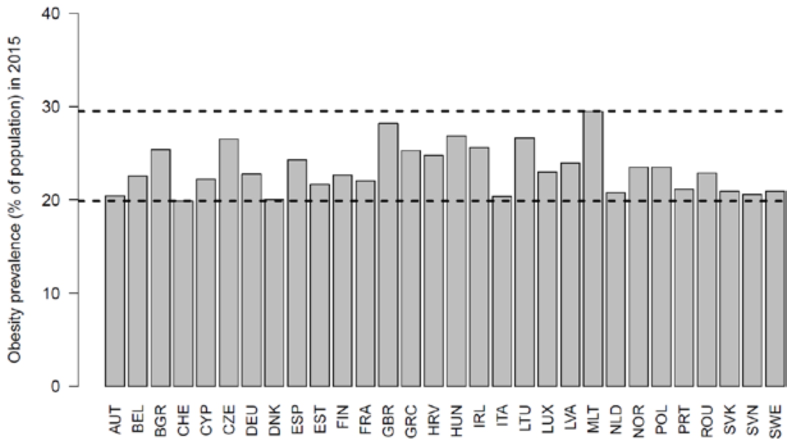

Figure 25 - Percentage of population with BMI>30 in European countries in 2015. Dashed horizontal lines depict maximum and minimum of the sample.

Finally, in regards to last aspect (PAL), due to the fact that no standardized global data on PAL for countries is available, the authors kept the factor constant at the same level observed for non-overweight adults in the United States[28]. It is important to consider the following: Changes in physical activity affect in theory both the population's BMI and by extent its calorie requirements. These intricate linkages were determined too complex to evaluate in the scope of this module.

Level 1 of calorie requirements in the EU Calculator is determined by extending the country-specific linear trends of BMI in time observed between 1990 and 2013 extracted from NCD-RisC 2016. From the future BMI a new BMR is derived assuming and average PAL equal to that in Hiç et al., 2017. Calorie requirements for Levels 3 and 4 are assumed to be those resulting from a decline in BMI so that overweight levels of a country are, respectively, a quarter of that observed in 2015 and half of that observed in 2015.

Table 18 - EU28+Switzerland levels of calorie requirements lever

Name / Unit	1	2	3	4

[27] http://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi

[28] http://www.fao.org/3/a-y5686e.pdf

Calorie requirements (kcal/cap/day)	2556	2508	2437	2400

Disaggregation by country

At the country-level calorie requirements are a function of demography, BMR (Basal Metabolic Rate) and Physical Activity Level (PAL), and are determined using the equation below. Constant *C,* and slope, *S,* depend on age and sex groups. The country-specific information for these variables has been taken from (Hiç et al., 2016). The energy requirements are separately calculated for the 10 age/gender classes in the EUCalc model.

$$Calorie\ requirements\ (kca\ per\ person\ per\ day) = BMR(\ C(age, sex) + S\ (age, sex) * BW\ (age, sex)) * PAL$$

5.3.10.4 Source references

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5.3.11 Food wasted

5.3.11.1 Lever description

This lever describes the amount of calories wasted at the consumer level and comes expressed in kcal/cap/day. An overall reduction in daily calories of food wasted, all other things kept constant, leads to a reduction in carbon emissions from the agricultural sector.

5.3.11.2 Rationale for lever

The 2017 report from FAO on the future of food and agriculture is a sobering touch of reality; in an age “where hundreds of millions of people go hungry”, about “one third of all food” is wasted of lost before it is consumed (FAO 2017). Fighting food waste and loss is therefore not only a matter of alleviating the resource pressure on the agricultural and climate system, but also a way to enhance the availability of food in regions where is most needed.

Current situation

For 2012, food waste at the EU-28 estimated at 88 million tonnes (Stenmarck et al., 2017). This equates to 173 kilograms of food waste per person in the EU-28. The total amounts of food produced in EU for 2011 were around 865 kg / person, this would mean that in total we are wasting 20 % of the total food produced. Recent estimates for 2017 puts the number at 89.2 million tonnes of food each year. Germany (10.3 million tonnes), the Netherlands (9.4 million), France (9 million) and Poland (8.9 million) make up the top five most profligate countries. Malta is the least wasteful country, with the relatively little excess of 25,000 tonnes per year[29].

Various scenarios for 2050

In terms of previous scenarios looking at potential trajectories of food waste it is common to find that these reply of very simple assumptions. For example, Hiç et al., 2016, evaluate the GHG emissions saved if global food surplus (which includes waste) is halved until 2050. In the 2050 long-term strategy, "A Clean Planet for all: A European long-term strategic vision for a prosperous, modern, competitive and climate neutral economy", it is proposed a reduction by half in the generation of food waste in all EU Member States (LTS 2018). Both of the scenarios highlighted echo the reductions in food waste of 50% by 2030 in order to achieve Target 12.3 of Sustainable Development Goal 12 (Responsible consumption and production), which calls for calls for cutting in half per capita global food waste at the retail and consumer level, and reducing food losses along production and supply chains (including post-harvest losses) by 2030.

Disaggregation methodology rational

[29] https://www.independent.co.uk/news/world/europe/how-much-food-does-the-eu-waste-a6778351.html

The average fraction of fractions of food waste in Europe per food group are taken from Gustafsson et al., 2013 and assumed unchanged for each country. This means for example that consumer-wasted fraction of cereal calories (around 25% of Europe's cereal consumption) is the same in every country considered. The absolute value of waste varies from country to country given the different dietary compositions and population.

Feedback from the stakeholder consultations

No specific feedback.

