EUCALC

Explore sustainable European futures

Lifestyles in Europe: Perspectives and scenarios.

D1.3

April/2018

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730459.

Project Acronym and Name	EU Calculator: trade-offs and pathways towards sustainable and low-carbon European Societies - EUCalc
Grant Agreement Number	730459
Document Type	Deliverable
Work Package	WP1
Document Title	Lifestyles in Europe: Perspectives and scenarios
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Release date	April 2018
Distribution	*All involved authors and co-authors agreed on the publication.*

Short Description

This deliverable defines ambition levels for demographic and demand-related lifestyle levers for the EU calculator. In the context of the EU calculator project a “lever” represents an input to the model of a particular lifestyle or technological aspect that can be manipulated by the end-user. Levels are available for levers passenger distance, calories requirements, diets, consumer food waste, building use intensity, population and urbanization. The deliverable compiles critical questions on level definition for expert feedback. Data files containing the levels calculations are made available to the consortia.

Quality check

Name of reviewer	Date
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Statement of originality:

This deliverable contains original unpublished work except where clearly indicated otherwise.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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List of abbreviations

AV – Autonomous Vehicles

BMI – Body Mass Index

DCiE – Data Centre infrastructure Efficiency

DMP – Data Management Plan

EU28 – All member states of the European Union as of 2018

FAO – Food and Agriculture Organization of the United Nations

GDP – Gross Domestic Product

GHG – Green House Gases

IIASA – International Institute of Applied System Analysis

ICT – Information and Communication Technology

IoT – Internet of Things

M2M – Machine to Machine

PAL – Physical Activity Level

pkm – Passenger-kilometre

PUE – Power Usage Efficiency

RoW – Rest of the World

SDGs – Sustainable Development Goals

SSP – Shared Socio-economic Pathways

UN – United Nations

1 Executive Summary

When attempting to model low carbon pathways several important data sets, which affect outcomes, are related to what humans/European citizens do, the choices they make about diet, travel and the kind of built environment and living space they require. In 2014, the transport and household sectors alone accounted for 58% of the total final energy consumption in the EU28 (EEA, 2017). Energy used for agriculture adds another 2% to accounting meaning that changes in lifestyles across the highlighted sectors leverage circa 60% of the final energy consumption have a profound impact on carbon emissions and shape the feasibility of achieving low carbon pathways.

This deliverable attempts to capture these “lifestyle” elements of our model by defining ambition levels for demographic and demand-related lifestyle levers in the EU calculator. Levels are defined, calculated and data is made available for a total of four lifestyle (passenger distance, calories requirements, diets, consumer food waste, building use intensity) and two demographic (population and urbanization) levers. Levels are determined in consultation with work packages (WPs) 2 and 4 and aligned with the socio-economic baseline elaborated in WP7 (detailed in Del. 7.1). Importantly, the definition of ambition levels takes up some of the main findings during the Lifestyles Expert Consultation Workshop (see Del. 1.6), most prominently, a country-specific accounting of income and age structure in shaping lifestyles. Individual determinants of lifestyles (for example amount of time a person is willing to travel) are also included whenever feasible.

This deliverable has three main outcomes; a semantic definition of ambition levels; a generalized methodology allowing ambition levels to be determined consistently to individual countries; and a database [1] of demographic and lifestyles levels. The semantic definitions of ambition levels will allow a targeted feedback from stakeholders in the upcoming sector-specific consultation workshops of transport, buildings and land-use/food. The generalized methodology guarantees that stakeholder feedback can be quickly integrated, and refined ambition levels recalculated. Finally, the provided database allows several modules of the EU calculator model to test their calculation trees and initiate consistency checks.

In addition to the definition of ambition levels, the deliverable collects a number of important “unknowns” to be discussed in the expert consultation workshops. For the transport lever we will conduct a discussion on the future prospects of average daily speeds in countries. This deliverable suggests a stagnation of current daily speeds for high income countries (at least in urban areas) and the likely continuation of these trends into the future, but we are unsure how to capture the effect of disruptive technologies like AVs in travel speeds. Regarding diets, this deliverable equates ambitious lifestyle changes to those of eating according to health recommendations from the world Health Organization (WHO). To what extent this ambition is feasible, or leverages meaningful mitigation ranges, will be further assessed in expert consultation. We detail the main criticalities regarding the estimation of the lever in Table 12 of the Conclusions section. This deliverable makes available to the consortium

[1] www.european-calculator.eu/?cdm_linkout=NzU5 Access is allowed by request. Contact the lead author of the deliverable for further inquiries.

demographic and lifestyle levels resulting from the assumptions adopted to date. A brief description of these as well as links of access can be found in the Conclusions section.

2 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.

For the purposes of the EU calculator project there is the need to acquire a more holistic understanding of lifestyle patterns and drivers across European countries and economic sectors. This need is inherent to one of the core the objectives of the EU calculator project, that is, to give the user’s ability to adjusting the magnitude of future *technological* and *lifestyle* changes. Although the boundaries and gradation of these adjustments are to be defined iteratively in co-design process with experts throughout the lifetime of the EU calculator project, this deliverable delivers the first definition of lifestyle levers and levels that set the demand side of the EU calculator model. The preliminary quantification of the different lifestyle levers anticipates the expert workshops of transport, buildings and food/land providing therefore input for further discussions with stakeholders.

In this deliverable the country-specific quantification of lever levels is done by exploring the statistical relations between factors influencing lifestyles discussed during the expert consultation workshop on lifestyles (see summary of lessons in Moreau et al, 2017, Del.1.6 - Exploring lifestyle changes in Europe). In case quantification of the levels is not possible at the time of writing, the definition of the levels is provided together with a description of strategies to estimate them in the future. In addition to the quantification of lifestyle levers, this deliverable also makes available to the consortium demographic and urbanization trajectories for individual countries. Data on each lever subject to quantification is made available to the consortium in the format agreed in the Data Management Plan part of Del. 11.2.

The deliverable is structured as follows: In section 3 we introduce a lifestyle framework geared towards orienting the selection of drivers of lifestyles. Section 4 enumerates the lifestyle levers considered in this deliverable as well as the interactions with other WPs. Section 5 describes the alignment process of the demographic and urbanization levels with baseline estimates of population from WP7. Sections 6 to 9 provide the definitions, methodological details and quantifications of the lifestyle levers focus of this deliverable. Finally, we document the conclusions and provide a brief description and access to the dataset created in section 10.

3 Framing lifestyles in the EU calculator

We start by investigating "lifestyles" from a *consumer lifestyle perspective* adapting the framework proposed in Bin and Dowlatabadi (2005), see Figure 1, and in which lifestyle is defined as the "way of living that influences and is reflected by one's consumption behaviour" (pp 198). The influence and reflection of one's lifestyle can be traced across four large domains. In short, the "External environment" to the individual influences hers/his lifestyle through elements like accessibility to a given technology, the macroeconomic structure of the country, the physical infrastructure providing particular good or service or a set of national or supra-national (e.g., European) regulations.

Many of the products and services consumed at the individual level are not independent from the household characteristics in which she or he dwells. The consumer lifestyle approach acknowledges this by introducing the "Household characteristics" quadrant where factors such as age structure, education, income or location are accounted for.

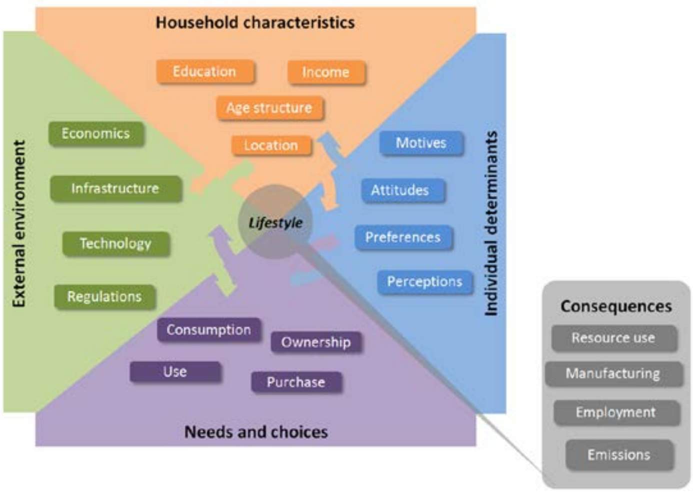


Figure 1 - Framework of consumer lifestyles in the EU calculator, adapted from (Bin and Dowlatabadi, 2005)

After the "External environment" and the "Household characteristics" shaping individual lifestyles we find the domains of "Needs and choices" and "Individual determinants". The first highlights lifestyles factors such as ownership patterns, consumption, purchase or usage, while the second accounts for factors such as attitudes, motive, perceptions and preferences of a consumer.

The key message is that according to the framework proposed "lifestyle" is a product of the interactions between the described domains. Hence, lifestyle is not a factor that one can measure in isolation (say for example the consumption of a good) but rather in combination of external environment, household characteristics and individual determinants that shape the consumption of that good. Given that not all factors in the quadrants can be effectively measured (e.g., those in the "Individual determinants" quadrant can be rather illusive), nor are they the chief concern of the EU calculator work; the lifestyles quantified in this deliverable are the reflection of a broader social, technological and cultural phenomenon.

Moreover, the framework materializes at some extent the concerns raised during the "Sustainable Lifestyle expert Consultation Workshop" (see Del.1.6). In this workshop, lifestyles were defined as "*a cluster of habits and patterns of behavior embedded in a society and facilitated by institutions, norms and infrastructures that frame individual choice".* In particular the framework makes an explicit account of expert feedback concerning that "*among the most important drivers of energy consumption, income and age distribution, are directly linked to lifestyles. The evolution of both of these variables was therefore identified as priorities to be integrated in the EU Calculator*" (pp 5).

Finally, it is important to underline that with the proposed lifestyle framework we do not intend to expand on the numerous discussions taking place on structuring the drivers of consumer lifestyles. The framework serves the purpose of providing the deliverable with a consistent reference of domains to be accounted, or reflected upon, when defining and projecting the lifestyle levers.

4 Lifestyle levers and interactions across work packages.

Based on the interactive consultations between WPs 2, 4 and 7, a total of six lifestyle and two demographic levers have been identified as critical for the core development of the model (see Table 1). Demography and urbanization levers are aligned with baseline projections documented in Del.7.1, in particular the matching of a suitable population age structure.

Table 1 - Levers investigated in the context of Del.1.3.

Sector/Scope	Levers	Units	Comments
Demography	Population	Habitants	Aligned with baseline in Del.7.1
	Urbanization	% of urban population	
Transport	Passenger travel distance	Pkm	In cooperation with WP2
Buildings	Use intensity	m^2/cap	In cooperation with WP2
Land	Calorie requirements	Kcal/cap/day	In cooperation with WP4
	Diets	Kcal/cap/day/food group	
	Waste	Kcal/cap/day	
Data	Data intensity	Gb/cap/day	In cooperation with WP4

In addition, baseline Gross Domestic Product (GDP) projections from Del.7.1 are used to partially drive transport demand. The transport demand lever has been developed in consultation with WP2 (Transport) in order to provide the basis for subsequent potential modal shift. Calorie demand, diets and waste levels are developed in consultation with WP4 (Land, Water & Biodiversity) in order to minimize potential feedback loops and adequate spatial coverage beyond EU28+Switzerland. Estimates on use intensity of buildings have been done in consultation with WP2 (Buildings).

5 Demography & urbanization

5.1 Population

Long term projections of population on continental and country scales have been developed for a multitude of scenarios. For instance, population projections in Europe can be retrieved from a number of sources such as the Eurostat (2016)[2], the EU-reference scenario (Capros et al., 2016), UNDP population prospects (2015)[3] or derived from the Shared Socio-economic Pathways (SSP) work (KC and Lutz, 2017). Although scenarios differ in time span and underlying assumptions (see Table 2), a plain comparison of the different data sources provides us a good starting point to understand the overall direction of population dynamics in EU28+Switzerland.

Independent of the dataset investigated, all projections anticipate some moderate growth in population until 2030 but from there on they start to diverge. UN population projections for EU28 peak around 2030 and decline steadily afterwards to circa 480 million by 2100, which is a drop of about 5.5% from 2015. Population gathered by the Eurostat suggest a continuous growth in population until 2050 followed by a slight decline.

Table 2 – Listing of population projection scenarios available for Europe.

Source	Scenarios
SSPs	SSP1 – Medium fertility of rich-OECD and medium migration. SSP2 – Medium fertility of rich-OECD and medium migration. SSP3 – Low fertility of rich-OECD and low migration. SSP4 – Low fertility of rich-OECD and medium migration. SSP5 – High fertility of rich-OECD and high migration.
Eurostat	Low fertility Low mortality High migration Low migration No migration
EU ref	Reference scenario

[2] http://ec.europa.eu/eurostat/cache/metadata/Annexes/proj_esms_an1.pdf, http://ec.europa.eu/eurostat/cache/metadata/en/proj_esms.htm
[3] http://www.un.org/en/development/desa/publications/world-population-prospects-2015-revision.html

		Low fertility
	UN	Medium fertility
		High fertility

SSPs' projections are based on different assumptions of fertility; mortality and migration for rich-OECD countries (encompassing 22 of the 28 Member states) and Switzerland). Except SSP5, they all show a population peak, albeit at different timings and different levels. Because SSP5 combines high human mobility and high fertility, the result is an ever increasing population for the EU28, toping at 750 million in 2100 (half of China's population today). In the other scenarios, migration and fertility rate of rich-OECD countries are kept moderate or low. Although the future portrayed by SSP5 is possible, the assumptions are hard to justify. According to SSP5, the population of EU28 by 2050 is estimated at circa 630 million. The Eurostat reports the population of EU28 at 508 million [4] for the year 2015. In order for 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 match SSP5 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[5]. 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[6].

The Eurostat scenarios also encompass several combinations of fertility and migration assumptions to project population numbers in Europe. The Low fertility scenario assumes shrinkage of the fertility rate by 20% over the projections period. In the Low mortality scenario age- and sex-specific mortality rates are reduced until reaching about +2 years of life expectancy at birth by 2070. Low and high migration scenarios assume, respectively, a decrease and increase of net migration by one third all over the projections period. Original to the Eurostat, in the realm of the analysed studies, is the inclusion of a no migration scenario in which net migration is set to zero.

5.1.1 Level definition

Against the background described in Section 5.1, two important constraints become evident when opting for the selection of future demographic development in the EU28 countries and Switzerland. The first is that the current positive trend in population numbers is expected to continue into the near future, the second is that high-end projections of population development are hard to justify from the stand point of the recent present. Accordingly, two levels of population proposed anticipate a sustained increase in population in EU28+Switzerland until the year 2050 and only two levels are devoted to capture a potential decline of population. Furthermore, we render a population increase

[4] http://ec.europa.eu/eurostat/tgm/table.do?tab=table&language=en&pcode=tps00001&tableSelection=1&footnotes=yes&labeling=labels&plugin=1
[5] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=migr_asyappctza&lang=en
[6] http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Fertility_indicators,_EU-28,_2001%E2%80%932015_YB17.png

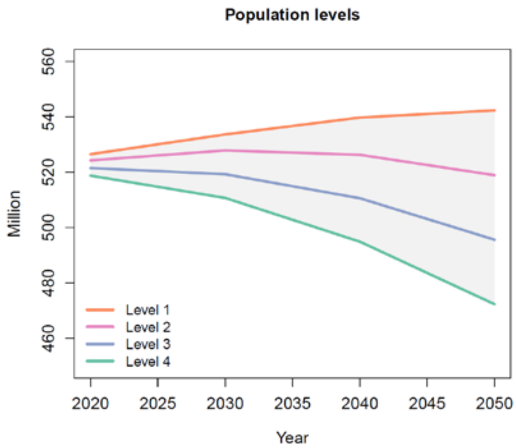
similar to that suggested in SSP5 as highly unlikely and hence our upper estimates have been constrained below SSP5 levels.

The suggested definitions of each level are shown in Table 3 while a graphical representation of their implications for the EU28+Swizerland, and individual countries is shown in Figure 2. We align the four levels with particular developments of population in existing literature and widely used in the scientific community. Level 1 is aligned with EU AR2015 (2015) population projection. This represents a scenario of moderate population growth in which by 2050 EU28+Swizerland population tops at 540 million, a relative increase of 6% in relation to 2015. With a per annum growth of about 1 million, this level best mirrors the continuation of the decadal-long positive trend of 1.3 million/year between 1994 and 2014 (European Commission et al., 2015). This population trajectory has been utilized in WP7 for the establishment of baseline GDP trajectories, refer to Del.7.1 for details. The country-specific estimates implied by Level 1 in EU28+Switzerland are shown on the right panel of Figure 2 for the year 2050.

Table 3 - Suggested definition of level for the population lever.

Level 1	Level 2
By 2050 the combined population of EU28+Switzerland reaches 540 million, in line with country trajectories from EU AR2015 and those in IIASA SSP2. This represents a 6% increase in relation to 2015.	By 2050 the combined population of EU28+Switzerland reaches 520 million, in line with country trajectories from IIASA SSP4. This represents a 2% increase in relation to 2015.
Level 3	**Level 4**
By 2050 the combined population of EU28+Switzerland reaches 495 million, an intermediate scenario between IIASA SSP4 and SSP3. This represents about 2% decrease in relation to 2015.	By 2050 the combined population of EU28+Switzerland reaches 472 million, in line with country trajectories from trajectories from IIASA SSP3. This represents a 7% decrease in relation to 2015.

Level 2 is aligned with SSP4 and portraits a population trajectory of low population growth resulting in a total of 520 million, a 2% increase over 2015 values. This scenario is a scenario of near-stagnation in which influx migration and fertility balance the loss of population through population aging.



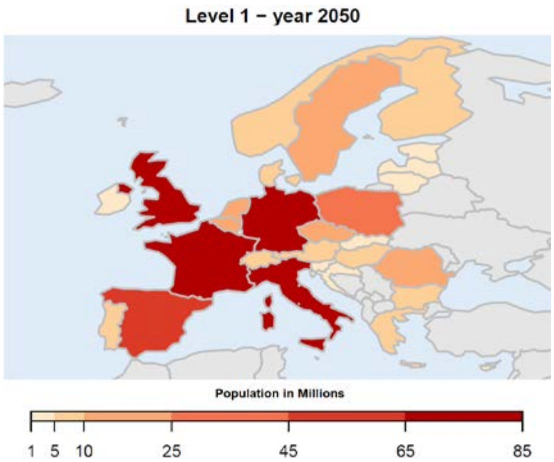


Figure 2 - Development of the population levels for EU28+Switzerland (left) and geographic distribution by 2050 according Level 1 (right).

Level 4 delivers a scenario in which EU28+Swizerland population steadily declines from circa 520 million in 2020 on to 472 million, a 7% decrease to 2015 levels. This level represents a future in which influx migration is tightly constraint and the fertility in EU28+Swizerland declines steadily. The inclusion of such scenario highlights the volatility of migration policies and increases the range of potential scenarios for user exploration. Level 3 is constructed as an intermediate scenario between that of level 2 and 4, characterized by a mild population decline of circa 2% by 2050 in relation to 2015.