5.3.11.3 Ambition levels and disaggregation method

EU-Levels

For level 1 food waste at the consumer level is assumed to remain at the current levels suggested in Gustafsson et al., 2013 for the food groups considered. Applying these to the EU28+Switzerland population, results in an average of 522 kcal/cap/day of food waste by 2050.

For level 3 it is assumed that by 2050 countries achieve food waste reductions at the consumer level of 50%, thus complying with the SDG target 12.3 (originally set by 2030). This translates to an average food waste for EU28+Switzerland of 390kcal/cap/day. For level 4 countries achieve food waste reductions at the consumer level of 75% by 2050, thus overcoming the SDG target 12.3 by 2030. This translates to an average food waste for EU28+Switzerland of 130kcal/cap/day.

Table 19 - EU28+Switzerland levels of the food waste lever

Name / Unit	1	2	3	4
Calorie requirements (kcal/cap/day)	522	390	260	130

Disaggregation by country

Countries converge to the individual food waste targets which take into account the current consumption levels of each country.

5.3.11.4 Source references

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5.3.12 Diets (calorie split)

5.3.12.1 Lever description

This lever describes the composition of individual diets and comes expressed as the daily calories demand for 26 food groups.

5.3.12.2 Rationale for lever

Increasing income levels have also been associated with a higher share of meat in contemporary diets in emerging economies, while in developed countries this share stagnated or even decreased in the last decades.

Current situation

Recent investigations confirm that the total share of animal based calories is estimated to rise strongly for income for low-income groups but that for high income groups slight negative time-trends are possible (Bodirsky et al., 2015). These shifts in consumption towards more animal-base products are expected to lead to an increase of GHG emissions. Hence, dietary shifts have been proposed as an effective way of reducing associated greenhouse emissions in the agricultural sector (Springmann et al., 2018).

Various scenarios for 2050

Springmann et al., 2018 has produced to date one of the most comprehensive evaluations of the implication of alternative dietary patterns in GHG emissions from agricultural systems. It is suggested that by 2050 a flexitarian diet - composed of at least 500 g per day of fruits and vegetables of different colours and groups, at least 100 g per day of plant-based protein sources and very modest amounts of animal-based proteins - to result in a decrease of GHG emission in the order of 57% (see Figure 26).

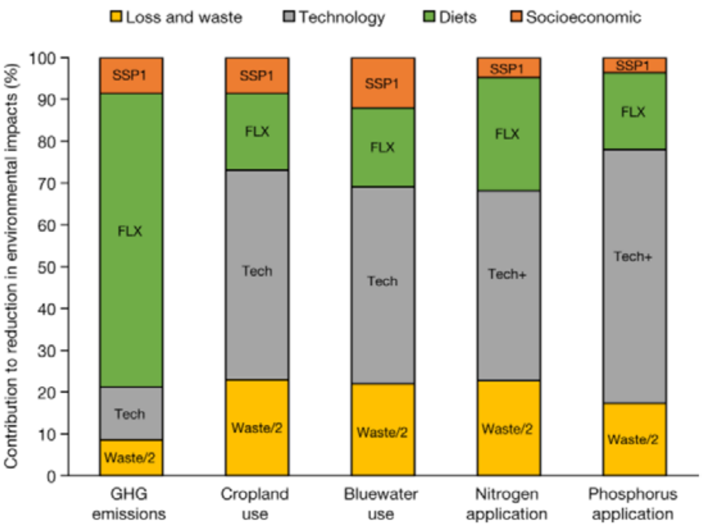

Figure 26 - Mitigation measures that simultaneously reduce environmental impacts below the mean values of the planetary-boundary range.

A dietary pattern consisting in the fulfilment of health dietary guidelines in WHO would result in a decrease of emissions of about 29% in reference to the baseline (Springmann et al., 2018).

Food and its consumption has also been linked to gendered practices. Sumpter (2015) describes meat consumption as a gendered practice of dominant masculinity. According to different sources, meat is consumed in higher quantities by men (Clonan et al. 2016; Wyness et al 2011; Linseisen et al. 2002). Reasons for this can include a lower economic status of women, women being more concerned with animal welfare (Clonan et al. 2015), and women trying to live a healthier lifestyle (Samoggia et al. 2016), all due to socialization processes.

A UK study by the British Nutrition Foundation with data from 2008/2009 (National Diet and Nutrition Survey) on red meat consumption makes clear that the average intake of meat for girls and boys between the ages of 4 to 10 is similar, whereas disparities begin at the age of 11. The average intake in grams differs by up to 50 grams per day between men and women (Wyness et al. 2011). The United States Department of Agriculture assesses socioeconomic differences in the consumption of all food categories and data from 2007/2008 also verifies that meat, poultry and fish are consumed about 30 pounds more per year by boys than girls and about 70 pounds more by men than women (Economic Research Service 2012). Furthermore, the European Prospective Investigation into Cancer and Nutrition (EPIC) study states that "gender differences in meat intake were quite striking and can be explained only partly by different energy intakes in men and women." The study was conducted in Greece, Spain, Italy, Norway, Sweden, Germany, France, Netherlands, Denmark and the United Kingdom with almost 40 000 participants (Linseisen et al. 2002). Specifically, red processed meat is consumed in higher quantities by men (Clonan et al. 2016; Wyness et al 2011; Linseisen et al. 2002).

Disaggregation methodology rational

For ambition level 1 the countries evolve according to their individual trajectories for the food groups for which dietary recommendation for which WHO recommendations are available; these are all meat groups (including fish), sugars and sweeteners, fruits and vegetables. The calorie sum of these groups is then subtracted to the total calories needed (see ambition levels in section 5.3.10.3), which results in a total calorie amount for the rest of the food groups. The absolute values of calories for the rest of the food groups are determined by multiplying the total of calories left by the group-specific fraction of calories in the 2015 total (see Figure 7).