5.2 Urbanization

Almost three quarters (72.5%) of EU28 inhabitants lived in cities, towns and suburbs in 2014, with considerable differences in the size and spatial distribution of urban developments between member states. Unlike for the case of population, long-term urbanization projections on a country scale are harder to come by for Europe. That said, we investigate urbanization estimates from the SSPs and the UN urbanization prospects (2014)[7]. 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.

5.2.1 Level definition

None of the scenarios in the two data sources gathered anticipates a decline in urbanization across EU member states. Accordingly, the continuation of the global megatrend of more people moving into cities and the slow decline of small settlements 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.

[7] http://www.un.org/en/development/desa/publications/2014-revision-world-urbanization-prospects.html

Table 4 - Suggested definition of levels for the urbanization lever.

Level 1	Level 2
By 2050 the average fraction of urban population in EU28+Switzerland reaches 84%, in line with projections from IASSA SSP2. This represents a 15% increase in urban population in relation to 2015.	By 2050 the average fraction of urban population in EU28+Switzerland reaches 80%, an intermediate scenario between the projections from IASSA SSP2 and SSP3. This represents a 11% increase in urban population in relation to 2015.
Level 3	**Level 4**
By 2050 the average fraction of urban population in EU28+Switzerland reaches 77%, in line with projections from IASSA SSP3. This represents a 7% increase in urban population in relation to 2015.	Given the current global urbanization megatrends a more aggressive level of urbanization slowdown is not considered for Europe.

The average urbanization trends implied in the levels defined in Table 4 are shown in the left panel of Figure 3. All levels show an upwards trend in the fraction of population living in cities between 2020 and 2050 though the urbanization speeds are rather distinct. Level 1 suggests an average fraction of urban population for the EU28+Swizerland at circa 84%, a substantial 15% increase from 2015 values. At circa 0.48% growth a year of urban population, this level is the highest of those investigated. Despite the relative convergence of countries towards more urban population, substantial regional discrepancies are estimated. Under Level 1 (right panel Figure 3), urban population in Slovenia reach 68% of the total, while Belgium's urban habitants are expected to make up 98% of its total population. The other countries, par Malta, rank between these two values.

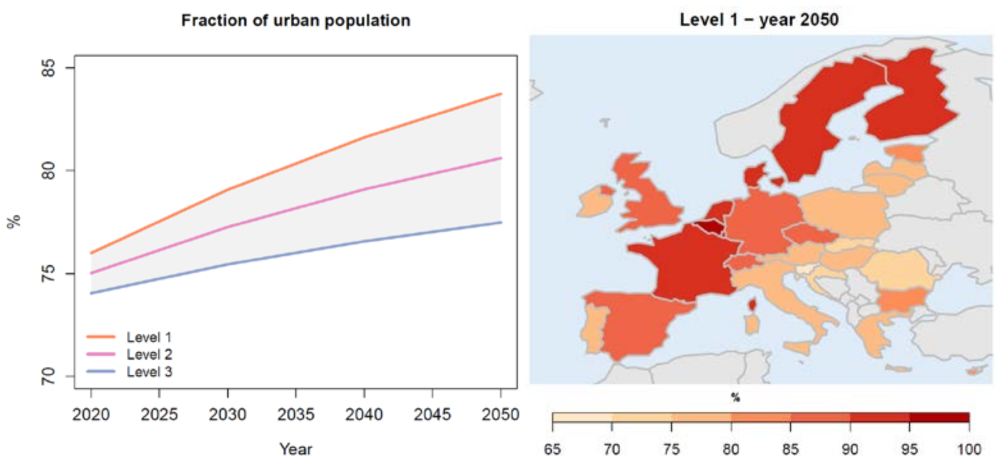


Figure 3 - Development of the population levels for EU28+Switzerland (left) and geographic distribution by 2050 according Level 1 (right).

Level 2 anticipates a constant growth in urban population of about 0.35% a year, reaching a total of about 80% by 2050. The spatial distribution of fraction of urban population implied by Leve 2 is similar to that of Level 1. Finally, in Level 3 the lowest rates of urban population growth are estimated. By 2050 average urban population in EU28+Swizerlamd reaches 77%, a shy increase of 7% in relation to 2015.

6 Transport

6.1 Passenger travel distance

In this deliverable only the lever passenger travel distance is evaluated for the transport sector. Other relevant levers such as freight transport and model shift are evaluated in WP2. The reasons for this choice are as follows: Regarding modal shift it was decided that this lever is very much interlinked with the degree of availability of certain transport technologies, say for example the availability of fast train connection, public transportation or AVs. Accordingly, we opted to have both the technologies affecting the modal shift and the modal shift itself treated in WP2. Freight transport is a reflection of the economic activity, which to some extent is shaped by individual lifestyle, but less so than passenger.

Passenger travel distance in EU28+Swizerland (usually given in the units of passenger kilometres per year per person, or 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 4). Broken down between air and land (see inserted area plot), total distance is highly skewed to the latter. In 2014 travel distance by land in EU28+Swizerland accounted for 85.9% of total travel distance, 3.5% less than in 1995; over the same time period, air travel rose from 10.6 to 14.1%. The relative decrease of travel distance by land in an age of generalized increase in travel can be traced to the drop in road passenger transport. Road passenger demand is the current dominant mode in the EU28, accounting for circa 80% of total passenger transport in 2015 (European Commission, 2016). The rate of change of road passenger transport has declined from 1% a year in 1995-2000 to circa 0.6% year in 2000-2015 (European Commission, 2016).

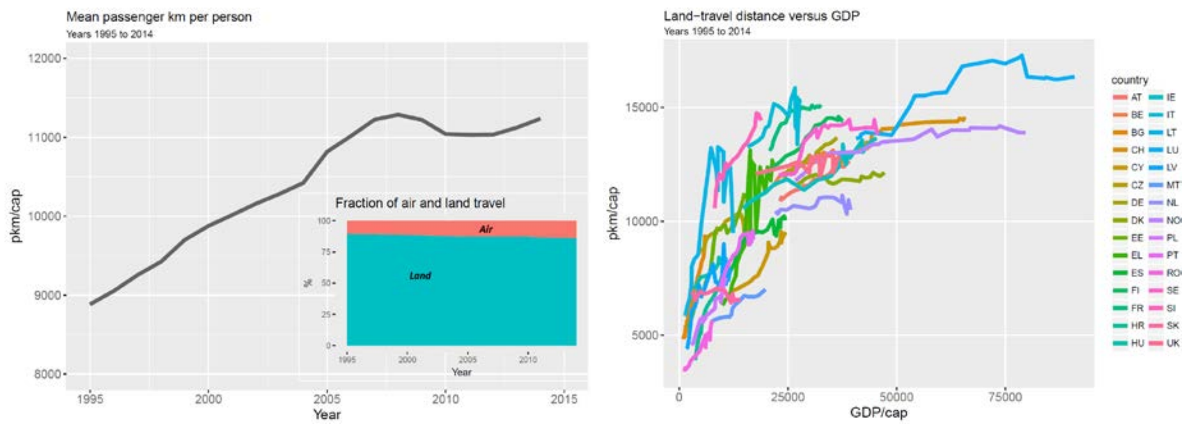


Figure 4 – Average pkm/cap (total travel) in the EU28+Switzeralnd (1995-2014) (left). Fraction of air and land pkm (inset). Pkm vs GDP in countries (right). Data: "EU Transport Figures, Statistical pocketbook 2016, (European Commission, 2016)", GDP from EUROSTAT[8].

Car passengers currently dominate road transport demand. But the sluggish growth in road passenger transport has increased the prospect of Europe being reaching, or at the edge of reaching "peak car" demand (Caralampo and

[8] http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=naida_10_gdp&lang=en

Panayotis, 2016; Millard-Ball and Schipper, 2011). For the US, pkm values of land-transport are only expected to significantly increase due to the introduction of disruptive technologies such as Autonomous Vehicles (AV's) and sharing schemes such as Transport as a Service (Arbib and Seba, 2017). By contrast, passenger transport by air within the EU28 has grown steadily above 2% a year since 1995 until today.

The travel demand response to economic development is mirrored in the 2008/2009 decline following economic recession. Although there are other factors influencing pkm values (which we describe in the section below), the most recent transport outlook is clear in stating that "despite political will and technological progress, demand for transport still primarily responds to the economic environment (*ITF Transport Outlook 2017*, 2017)" (pp 22). At the global scale, scholars have noted and quantified a close statistical correlation between the growth of GDP and growth in transport, both passenger and freight (Banister and Stead, 2002). The right panel of Figure 4 suggests that the relation between land-travel distance and GDP is also valid for EU28+Swizerland and it is likely of non-linear nature. The reductions in growth of land-travel distance for GDP values superior to 50000€/cap highlights that, within the current technological paradigm, other factors beyond GDP are at play in determining country-specific trajectories of pkm in time.

Despite the role of GDP per capita as a major driver behind the evolution of passenger travel demand across regions (Schäfer et al., 2009), there are a number of other factors that are required to reflect upon. These have been sampled from dedicated literature (Buehler, 2011; *ITF Transport Outlook 2017*, 2017; Metz, 2012).

In particular, income influences passenger travel distance: the greater income, the higher distance travelled. Age also impacts road travel demand. Many seniors (those over age 65) and people with medical conditions often face challenges traveling freely and independently and must rely on family, friends, government, or other providers to meet their basic mobility needs (Harper et al., 2016). On the individual side, travel time budget plays a pivotal role on influencing travel demand. Some authors pinpoint global and regional analysis on the apparent stability of this metric at circa 1.2h/day across socio-economic contexts and propose a maximum of 2h/day as upper limit of travel time (Schäfer et al., 2009).