Feedback from the stakeholder consultations

The feedback from the consultation noted that the lever was important and also that the calories on a "*national scale it depends on demographics, e.g. younger generations eat more, elderly and adults have different energy requirements*".

This recommendation was taken in the development of the Lifestyle module. Firstly, age distribution is taken to determine the calorie requirements through the differences in metabolic rates and body masses, which in turn influence the absolute amount of calories of a given product consumed. Furthermore, in the context of reducing meat and animal based product consumption, Rothgeber (2013) suggests to "enlist women as change agents" to influence men around them and to promote women's dietary practices.

5.3.12.3 Ambition levels and disaggregation method

EU-Levels

Ambition level 1 is assumed to be the continuation of the past (2000-2013) trend of calories change for each food group until the year 2050. It is important to mention that in some cases the reduction of particular food groups (say bovine meat) might be enough to fulfil the dietary guidelines of levels 3 and even 4. If that is the case then the dietary requirements for the meat-related food groups in question are further lowered to 60% of the dietary recommendation. This assumption goes beyond the level proposed in WHO but is still in line with the most ambitious level of dietary change in Springmann et al., 2018. In case the historical trend determined under level 1 delivers already the best dietary requirements for vegetables and fruits the same calorie values are kept at level 1 for all levels. In case the historical trend determined under level 1 delivers already the best dietary requirements for sugar and sweeteners, the same calorie values are kept at level 1 for all levels.

Table 20 - EU28+Switzerland levels for the diet lever

Name / Unit	1	2	3	4
Calories per food group (kcal/cap/day)				
Bovine Meat	41	31	21	14
Demersal Fish	12	8	3	2
Freshwater Fish	7	4	2	1
Fruits - Excluding Wine	79	157	234	351
Meat, Other	5	4	3	2
Mutton and Goat Meat	7	6	4	3
Offals	11	9	7	7
Pelagic Fish	23	14	5	3
Pigmeat	150	114	79	52
Poultry Meat	85	54	24	15
Sea food	5	3	1	1
Sugar	301	248	195	118
Sweeteners	46	38	30	18
Vegetables	54	112	171	256

Beer Beverages, Alcoholic Beverages, Fermented Cereals - Excluding Beer Rice Coffee and products Eggs Fats, Animals, Raw Milk Oilcrops Pulses Starchy Roots Stimulants Vegetable Oils Wine	A function of the difference between calorie requirements and the sum of the calories from the groups above implied in the lever selection.

For level 3 it is assumed that counties converse to fulfil the dietary requirements of World Health Organization 2003 and WCRF 2017. This means that countries converge to a diet in which all meat does not go over 90g/day (of which only up to 71g/day is read meat); where sugars and sweeteners are kept below 10% of calorie consumption and where fruits and vegetables consumption is of at least 400g/day.

Level 4 assumes a general improvement of all the above calories so that countries converge to the flexitarian diet proposed in Springmann et al., 2018. This implies meat to be capped at about 40g/day with red meat to be kept at about 13g/day; sugars and sweeteners at below 5% of calorie intake; and fruits and vegetables consumption to be over 600g/day. Fractions of calories for the remaining of the food groups considered (26 in total, see section 4.4.1.3) are kept constant to their relative values of 2013. The absolute calorie values for the remaining food groups are calculated as detailed in section 4.5.5.

Disaggregation by country

In level 1 the countries evolve independently according to their past dietary trend. For level 3 and 4 countries converge to per capita food group consumption that best mimics the health guidelines in WHO and to the Flexitarian diet in Springmann et al., 2018. For level 2 countries converge to the mid-point between level 1 and 3.

5.3.12.4 Source references

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5.3.13 Paper and packaging demand

5.3.13.1 Lever description

This lever describes the trajectories for the demand of paper in the form of graphics and sanitary paper, and the demand for plastic, paper, aluminium and glass used for packaging. A reduction on the demand for paper and packaging (decomposed in the several materials), all other things kept constant, leads to a reduction in carbon emissions.

5.3.13.2 Rationale for lever

Current situation

Graphic and sanitary paper

In 2015 the global demand for graphic paper declined for the first time and the fall in demand for these products in Europe and North America over the past five years has been more pronounced than even the most pessimistic forecasts[30]. The overall the global paper and forest-products industry is now growing at a slower pace as other products are filling the gap left by the shrinking graphic-paper (see Figure 27). Paper packaging is growing in Europe along with tissue papers, and pulp for hygiene products[31].

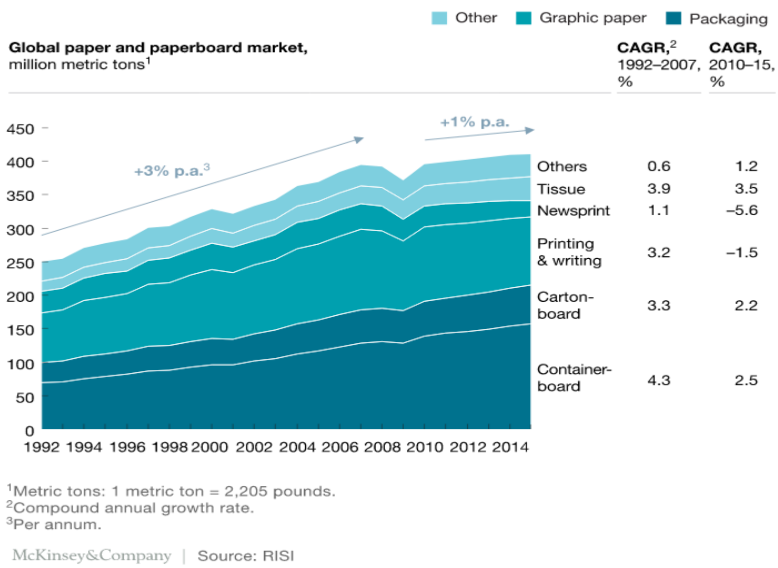

Figure 27 – Evolution of the global paper and paperboard market

[30] https://www.mckinsey.com/industries/paper-and-forest-products/our-insights/pulp-paper-and-packaging-in-the-next-decade-transformational-change