Besides household characteristics and individual determinants, also the external environment in the form of infrastructure, laws and technology play an important role. Traffic congestion and the alternatives offered by public transport, walking and cycling contribute for saturation of car demand (Focas et al, 2016). As city-centre congestion increases, people are willing to pay more for space and amenities, so they travel farther to live where land is less expensive and home-based movement easier (Gwilliam, 2002). In addition, household proximity to public transport is associated with a lower share of trips by car (Buehler, 2011), the driving force of road transport demand. Changes in technology have significant effects on travel demand (Golob and Regan, 2001) and the speed to which technological change can affect transport demand is suggested to be substantial. By 2030, within 10 years of regulatory approval of AVs, 95% of US passenger kilometers travelled are expected to be done in on-demand autonomous electric vehicles owned by fleets, not individuals (Arbib and Seba, 2017). The net result, the authors say, is a growth of passenger miles from 4 to

6 Trillion in the time frame 2020-2030 after a period of stagnation between 2017 and 2021. Fuelling this change is the scale of the cost differential between public and private ownership influencing consumer choice (Arbib and Seba, 2017). This reinforces the role of income in travel distance.

While the absence of future growth in per capita daily travel by land would seem a reasonable assumption for a central case, business-as-usual scenario (Metz, 2012), the emergence of disruptive technologies such as AVs, would reconfigure the dependency network described. Not only would individuals have more disposable income for transport given the cheaper prospect of not having to own a car, but other factors would be transformed as well. Distance to public transport would be reduced to a minimum given that AVs would just stop at the doorstep. Automated vehicles represent a technology that promises to increase mobility for many groups, including the senior population but also for non-drivers and people with medical conditions. Increases of AVs could lead to an estimated 14% increase of vehicle travelled miles for the US population 19 and older (Harper et al., 2016). The emergence of such technological disruptions in the transport sector will be mimicked by a modal shift lever developed in WP2 (transport section). This deliverable is only concerned at the moment in determining plausible approximations of total distance travel without developing further granularity regarding the transportations mean.

6.1.1 Level definition

Departing from our understanding of the influencing factors determining passenger travel demand we narrow our investigation to the interplay between three factors: income, age structure, travel budget (broken down by travel activity) and speed of transportation (daily speed). These factors are incorporated in a model of passenger travel demand (see Figure 6). Similar to others, the proposed model hinges on the basic principle that the maximum amount of time a person dedicates to travel is limited, is rather independent of socio-economic or cultural differences between countries and is set at about 2 hours per day (Schäfer et al., 2009). A compilation of daily travel times for 17 European countries (see Figure 22 in section 11.1 of the Annex) reveals a typical mean value of 1.2 hours, which indicates the potential for a growth in travel distance in Europe. Countries are also remarkably similar between themselves. Daily travel times below 1 hour are rare from the sample investigated with standard deviation at around 10 minutes. When disaggregating travel time by activity (see Figure 23 in section 11.1 of the Annex) it is apparent that the dominant activities determining 80% of daily travel time are: leisure, work/study and services/shopping.

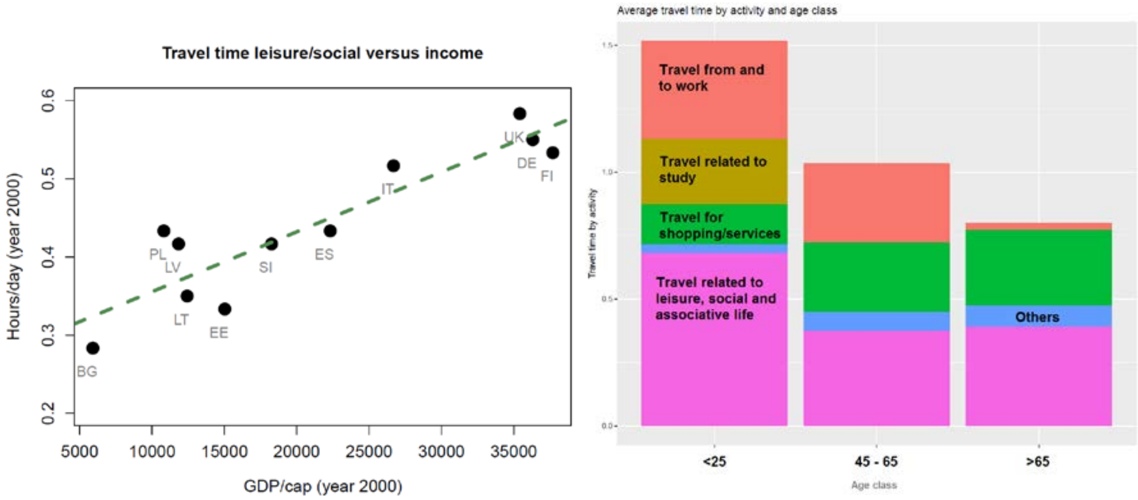


Figure 5 – Linear correlation between travel time for leisure/social activities and GDP for the year 2000 (left). Average travel time by activity and age class (right).

We treat these three activities as separate in our model in order to allow for a sensitivity analysis of the consequences that lifestyles changes (say, less time spent on travel commuting) might entail for passenger travel distance. Employing a simple linear correlation analysis between hours spent traveling for leisure activities vs income per capita (see Figure 5 left panel), we observed a strong association between the two quantities for the year 2000 (adjusted $R^2=0.79$ at *p*-value[9] <0.001). The analysis comprises 11 data points for which complete information on travel time by activity was available for the year 2000 (Eurostat, 2003). A similar statistical association was investigated for the cases of travel time dedicated for work/study and for services/shopping (see Figure 23 in Section 11.1 of the Annex). In both cases no significant correlations with the income level of a country. It was noted observed nevertheless a change in travel time with age, in particular a marked decline of travel time dedicated to work/study activities between the age classes of individuals below 25 and above 65 (Figure 5 right panel). Changes in travel times for shopping and services are also noted albeit in a much less pronounced way.

The implications of this empirical evidence for our model are as follows. We assume that travel time for leisure is a linear function of income levels in a given country so that as countries get richer more time is devoted to leisure and social activities, which implies a general increase in total travel times. On the other hand, we assume travel time dedicated to work activities is a linear function of the age structure of a country, so that travel times to work/study decline with aging population. Travel time for work activities has been acquired from the European Quality of Life Survey[10] for the years 2003, 2011 and 2016 (Eurofound, 2017). Across the EU28 members, the differences in travel time dedicated to work/study activities between the age groups <25 and >65 have been calculated to range between 0.1 for countries such as France and Finland, to 0.6 hour for countries such as Netherlands and Poland (see Figure 24 in section 11.1 of the

[9] In statistics a small p-value (typically ≤ 0.05) indicates strong evidence of the existence of a relationship between two measured phenomena, in our case, income and travel time for leisure activities.
[10] https://www.eurofound.europa.eu/data/european-quality-of-life-survey

Annex). For each country specific linear slopes between the time travel for work/study between the age classes <25 and >65 was determined for the average of the 2003, 2011 and 2016 surveys. The country-specific decline of time travel for leisure is then interpolated for the age prime classes 25-54. Due to the lack of a meaningful observed dependency between travel times for shopping activities with income or age, our model assumes a constant 0.20h of across all countries. This oversimplification is noted and will be a point of further discussion in the upcoming expert consultation workshop for transport.

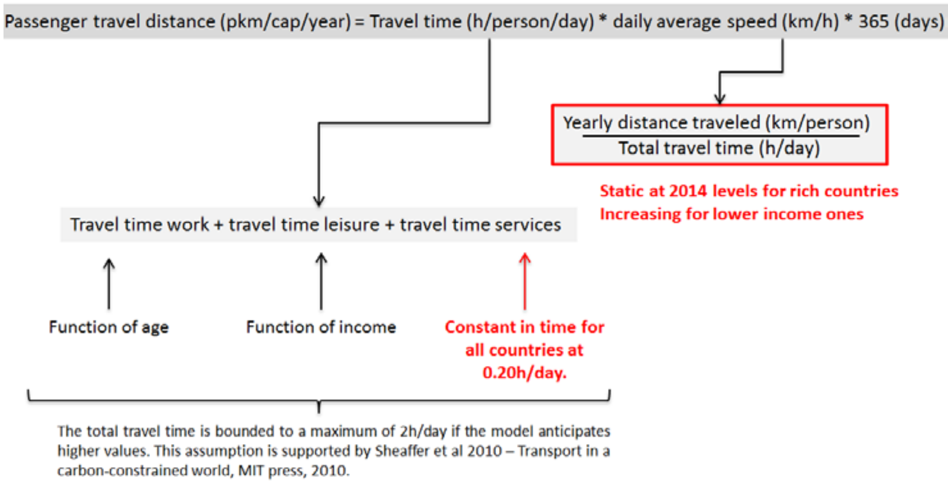


Figure 6 - Proposed EU-calculator model of passenger travel demand and important discussion points for the transport expert workshop (in red).

The final aspect to consider with respect to passenger travel distance within our framework is average daily speed. This is an important issue, especially in the hypothetical case when individual travel time distances converge and saturate at the suggested maximum of 2h. In such a scenario the totality of future increase or decrease in passenger travel distance would be controlled by average daily travel speeds. Consistent databases on average travel speed that would range across all, or at least a significant proportion of EU28 member states, were not found.

Accordingly, this deliverable takes an alternative route to determine the past evolution of average daily travels speed. The rationale of our exercise rests on three lines of evidence. The first is that land transport, specifically road transport, dominates total passenger travel demand in Europe (European Commission, 2016). The second is that urban population in Europe constitutes more that 70% of the total, with no prospects of a reversing of the trends (see section 5.2). The third is that cities (where urban population dwells) may be facing a reduction of average travel speeds. Across the 1.360 cities studied by INRIX, a consultancy, average traffic speed in congestion for the year 2017 was just 14.4 km/h, the same value as in 2016 (Cookson and Pishue, 2017) (pp 3). For Central London, the time required for traveling 8 km at peak times has increased from below 20 minutes to more than 25 between the years of 2012 and 2015. The same declining trend has been observed for Greater London, where travel times are usually smaller for the same distance.

The London Streets Performance Report (Transport of London, 2017), issued by the Department for Transport (DfT), shares the same negative view on road congestion. In the Third quarter of 2016/17 average traffic speeds for the 12 hours between 07:00 and 19:00 across central London were 11.7km/h, a 5.3% decrease year-on-year (Transport of London, 2017). On longer time scale, the overall trend in traffic speed has been reported as “remarkably stable” between 2007 and 2012 (Transport of London, 2016). Since 2007 the trend for average vehicle speed has been downwards in all parts of London, but particularly in Central London. Average traffic speeds have declined in all sectors and time periods between 2014/15 and 2015/16. Largest declines were observed across the central area, between 12.6 and 11%. We further evaluate average speed on local ‘A’ roads for urban roads across all England[11] for the years 2014, 2015 and 2016 (black dots in Figure 7) and found a small but consistent downwards trend in average speeds, from circa 31.7 km/h in 2014 to 29.9 in 2016, a 5.6% decrease. We suggest there are strong indications that urban travel speeds from road transport have either remained stable of slightly declining in London and in England’s urban areas. It is not given that such trends also apply to other major urban areas in Europe but taking London/England as a test location we devise the following exercise.

Based on the empirical relations between income and travel time for leisure, and age and travel time for work/study, we “backcast” travel time from 2014 to 1995 based on our own estimates of travel time and observed value of passenger travel distance (see Figure 4 right panel). In practical terms, we solve our model in order to return travel speeds, knowing in advance the passenger travel distance and estimating travel times. The results for Germany, UK, Poland, Portugal and Romania are presented as lines in Figure 7.

We observe generally a stabilization or slight decline of average daily speeds in rich countries such as the UK and France. For Poland and Romania average speeds have been estimated to be increasing during the 1995-2014 period. We also present how our estimated of average travel speed fair regard to the observed average speed on local ‘A’ roads for urban roads across all England[12], represented as back dots in Figure 7.

[11] https://www.gov.uk/government/statistical-data-sets/average-speed-and-delay-on-local-a-roads-cgn05

[12] https://www.gov.uk/government/statistical-data-sets/average-speed-and-delay-on-local-a-roads-cgn05

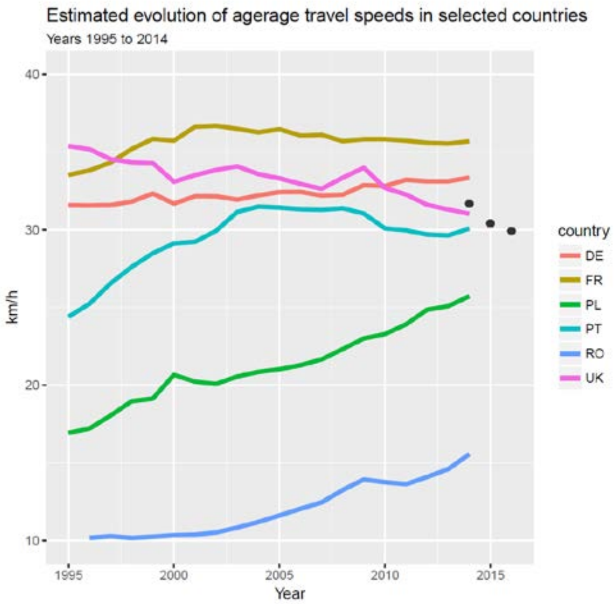


Figure 7 – EU-calculator reconstruction of average daily speeds for selected countries. Black dots refer to average speed on local 'A' roads for urban roads across all England[13] for the years 2014.

Interestingly the estimates align well with observations, both regarding the overall trend and the magnitude of the speeds. Although this does not constitute a clear cut validation of our method, it does give us confidence to consider that daily travel speeds might have a dual behaviour in rich and less affluent countries. Additionally, having daily speed explicitly modelled provides the consortium with additional flexibility for incorporating expert inputs regarding potential disruptions in the transport system improving travel speeds. We will subsequently present this approach in the expert consultation workshop for transport. Building from the descriptions and results beforehand, we elaborate in Table 5 the definition of the levels of passenger travel distance.

Table 5 - Suggested definition of levels for the passenger travel distance lever.

Level 1	Level 2
By 2050, average passenger travel distance in EU28+Switzerland reaches 14000 pkm per person, a 25% increase from 2015 levels. Increases are driven primarily by the growth in travel time dedicated to leisure/social activities. Travel to work/study decreases with aging population and travel time for shopping is kept constant. Daily travel speeds are kept constant at 2015 levels for countries with high GDP in 2015 and increases for the ones below according to past rates.	By 2050, average passenger travel distance in EU28+Switzerland reaches 13000 pkm per person, a 15% increase from 2015 levels. Moderate changes in lifestyles make the need of daily travel time to work/study fall by 20% in rich countries and 10% in others, while advances in automation cut the need for travelling for shopping by 5% in all countries. Travel time dedicated to leisure/social activities increases as in level 1. Daily travel speeds are kept constant at 2015 levels for countries with high GDP in 2015 and increases for the ones below according to past rates.
Level 3	**Level 4**
By 2050, average passenger travel distance in	By 2050, average passenger travel distance in

[13] https://www.gov.uk/government/statistical-data-sets/average-speed-and-delay-on-local-a-roads-cgn05

EU28+Switzerland reaches 12400 pkm per person, a 10% increase from 2015 levels. Moderate lifestyle changes that make the need of daily travel time to work/study fall by 20% in all countries and advances in automation cut the need for travelling time for shopping by 10%. Travel time dedicated to leisure/social activities increases as in levels 1 and 2. Daily travel speeds are kept constant at 2015 levels for countries with high GDP in 2015 and increases for the ones below according to past rates.	EU28+Switzerland reaches 11000 pkm per person, roughly the same level of 2015. Substantial changes in lifestyles make the need of daily travel time to work/study fall by 50% in all countries and advances in automation cut the need for travelling time for shopping by 25%. Travel time dedicated to leisure/social activities increases as in levels 1, 2 and 3. Daily travel speeds are kept constant at 2015 levels for countries with high GDP in 2015 and increases for the ones below according to past rates.

The quantitative estimates of passenger travel distance for EU28+Swizerland in time and disaggregated by country implied by Level 1 are shown in Figure 8.

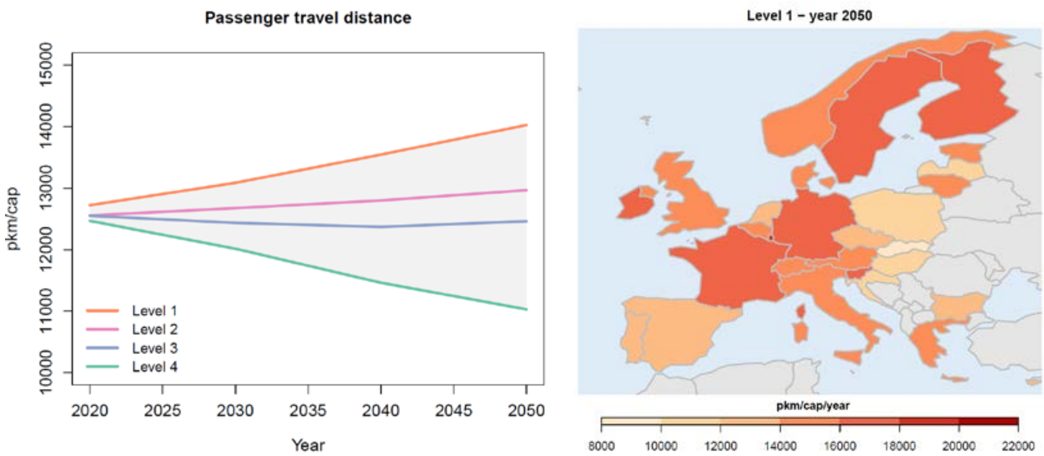


Figure 8 – Development of EU28+Swizerland passenger travel distance implied in the definition of the levels (left). Spatial distribution of Level 1 for the year 2050 (right).

Three levels anticipate an increase in average passenger travel distance in Europe while one anticipates stagnation to 2015 values (which a peak in the year 2020). Levels 1 and 2 are those in which the increase by 2050 is higher, respectively 25 and 15% of current 2015 values. In Level 3, the proposed changes in lifestyles cut the increase to circa 10%, while in Level 4 a near stagnation of average values around 11000 (similar to today but do note the peak by 2020 at circa 12500 pkm/cap) is achieved mostly due to significant reductions in travel to work and shopping. The latter are possible due to important advances in teleworking and automation that cut travel times for work and shopping by 50 and 25% in all countries considered.

7 Buildings

7.1 Building use intensity

Eurostat defines a building as any “independent structure containing one or more dwellings covered by a roof and enclosed within external walls” [14]. Within buildings, dwellings are rooms or suite of rooms designed for habitation by a

[14] http://ec.europa.eu/eurostat/statistics-explained/index.php/People_in_the_EU_%E2%80%93_statistics_on_housing_conditions

private household. In 2012 the Eurostat 2012 ad-hoc module 'Housing Conditions' 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, see original data table and reference in Section 11.2 of the Annex. Furthermore, 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 average floor area of dwellings from the EU Buildings Observatory Database[15] and determine the per capita floor area of dwellings for EU28 Member states between the years 2000 and 2014. The evolution in time of the median is characterized by an increase from 38.1 to 46.4 m^2 between the years 2000 and 2014, a per annum increase of 1.45% (referenced to the year 2000), see Figure 9.