[31] https://www.mckinsey.com/industries/paper-and-forest-products/our-insights/pulp-paper-and-packaging-in-the-next-decade-transformational-change

Plastic, glass and aluminium packaging

The production of plastics has grown globally since the 1950ies to reach the present production of 330 million metric tons (Mt) for 2016 (Plastics Europe, 2017). In Europe, the demand for plastic products in Europe in 2017 has totalled at 52.1 Mt (Plastics Europe, 2017) or circa 15% of the global production. Of the several uses plastic can have in Europe the main demand for plastic products comes from packaging (circa 40% of total production), followed by building and construction (circa 20%) and finally the demand from automotive industry (circa 10%).

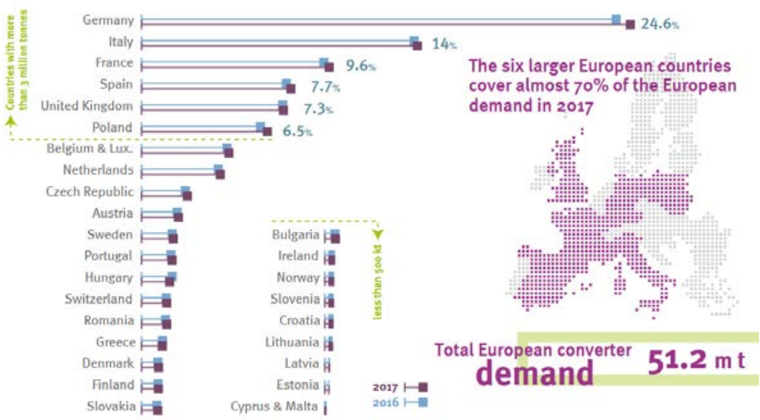

Figure 28 – Plastic demand in Europe for the years 2016 and 2017

The demand for plastic products is very unbalanced across the EU28 member states with roughly Poland, UK, Spain, France, Italy and Germany accounting for nearly 70% of the entire European demand (Plastics Europe, 2018), see Figure 28.

The European Container Glass Federation (FEVE) reported early in 2018 that the glass packaging production in Europe grew by 1% in volume (tonnes) compared to the previous half year. The growth continues the trend verified in 2017 growth of 2% in weight terms and 2.4% in units and compares favourably with the historical trend since 2012 (FEVE 2019). Between 2012 and 2017, production has increased by almost 1.7 million tonnes, an 8.3% increase. The food and beverage market segments experienced a strong demand growth for glass in the order of 2% in 2017, see Figure 29.

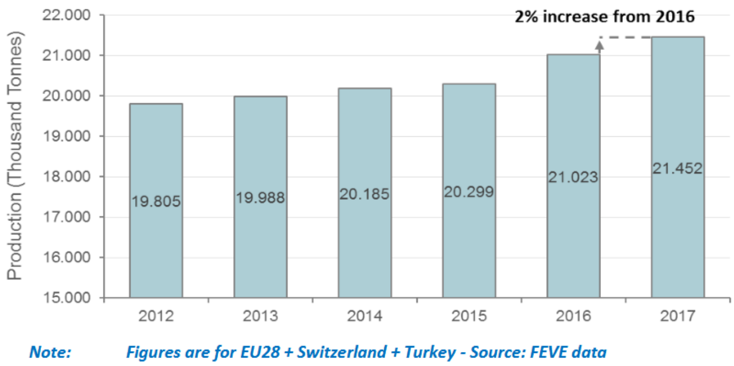

Figure 29 - Glass container production for food and beverages in Europe

FEVE links the positive development in glass container demand to an *"increasing consumer engagement with environmental causes. Consumers – and particularly millennials – are increasingly aware of the impact their daily lifestyle can have on the environment"* (FEVE 2019).

Regarding the effect of gender, studies show that female consumption patterns are more sustainable: women tend to recycle more, purchase eco-friendly labelled goods more frequently than men and value energy efficiency (OECD 2008b). A study presented at the UN Commission for Sustainable Development by Sweden makes clear the ways women in Sweden live a more sustainable lifestyle and consume less, or more sustainably (Johnsson-Latham 2007).

According to OECD findings, setting women's behaviour and consumption patterns as the norm would lead to an overall smaller impact on the environment and promote sustainable patterns that would be beneficial for economy and society (OECD 2008).

While focusing on consumer preferences and gendered consumption patterns individual choices and actions are only a partial solution. It is important to note that "governments and businesses have an essential role in promoting more sustainable production practices, halting overexploitation of natural resources and fostering innovations that support sustainability throughout the supply chain", this is recognized in goal 12 of the Agenda for Sustainable Development (UN Women 2018). In addition setting women's consumption choices and behaviors as a norm might also be beneficial to achieve sustainable consumption and production patterns.

<u>Various scenarios for 2050</u>

Graphic and sanitary paper

The graphic-paper market is expected to face declining demand worldwide following the current trends, see references above. The demand for graphics paper between 2016 and 2021 is expected to fall in Western Europe in all its variants (see Figure 30) while in Eastern Europe some products might still see a rise in demand. Case studies reinforce the potential for change regarding the reduction of paper use. Calloway (2003) showed a decrease of 10% in paper use as a response to information about paper use in the university library over a 2-year period. 10% reduction also appears to the potential saving in energy incurred in shifting from printed newspapers to tablet or e-reader (Moberg *et al.,* 2010). On a longer time frame (by 3030), Hänninen et al., 2014, estimates a drop in graphics paper consumption in Europe of circa 26% in relation to its 2010 levels. Paper packaging and sanitary application (such as tissues) are expected to experience moderate to healthy growth in the order of 2% a year (see Figure 30).

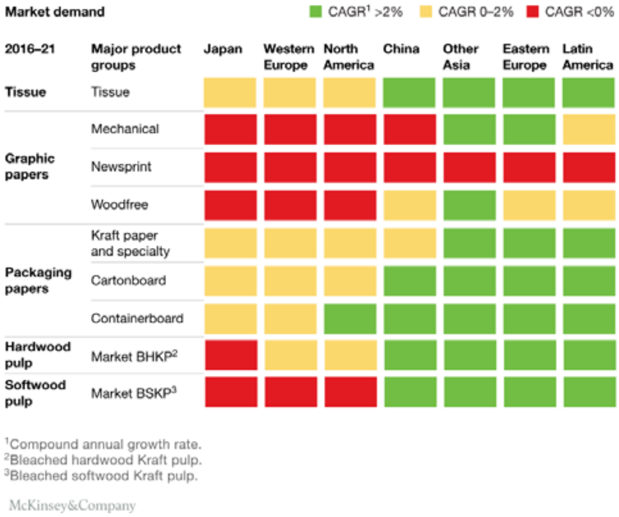

Figure 30 - Demand scenarios for fiber-based products available online at: https://mck.co/2z21cvo

Plastic, glass and aluminium packaging

Lebreton and Andrady (2019), evaluate the implication in plastic waste generation globally according to varying scenarios of plastic use and recycling targets. The regional breakdown of the analysis reveals a range of possible scenarios of plastic use and disposal for Europe for the decades of 2020, 2040 and 2060. Taking 2050 values as the middle point between the projections for 2040 and 2060, the average plastic waste in Europe is projected to increase by 20% from 2020 levels under a strict coupling of plastic use with income (BAU scenario in Lebreton and Andrady (2019), middle variant). The rise is not equal distributed across Europe with growth projected for Western, Southern and Northen Europe of 22, 18 and 25% respectively in relation to 2020. Reductions in plastic waste are assumed in Lebreton and Andrady (2019) under scenario C, which caps the fraction of plastic in municipal solid waste to only 10% by 2020 and 5% by 2040. Moran et al., (2018) assumes that plastic use could be reduced by both industry and by households (reduce household final demand of Plastics) by 10% (technical potential).

Disaggregation methodology rational

Countries reduce their demand in paper in packaging according to the European % reduction target assumed in the ambition levels.

Feedback from the stakeholder consultations

This lever was not available during the stakeholder consultations carried in the Lifestyles workshop.

5.3.13.3 Ambition levels and disaggregation method

EU-Levels

For level 1 the change in paper printing and graphics arrive in 2050 to the negative trend proposed in Hänninen et al., (2014) for 2030 - 26% reduction.

For level 2 we extend the Hänninen et al., (2014) trend to 36% by 2050. Regarding level 4, we add the reductions in level 2 those identified in Calloway and Michel, (2003) and Moberg et al., (2010) - that is 10% each – to arrive at an ambition level of 56% reductions by 2050. Level 3 is set an intermediate level between 2 and 4. The indicative 2% growth trend (over 5 years) in tissue paper in Figure 30 is used to set level 1 for paper sanitary and household by 2050 at an increase of 17%. For level 2 the growth is set at 1%, reflecting the possibility of Eastern European countries curbing their growth faster that Wester European countries did in the past. In level 4 we assume a complete stagnation of sanitary paper use, which would be extremely ambitious. Level 3 is set as an intermediate level.

For plastic packaging level 1 reflects the growth scenario in Lebreton and Andrady (2019) under which disposable plastic, and hence also packaging demand, increases by 25%. Level 4 is set at the technical feasibility of reducing household plastic consumption by 10% in Moran et al., (2018). Level 3 is equated to stagnation of today's levels of packaging and level 2 and intermediate level between 1 and 3. These levels are also assumed for the case of aluminium packaging.

Glass packaging is rising as seen beforehand in this section and its growth is level 1 is set at a yearly rate of 1.6% as implied in the 2012-2017 growth rate reported in FAVE 2019. This would yield a rise in about 50% in 2050. For level 4 a growth of 70% is assumed in order to compensate the drops in plastic and aluminium packaging. Levels 2 to 3 are constructed as intermediate scenarios.

Table 21 - EU28+Switzerland levels for the paper and packaging demand lever

Name / Unit	1	2	3	4
Plastic packaging change [%]	125	112	100	90
Glass packaging change [%]	150	155	165	170
Aluminium packaging change [%]	125	112	100	90
Paper printing and graphic change [%]	26	36	46	56
Paper sanitary and household change [%]	117	108	104	100

Disaggregation by country

Countries reduce their demand in paper in packaging according to the European % reduction target assumed in the ambition levels.