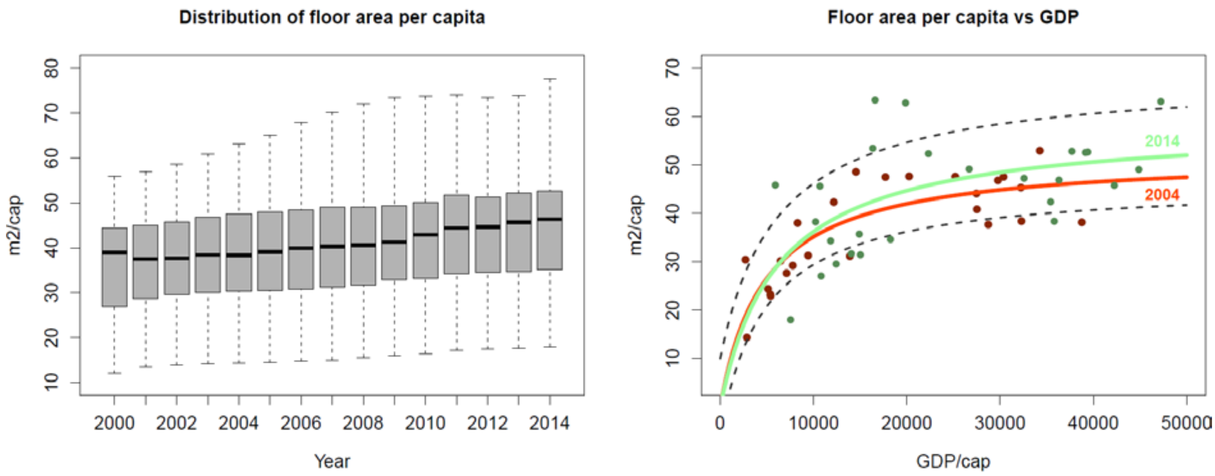


Figure 9 - Evolution of residential floor space per capita between 2000 and 2014 (left) and its relation to country GDP for the years 2004 and 2014 (right).

The variability across member states is likely the results from an intertwined dynamic between economic development, construction prices, population dynamics and urban-planning philosophies among others. In this deliverable we explore the empirical relation between income levels and average residential floor space in the EU28 between 2000 and 2014. We apply a generalized non-linear function to estimate the average per capita floor area (x):

$$x = \mathrm{a} * \frac{GDP}{b + GDP}$$

In which GDP is the country-specific GDP per capita; *a* is the asymptotical maximum of the function and *b* the speed to which par capita floor area converges to the maximum. A similar approach has been followed to approximate global housing area for heating and air conditioning energy demand (Isaac and van Vuuren, 2009). We chose a non-linear function with an asymptotical maximum because it is not realistic (nor physically possible) that

[15] https://ec.europa.eu/energy/en/eu-buildings-database

that the floor size per capita increases indefinitely with income. At some point more income does not translate into largest floor area per person. Furthermore, we need to have a model that does not treat the increase in the floor area equally across income levels. Countries with lower income levels have more potential to increase their floor space per capita than those enjoying already from higher incomes; in simple terms: one additional euro in income would “buy” you more floor space in Romania than in Luxemburg.

The parameters *a* and *b* are estimated using Non-linear Least Square method and are, respectively, 52.6 and 4798.1 at p-values <0.0001 and residual standard error of 5.7m^2/cap for the year 2004 fit (for 2014 a=58.4, b=6133.6, p-values= 0.001 and residual error =9.98). The model captures the sharp rise in average floor area taking place in the region of income below 15000€/cap. In this region small gains in income come associated with comparatively high increases of floor area. Average floor area gains with income start to level-off at income levels of 20000 and beyond.

The resulting maximum of the function highlights the unlocked potential for further growth in residential floor space in Europe. According to our simplistic model, average residential floor space in Europe can grow by a further 12 m^2 (the difference between the fit maximum for the year 2014 and the 2014 median value, 58.4 - 46.4m^2) with raising income level. In theory the floor space per capita could grow even further but taking into account the time horizon between today and 2050, and the lack of a better informed opinion, we take this potential for growth as a valid limit to inform the establishing of levels for the floor area intensity lever. In case this value proofs too conservative during the expert consultation discussions it will be revised accordingly.

By focusing on the mean evolution of floor space in Europe the model disregards a number of factors contributing for the contrasting distribution of floor area across the different member states. Some of these are connected to past regulatory frameworks (see “External Environmental” quadrant in Figure 1). This has been the case for example of former centrally-ruled socialistic states. Until 1956 it was allowed for an individual in the Soviet Union to build a house with maximum 5 rooms without having laying down a limit in terms of its overall size in square meter. From 1956 on, the Presidium of the Supreme Soviet declared 60m^2 as a maximum for private dwelling size (with concessions to certain social groups) (Andrusz, 1984).

In Europe, arguably, the biggest effect on rising per capita floor space comes from a reduction in the average household size. Between 2008 and 2014 median household in the EU28+Switzerland decreased from 2.50 to 2.40 persons. At the same time, median floor area per capita increased from 40.62 to 45.68 m^2/cap. The high sensitivity of residential floor size per capita with household size coupled with the differences in the fit maximum obtained in Figure 9 (right panel), leads us to propose the following theoretical model of floor size change in Europe. For lower incomes countries small gains in income lead to disproportional gains in floor space per capita and that this effect overrides that of demographic changes occurring simultaneously in the countries. Note how both curves (2004 and 2014) overlap in that region almost perfectly after 10 years of demographic change. From about 20000€/cap the income effect becomes progressively residual and average floor per capita is dominated by demographic changes in the population, namely household size. We suggest that a separation of the two curves for the region beyond 20000€/cap is an indication that income no longer plays the major role in determining floor area.

7.1.1 Level definition

The model proposed raises a fundamental challenge in the formulation of ambition levels (3 and 4 mainly) of per-capita numbers of residential floor area. Namely, we will have to venture into the "Individual Determinants" or "Needs and Choices" quadrant (see our framework) and decide upon future values of household size, which may be seen as controversial. In practical terms we assume that a change in the average household size for EU28+Switzerland leads to a corresponding shift in the maximum of the fit.

Table 6- Suggested definition of levels for the building use intensity lever

Level 1	Level 2
By 2050, average residential floor space in EU28+Switzerland reaches 57m2/cap, a 17% increase from 2015 levels. Changes in floor area are driven by the continuation of its past relationship with income and constant household size of 2.2.	By 2050, average residential floor space in EU28+Switzerland reaches 54m2/cap, an 0% increase from 2015 levels. Changes in floor area are driven by the continuation of its past relationship with income and constant household size of 2.3.
Level 3	**Level 4**
By 2050, average residential floor space in EU28+Switzerland reaches 51m2/cap, a 4% increase from 2015 levels. Changes in floor area are driven by the continuation of its past relationship with income and constant household size of 2.5.	By 2050, average residential floor space in EU28+Switzerland reaches 49m2/cap, a near zero increase from 2015 levels. Changes in floor area are driven by the continuation of its past relationship with income and constant household size of 2.6.

We parameterize this shift as follows: In the year 2000 the average household size in Europe was of 2.6 persons[16] and the maximum of our fit for the same year 48.1. In 2014, average household size in Europe was of 2.4 and the maximum of that year fit 58.4. This implies that for each decrease of 0.1 in household size, the maximum of the model proposed increases by approximately 5m^2. In practice, a future decrease of household size in our model by 0.1 would result in a shift upwards of 5.25 in the *a* parameter. For simplicity, the *b* parameter is fixed for now at 2014 levels. These two constraints will be discussed in the forthcoming expert workshop and if needed they will be changed accordingly. Finally, we acknowledge that the over simplistic model here proposed is best at explaining the evolution of average floor area per capita for Europe as a whole and that it partially ignores some of the inter-member-state variability, note nevertheless that that most countries can be found within 1σ of the fits (see dashed lines in Figure 9).

16 https://www.bmdw.gv.at/Wirtschaftspolitik/Wohnungspolitik/Documents/housing_statistics_in_the_european_union_2010.pdf

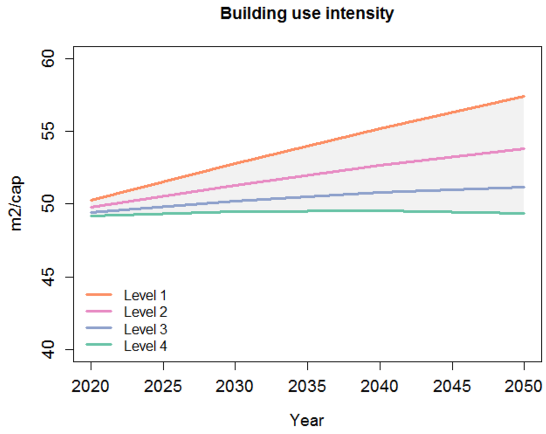


Figure 10 - Development of EU28+Swizerland building use intensity implied in the definition of the levels.

In order to obtain country-specific estimates we assume all countries keep their relative position to the fit in the future. We define levels 1 to 4 for the lever building use intensity as described in Table 6. The quantification of each of the proposed levels between 2020 and 2050 is shown in Figure 10. Given the critical issue of suggesting an inversion in the evolution of the household size, we do not further explore the implications of our results but will intensively discuss these in the expert workshop on buildings planned for June 2018. The main take home message is that our empirical model is flexible enough to allow for a recalculation of the level after expert feedback.

8 Food

8.1 Calories, diets and waste

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 midcentury (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 (above 2150 and 2270 kcal/cap/day respectively) (Pradhan et al., 2013). In regard to particular food groups, 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. 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 strong and slight negative time-trends are possible (Bodirsky et al., 2015). It is important to mention that the abovementioned studies equate total calorie availability in a country as calorie demand. In this sense, they do not estimate the real consumption of calories by the population but rather the calories per capita that are in theory available for each person in a given country.