5.3.13.4 Source references

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6 Description of constant or static parameters

6.1 Constants list

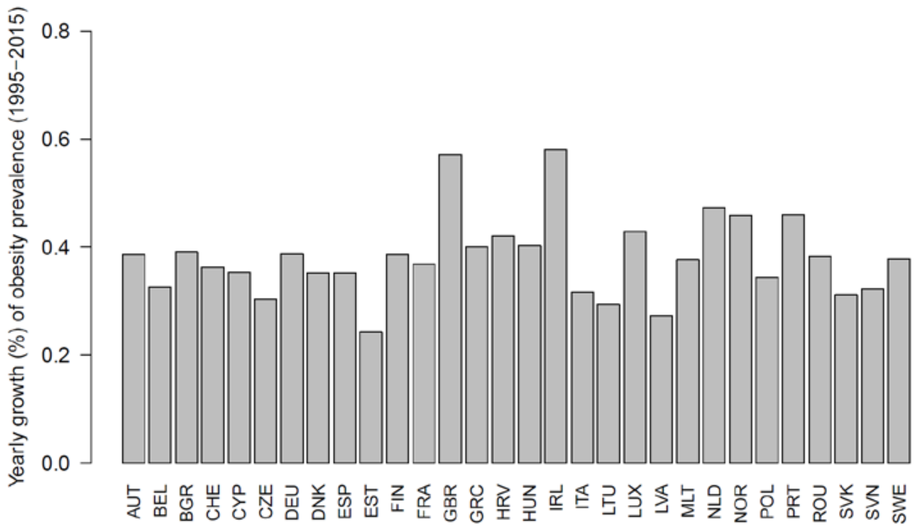

Figure 31 - Yearly changes of obesity prevalence (BMI>30) in European countries between 1995 and 2015 (values given in yearly % growth)

6.2 Static parameters

Household composition in terms of person per household: This value is kept static to 2015 levels.

Country	2015
Austria	2.73
Belgium	2.50
Bulgaria	2.78
Croatia	2.71
Cyprus	3.26
Czech Republic	2.70
Denmark	2.11
Estonia	2.30
Finland	2.21
France	2.54
Germany	2.23
Greece	3.04
Hungary	2.66
Ireland	3.28
Italy	2.81
Latvia	3.00
Lithuania	2.65
Luxembourg	2.84
Malta	3.01
Netherlands	2.45
Poland	3.17
Portugal	3.08
Romania	2.73
Slovakia	2.88
Slovenia	3.02
Spain	3.46
Sweden	2.16
Switzerland	2.26
United Kingdom	2.49

Figure 32 - 2015 values of average household size in Europe taken from Eurostat.

Shares of food groups not affected by the dietary requirements considered in the diet lever. This value is kept static to 2013 levels. Data is constructed from the FAO food-balance sheets[32] by subtracting to the total calorie availability in a country the share of calories wasted and the sum of calories in the food groups for which dietary requirements are considered.

Country	share_afats	share_beer	share_bev-alc	share_bev-fer	share_cereals	share_coffee	share_egg	share_milk	share_offal	share_oilcrops	share_pulses	share_starch	share_stm	share_voil	share_wine	share_rice-
Austria	0.092	0.055	0.015	0.000	0.327	0.005	0.022	0.162	0.002	0.022	0.003	0.042	0.004	0.213	0.023	0.014
Belgium	0.081	0.038	0.005	0.001	0.308	0.004	0.019	0.215	0.004	0.008	0.009	0.065	0.002	0.188	0.020	0.034
Bulgaria	0.054	0.047	0.031	0.001	0.497	0.003	0.015	0.127	0.007	0.017	0.010	0.022	0.003	0.144	0.011	0.012
Croatia	0.053	0.050	0.013	0.001	0.424	0.004	0.015	0.162	0.003	0.027	0.003	0.036	0.035	0.151	0.013	0.012
Cyprus	0.003	0.025	0.011	0.001	0.400	0.004	0.020	0.140	0.005	0.032	0.017	0.030	0.028	0.240	0.017	0.028
Czech Republic	0.032	0.078	0.020	0.000	0.338	0.002	0.018	0.167	0.004	0.010	0.008	0.056	0.013	0.228	0.008	0.020
Denmark	0.080	0.040	0.013	0.001	0.382	0.006	0.030	0.197	0.010	0.009	0.005	0.052	0.025	0.105	0.025	0.023
Estonia	0.005	0.057	0.087	0.002	0.410	0.003	0.019	0.182	0.005	0.004	0.033	0.062	0.029	0.080	0.012	0.010
Finland	0.016	0.048	0.015	0.000	0.401	0.007	0.016	0.282	0.002	0.010	0.005	0.053	0.012	0.104	0.010	0.020
France	0.026	0.013	0.008	0.004	0.383	0.003	0.022	0.219	0.008	0.010	0.007	0.040	0.011	0.196	0.030	0.022
Germany	0.057	0.052	0.036	0.004	0.347	0.003	0.020	0.194	0.001	0.015	0.003	0.048	0.007	0.184	0.018	0.015
Greece	0.005	0.019	0.007	0.001	0.365	0.003	0.016	0.170	0.004	0.022	0.019	0.055	0.010	0.266	0.014	0.025
Hungary	0.112	0.039	0.023	0.001	0.369	0.005	0.022	0.120	0.002	0.005	0.013	0.038	0.011	0.218	0.020	0.009
Ireland	0.029	0.080	0.028	0.001	0.413	0.002	0.014	0.176	0.004	0.010	0.012	0.061	0.012	0.135	0.012	0.012
Italy	0.033	0.015	0.003	0.001	0.428	0.003	0.021	0.135	0.003	0.007	0.021	0.026	0.002	0.259	0.022	0.023
Latvia	0.052	0.044	0.031	0.001	0.399	0.003	0.023	0.170	0.009	0.007	0.013	0.093	0.022	0.133	0.003	0.010
Lithuania	0.029	0.058	0.052	0.001	0.480	0.003	0.022	0.155	0.005	0.007	0.013	0.074	0.001	0.079	0.011	0.013
Luxembourg	0.020	0.051	0.039	0.004	0.380	0.014	0.024	0.184	0.006	0.009	0.005	0.040	0.049	0.119	0.043	0.015
Malta	0.067	0.023	0.018	0.001	0.480	0.003	0.021	0.153	0.003	0.019	0.017	0.035	0.033	0.093	0.014	0.023
Netherlands	0.036	0.035	0.011	0.004	0.334	0.002	0.027	0.239	0.002	0.016	0.008	0.083	0.001	0.175	0.019	0.014
Poland	0.042	0.054	0.015	0.005	0.484	0.001	0.012	0.150	0.004	0.004	0.007	0.078	0.000	0.139	0.003	0.004
Portugal	0.076	0.025	0.030	0.000	0.354	0.002	0.014	0.123	0.006	0.004	0.015	0.050	0.018	0.191	0.031	0.063
Romania	0.026	0.041	0.004	0.001	0.505	0.001	0.019	0.168	0.004	0.005	0.007	0.068	0.008	0.119	0.015	0.009
Slovakia	0.103	0.045	0.021	0.002	0.459	0.003	0.029	0.113	0.002	0.014	0.006	0.044	0.014	0.132	0.004	0.014
Slovenia	0.034	0.042	0.006	0.000	0.476	0.003	0.015	0.160	0.005	0.013	0.008	0.041	0.027	0.145	0.008	0.016
Spain	0.013	0.045	0.008	0.001	0.323	0.002	0.023	0.121	0.007	0.018	0.022	0.048	0.010	0.303	0.018	0.035
Sweden	0.021	0.035	0.013	0.000	0.337	0.006	0.025	0.253	0.001	0.016	0.008	0.049	0.005	0.186	0.018	0.028
Switzerland	0.036	0.036	0.012	0.002	0.313	0.004	0.019	0.253	0.005	0.011	0.008	0.036	0.002	0.217	0.033	0.012
United Kingdom	0.021	0.041	0.009	0.001	0.360	0.001	0.019	0.178	0.003	0.016	0.014	0.079	0.020	0.194	0.015	0.030