This section will determine in total level for three levers: calorie requirements for human population (not the theoretic calorie availability), the slit of calorie requirements by food groups (e.g., animal products, vegetables, sugar…) and calories lost due to food waste at the consumer level. It is important to highlight that, very much as with the case of travel distance, income is not the only factor influencing calorie demand, dietary choices nor waste. An in-depth literature review (Stoll-Kleemann and Schmidt, 2017) looking for factors that influence meat-eating behaviour has exposed a myriad of emotional, cognitive, socio-economic, political and incentive factors controlling personal behaviour. Many of these factors link directly to the framework in Section 3. Notably, the review argues that the promotion of new social norms and the use of the health argument (health gains obtained by the reduction of meat consumption) are promising pathways to motivate change. Accordingly, the estimation of the three levers will be based on, a) the evidence that calorie demand increases with income and that stagnating to negative trends are observable for high income countries and b) that the health argument and the adoption of new social norms facilitates behavioural change.

8.1.1 Level definition (biophysical calorie requirements)

Our estimates of calorie requirements are mostly based on the methodology put forward in Hiç et al., (2016). In this work biophysical 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[17]. Accordingly, demographic changes alone (given BMI and PAL constant) are enough to observe changes in calorie requirements. The energy requirements are separately calculated for four age groups, “infants”, “children and adolescents”, “adults”, “elders”, and “pregnant and lactating women”.

Changing lifestyles, for example, towards more sedentary activities, or the option for less healthy and more heavily processed food, influence BMI. Historically, BMI has been increasing at a slow pace in several European countries (see Figure 25 in section 11.2 of the Annex). This highlights the potential to now reverse the trends and start pushing for a generalized achievement of desirable weight across the population (BMI of between 18.5–24.9 according to World Health Organization (WHO) while BMI’s above 30 is taken as an indicator of obesity[18]). 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 (see Figure 1 Figure 11). Worryingly, the decadal trends of obesity prevalence have been increasing across Europe at rates as high as 0.5% a year (see Figure 26 in section 11.2 of the Annex). The potential for weight reduction, diminution of the BMI and by extent a decrease in dietary requirements in European countries seems substantial.

[17] http://www.fao.org/3/a-y5686e.pdf
[18] http://www.euro.who.int/en/health-topics/disease-prevention/nutrition/a-healthy-lifestyle/body-mass-index-bmi

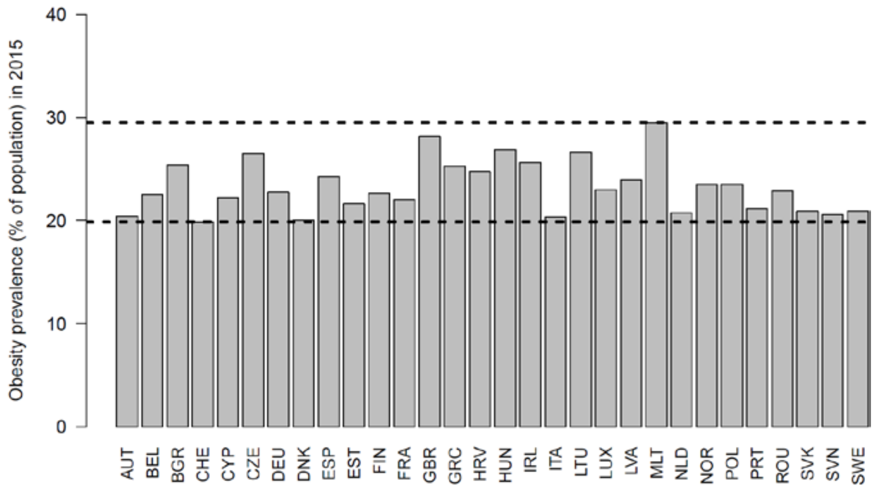


Figure 11 - Percentage of population with BMI>30 in European countries in 2015. Dashed horizontal lines depict maximum and minimum of the sample.

Finally, in regards to last aspect (PAL), due to the fact that no standardized global data on PAL for countries is available, Hiç et al., (2016) kept the factor constant at the same level observed for non-overweight adults in the US[19]. We take the same approach. It is important to consider that 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 deliverable and therefore are not explicitly investigated. They may be taken up as discussions points in expert consultation promoted in WP4.

Accordingly, we scale the central estimates (using SSP2 demographics) of calorie requirements in Hiç, et al., (2016) in order to reflect the different levels defined in Table 7. The scaling is done as follows: the central estimate in Hiç, et al., (2016) for each country is related to their current (2015 BMI). For Level 1, we estimate the past individual trends of a country BMI (200 to 2015) and extrapolate these, linearly to 2050. We then determine the relative increase of the BMI in 2050 to that of 2015 and scale the calorie requirements proportionally. For level 2 we directly take the calorie values of the above publication. For levels 3 and 4 the pressure is similar but now the future BMI is determined by evaluating what fraction of the present country's BMI is associated with obesity. This fraction is then divided by 35 years (the years between 2015 and 2050) and subtracted, year-by-year, from the present BMI of a country. The calorie requirements resulting from the new BMI are then determined using the same rule as for level 1.

Table 7 - Suggested definition of levels for the calorie requirements lever.

Level 1	**Level 2**
By 2050 average daily kilo-calorie requirements per person in the EU28+Switzerland reaches circa 2560, a 3% increase over 2015 levels. BMI increases following country-specific observed rates. Physical activity levels are assumed to be the same across countries and	By 2050 average daily kilo-calorie requirements per person in the EU28+Switzerland reaches circa 2450, a 3% decrease over 2015 levels. BMI is kept constant at current levels. Physical activity levels are assumed to be the same as in level 1.

19 http://www.fao.org/3/a-y5686e.pdf

equated to that of non-overweight adults in the United States (FAO et al., 2001).	
Level 3	**Level 4**
By 2050 average daily kilo-calorie requirements per person in the EU28+Switzerland reaches circa 2330, a 8% decrease over 2015 levels. Changes in lifestyles lead to countries to quarter their current percentage of obese (BMI>30) population requiring less total calories. The remaining assumptions are common to levels 1 and 2.	By 2050 average daily kilo-calorie requirements per person in the EU28+Switzerland reaches circa 2210, a 15% decrease over 2015 levels. Changes in lifestyles lead to countries to halve their current percentage of obese (BMI>30) prevalence requiring less total calories. The remaining assumptions are common to levels 1 to 3.

Under the assumption made, average total (without differentiation of which type of food, see section 8.1.2) daily kcal requirements per person in Europe were estimated to range between 2560 (in a Europe of slightly increasing BMI) and 2200 (in a Europe where obesity is halved) by the year 2050. Intermediate levels 2 and 3, portrait respectively a future in which no further increase of BMI to those of current levels takes place and a Europe in which obesity prevalence is slashed to a quarter of current values by 2050. Under Level 1 assumption lower income countries catch-up, by 2050, to dietary requirements of those observed in high-income EU28 countries today (see Figure 12, right panel). Calorie requirements in high-income countries stagnate or decline. This has mostly to do with changes in the population composition towards higher fractions of elderly population, which require in average less food.

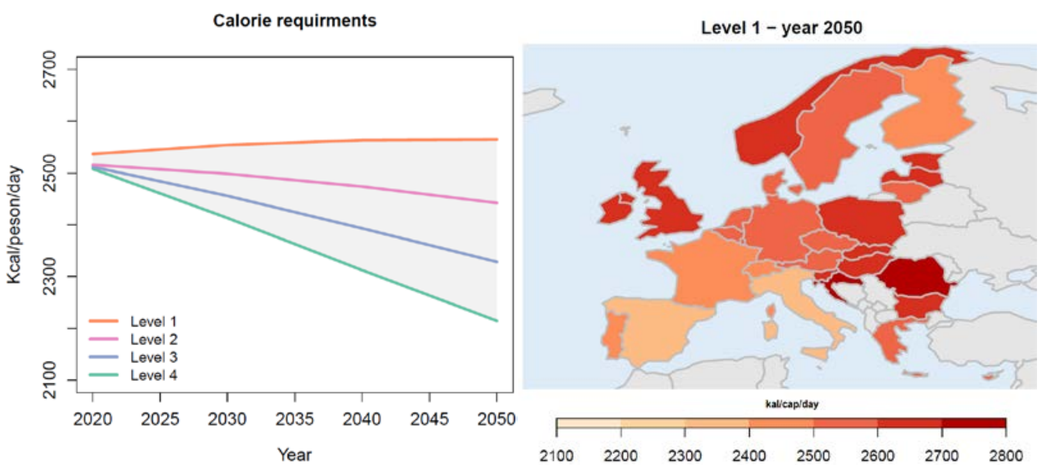


Figure 12- Development of EU28+Swizerland kcal/cap/year requirements (left). Spatial distribution of kcal/cap/year implied by Level 1 for the year 2050 (right).

8.1.2 Level definition (diets)

Fulfilling the calorie requirements proposed in section 8.1.1 can be done in a variety of ways. Cultural, geographic (e.g., proximity to coast) and climatic (e.g., cold climates) characteristics shape the diets - here defined as the composition of food groups to satisfy calorie requirements - of a given population. There are a number of ways food groups can be defined. In the EU calculator we have opted to define food groups based on FAO data but applying an aggregation scheme that would better suit the objectives of our model. The defined food groups adopted for the EU calculator are shown in Table 13 of Annex section

11.2. A total of 18 food groups are considered as basis for diet specification in the EU calculator. The choice of food groups was done in consultation with WP4 and WP6 in order to maximize the linkages with the agriculture production and economic flows respectively.