Figure 33 - Shares of calories for the Rest of the Food groups not affected by dietary recommendation considered.

a **and** ***b*** **parameters of the function to determine the non-urban transport distance**: See section 3.3.5.2 and table below. The parameters refer to a linear fit between the % of non-urban travel as a function of % of population living in urban areas between 1990 and 2015.

Fraction of non-shiftable travel distance in total urban travel in 2010: See section 3.3.5.2 and table below.

[32] http://www.fao.org/faostat/en/#data/FBS

Country	factor_a	factor_b	nshift-share	urb-share
Belgium	-0.13073	13.44228	0.060823802	0.362032566
Bulgaria	-0.00789	1.167835	0.068288182	0.409889171
Czech Rep	0.036801	-2.10993	0.059432395	0.414231648
Denmark	-0.00982	1.408473	0.133028814	0.451854188
Germany	-0.00258	0.888497	0.044370056	0.310863382
Estonia	-0.00642	1.087965	0.048503768	0.341310271
Ireland	0.000781	0.548485	0.083373854	0.395962988
Greece	-0.00789	1.112802	0.127440197	0.504123113
Spain	-0.00653	1.056982	0.071250786	0.462754472
France	-0.00607	1.157281	0.069501954	0.325318049
Croatia	-0.01377	1.328707	0.053177191	0.446647487
Italy	-0.01439	1.762128	0.03971204	0.233391289
Cyprus	-0.03082	2.449543	0.459670088	0.629601859
Latvia	-0.1498	10.74503	0.061246185	0.518969915
Lithuania	-0.08383	6.336346	0.019912775	0.301064797
Luxembou	0.00272	0.296266	0.071189663	0.468594217
Hungary	-0.00249	0.820725	0.052888986	0.353214049
Malta	-0.1006	9.735196	0.442914643	0.772439949
Netherlan	-0.00448	1.060459	0.183656456	0.349757249
Austria	-0.00755	1.026507	0.127736287	0.400679449
Poland	0.020216	-0.58653	0.026983381	0.36794661
Portugal	-0.00361	0.721975	0.127791451	0.504643696
Romania	-0.07077	4.419123	0.023286254	0.420359073
Slovenia	-0.00083	0.653601	0.017641086	0.391546825
Slovakia	-0.00115	0.732559	0.025225744	0.320688937
Finland	-0.01934	2.251502	0.113695656	0.404274983
Sweden	-0.00788	1.249194	0.078398513	0.427575328
United Ki	0.006352	0.06379	0.085018768	0.411538924
Switzerlar	-0.00258	0.888497	0.140139293	0.426897574

Figure 34 - a and b parameters of the function to determine the non-urban transport distance and the non-urban travel as a function of % of population living in urban areas between 1990 and 2015.

7 Historical databases

This section describes each historical dataset used for the Lifestyle module, its sources, quality and the hypotheses needed to fill the data gaps.

7.1 Databases used in the Lifestyle module

Table 2 – Database for passenger transport

Dataset	Description	Main sources	Data quality check	Hypotheses
Population data [hab]	Number of inhabitants per country.	Eurostat and IASSA SSP databases.	Eurostat population data is the reference source in Europe. Projection from IASSA are the standard source of socio-economic data for the IPCC. No outliers identified No alternative data source evaluated.	
Fraction of urban population [%]	fraction of the total population living in urban areas.	United nations world urbanization prospects and IASSA SSP databases	Projection from IASSA are the standard source of socio-economic data for the IPCC. United nations urbanization prospects are the only globally consistent and complete accounting of urban population fractions for aa the countries between 1990 and 2015 we could find.	
Total passenger distance [pkm]	Total distance travelled by passengers.	EU pocketbook 2017	The data source is commonly used at the European level and a compilation of data found in the Eurostat and national data sources. No outliers identified.	Total land distance is assumed to be the sum of car, 2W, Bus, Metro and Tram, and rail distances. Active mode distances are not considered here Air distance from 2011 to 2015, by country: the same growth is assumed for distance travelled than for the number of air passenger given by Eurostat data. Air passenger distance is calculated as the ratio of air passenger and air distance.

Residential floor area [m2]	Floor area dedicated to residential use in a country.	ODYSSEE MURE database EU buildings database (Building observatory) [1] Ostermeyer, Y.; Camarasa, C.; Naegeli, C.: Saraf, S.; "Building Market Brief Switzerland", ISBN 978-90-827279-0-6	The ODYSEE MURE database is well established and referenced in the building sector. In addition, the data is also available in the building observatory.	Except for the case of Switzerland, the residential floor area was extracted from the ODYSSEE MURE database.
Calorie availability [kcal/cap/year]	Total and by food group availability of calories for human consumption.	FAO food balance sheets	The data is a reference source for many international studies related to food and diets. No outliers identified. Provides consistent EU and global coverage. Important for consistency with the RoW. No alternative data source evaluated.	Diet composition of individuals is assumed to homogenous within a country and equal to the calorie availability of food groups, e..g., cereals, bovine meat, vegetables etc...
Appliance ownership [number/household]	Number of selected appliances per household.	[1] http://www.odyssee-mure.eu/ [2] Agence internationale de l'énergie, and IEA Staff. Cool appliances: policy strategies for energy-efficient homes. OECD publishing, 2003 [3] TekCarta - https://www.nakono.com/tekcarta/databank/personal-computers-per-household/ [4] The world Bank - https://data.worldbank.org/indicator/IT.NET.USER.ZS [5] https://newzoo.com/insights/trend-reports/newzoo-global-mobile-market-report-2018-light-version/ [6] https://www.slideshare.net/wearesocialsg/digital-in-2017-southern-europe	There was no EU-level database we could leverage on that would provide a comprehensive database of appliances. Accordingly, we were forced to compile our own database by making use of difference sources and strategies to fill the gaps/missing countries. Accordingly, issues of heterogeneity can be pointed to our database.	Unless specified otherwise, the number of appliances per household is taken from [1]. The exceptions are: For the case of missing data in fridges, freezers, wmachine, dryer, dishwasher and tv, appliance values are assumed to be equal to the respective European average sourced from [2]. For AC, the same rule applies except for the countries Greece and Cyprus in which ac penetration is assumed to be equal to that in Spain sourced from [1]. For computer appliances data is sourced from [3] between 2000 and 2012 and kept constant thereafter until 2015. 1990 to 1999 data is determined by assuming a direct proportionality to global trend of internet adoption taken from [4]. Finally, values of mobile phones are taken from [5] and [6] and interpolated as exponential decay.

Appliances use [h/appliance]	Number of hours each appliance is used.	[1] Pan European Consumer Survey on Sustainability and Washing habits [2] Bucksch J, Sigmundova D, Hamrik Z, Troped PJ, Melkevik O, Ahluwalia N, Borraccino A, Tynjälä J, Kalman M, Inchley J. International trends in adolescent screen-time behaviours from 2002 to 2010. Journal of Adolescent Health. 2016 Apr 1;58(4):417-25.	The landscape regarding surveys of appliance use, in terms of hours, is patchy. Fully harmonized EU-level studies were not found and we cannot attest for the quality of reference [1]. Reference [2] is peer reviewed.	[1] Country granularity was not possible given that the survey was only preformed at regional scale (e.g., Scandinavia). All countries belonging to the same geographic region are assumed to have the same pattern of appliance use. [2] Screen time hours was available for both computer and TV.
Paper and packaging [tons]	Tons of plastic, paper, aluminium and glass packing	Packaging waste by waste management operations and waste flow from EUROSTAT	Eurostat is a reliable source of information and the official statistical body of the EU	We assume that the demand for plastic and paper packaging equates to the quantity of packaging disposed as waste. Packaging in this context means all products made of paper or plastic to be used for the containment, protection, handling, delivery and presentation of goods, from raw materials to processed goods, from the producer to the user or the consumer.
Sanitary and graphics paper [tons]	Tons of paper for sanitary and graphics purposes.	Paper and cardboard production from EUROSTAT.	Eurostat is a reliable source of information and the official statistical body of the EU	Domestic demand for paper is assumed to be that resulting from (production + imports) -exports.
Comfort temperature [ºC]	Temperature at which human mortality is at its minimum.	Ballester, J., Robine, J.M., Herrmann, F.R. and Rodó, X., 2011. Long-term projections and acclimatization scenarios of temperature-related mortality in Europe. *Nature Communications*, *2*, p.358.	The publication makes extensive use of empirical mortality data to derive comfort temperature across Europe and is published is a very high ranking journal.	It is assumed that this is the minimum temperature at which residential rooms have to be in order to keep the population safe in case of heat stress.

7.2 Database references

See table above.