There are several possible guiding principles one can follow for defining the future of diets across the EU28 countries+Switzerland. Given that the focus of the EU calculator project it would be clear to assume that the guiding principle should be the potential mitigation effect of diets in GHG emissions. But while using the environmental argument to define diets is valuable its message will not resonate across all fringes of society, hardly any single argument will ever do. Accordingly, complementary to the environmental argument, diets can be defined from the sand point of health. Importantly, both the environmental and health view are not in contradiction when it comes to the GHG savings. A review by Aleksandrowicz et al., (2016) over 63 literature studies has pinpointed GHG savings form a variety of diets. The study reports that the largest GHG reductions are attained by vegan diets, median reduction of GHG in the order of 45%. Vegetarian diets were linked to median savings of 30% while diets following healthy guidelines 12%. Accordingly, both views on defining diet compositions lead to GHG savings, with the main difference between them hinging on the magnitude. For the purposes of this deliverable, and prior to user consultation on agriculture and land use, we opted to define future diet levels from the point of view of health but knowledgeable that these result in environmental gains from the point of view of GHG emissions. If the need for a more stringent dietary pattern based on environmental benefits is identified by experts; then we will do so.

We define a healthy diet in the EU calculator as that whose amount of sugars, fats, vegetables and fruits and red-meat match the healthy nutrition recommendation from WHO (WHO et al., 2003) and World Cancer Research Fund International and American Institute for Cancer Research (WCRF/AICR) (World Cancer Research Fund International and American Institute for Cancer Research, 2007). Whenever possible, we use ranges of minimum and best recommendation. The magnitude of the challenge ahead for achieving European-wide healthy diets is observable in Figure 13. Of the European countries assessed 11 are likely below the minimum healthy dietary requirements regarding the consumption of sugars and sweeteners, while none is likely to be below the best recommended level (see left panel of Figure 13) [20]. Switzerland champions on the availability of sugar and sweeteners for its population at circa 2.5 times the best WHO recommendations for a healthy diet. Reducing the demand for sugars will indirectly alleviate pressure on land by decreasing the need of certain plantations such as sugar cane.

[20] Calories estimated for each country refer to the total calories available in the market and not those actually ingested. Nonetheless, if the calories ara avaialble it is unlikely that they would not be at large estent ingested by the population. Hence the use of the word “likely”.

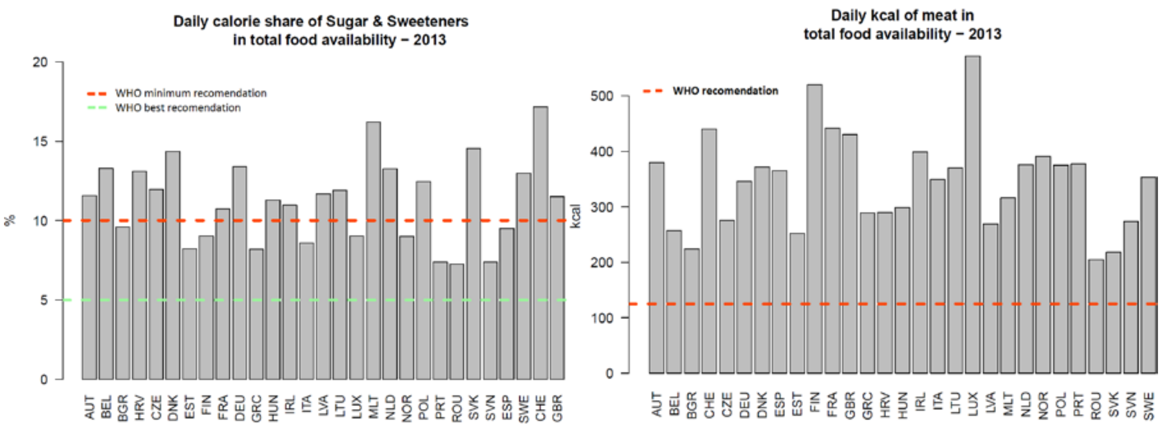


Figure 13 - Share of Sugar & Sweeteners calories available in European countries vs WHO recommendations for a healthy diet (left). Meat calories available in European countries vs WHO recommendations for a healthy diet (right).

Regarding meat (all types), countries appear to be above the WHO's recommendation of daily calories for a healthy diet. Necessary reduction to align the countries with such recommendation would range from a quarter of today's availability in Romania to 3.5 times the availability in Luxembourg. Again, it is important to keep in mind that we are contrasting diet recommendations with food availability and not with the food that is actually consumed. Giving that in Europe there is always more food available than that consumed, the reduction efforts to comply with the dietary requirements will be somehow smaller.

Table 8 - Suggested definition of levels for the diet lever.

Level 1	**Level 2**
By 2050 diets in European countries evolve as in the past, meaning generally an increase in meat consumption with income for lower/middle income countries and a stabilization or decline for high income ones. The consumption of sugars & sweeteners, vegetables & fruits evolves following past linear trends.	By 2050 diets in European countries are characterized by declining meat consumption at past rates for all countries where it has been observed and stagnation at current levels for the remaining. The consumption of sugars & sweeteners, vegetables & fruits evolves following past linear trends.
Level 3	**Level 4**
By 2050 diets in European countries are characterized by declining consumption of meat and sugars & sweeteners; and an increase of consumption of vegetables and fruits to comply with the minimum healthy diet recommendation of WHO. The same is applied to sugars & sweeteners and vegetables & fruits.	By 2050 diets in European countries are characterized by declining consumption of meat and sugars & sweeteners; and an increase of consumption of vegetables and fruits to comply with the best healthy diet recommendation of WHO. The same is applied to sugars & sweeteners and vegetables & fruits.

Following, we present the meat calorie estimates implied in levels 1 and 4 diets Against this background we formulate the different levels of the diet lever as detailed as follows (see also Table 8): Levels 1 and 2 reflect a future of either conservation of current trends or of little change. Levels 3 and 4 transform European diets to be aligned with health recommendations regarding the intake of fruits and vegetables, sugar and sweeteners and meat as detailed in (FAO and United Nations University, 2007; WHO et al., 2003; World Cancer Research Fund International and American Institute for Cancer Research, 2007). Quantitative information regarding the nutrition recommendation of healthy diets adopted in this deliverable are detailed in Table 14 of the Annex. Recommendations in the form of mass (grams) are further converted to calories following the FAO listing of nutritive factors[21].

for Poland in order to illustrate the approach taken. The contemporary evolution of meat calories available in Poland has been characterized by a steady rise from 340 kcal/person/day in 1995 to 375 in the year 2013. Regarding the specific food groups, it has been observed a slight decline in the availability of red meat from ruminants (a minor fraction of total meat in Poland) while red meat from non-ruminants and white meat has been increasing. The preservation of these trends into the future equates to Level 1. For Poland this would imply that by 2050 approximately 440 kcal of meat per person would be available, see left panel of Figure 14. Under these assumptions most of the meat calories in Poland's diet would come from non-ruminants, both red and white meat; while red meat from ruminants would preserve its marginal fraction. Because past trends are preserved, it is possible for some countries to have reductions in meat consumption under level 1.

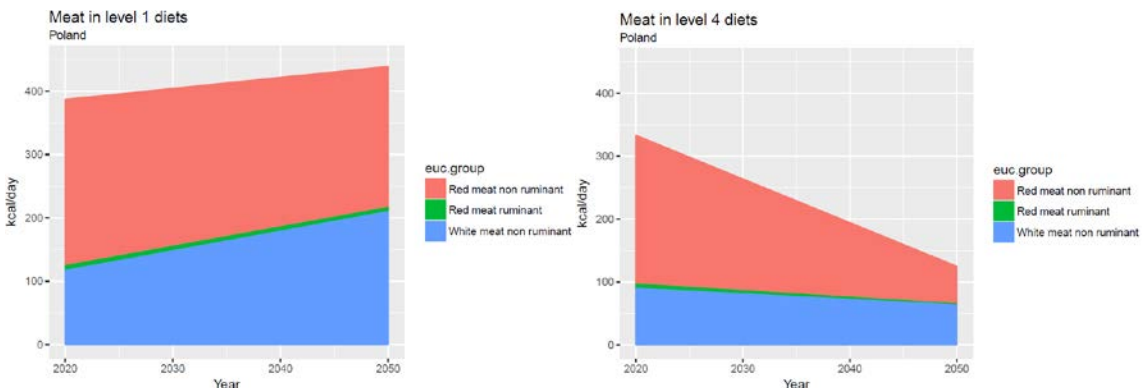


Figure 14 - Example of the evolution of the meat levels 1 and 4 in Poland's diet (left).

In the pursuit for a healthy diet, Level 4 implies a linear decline of total meat and red meat availability to the best recommended levels detailed in in Table 14 of the Annex. For Poland this implies a decline in daily consumption of meat calories to about 125 kcal per person per day, 61 of which for red meat (see right panel of Figure 14). For Levels 1 and 2, the split of total meat calories between red meat and white meat is done preserving the current fractions of each food group. For Poland, total meat calories available are split in 75% for red meat to 25% for white meat. For Level 3 the minimum recommended level of red meat is applied and the residual calories to the total meat are assumed to come from white meat. For level 4 the logic is the same, the exception being that countries reduce red meat consumption to the level expressed as best requirements in in Table 14 of the Annex.

For the Fruits & Vegetables food group the procedure is similar as for meat. In Level 1 and 2 daily calories evolve following past trends. For Levels 3 and 4 the calorie intake converges to, respectively, 200 and 300 kcal of Fruits & Vegetables per day (the calorie equivalent of 400 and 600g, see in Table 14 of the Annex).

[21] Available online here

The split between Fruits and Vegetables (individual groups) is done obeying to their current fraction. For Poland, total Fruits & Vegetables calories available are split in 53% for Fruits and 47% for Vegetables. For the food group Sweets & Sweeteners calories are determined in a similar manner with past trends preserved in Levels 1 and 2 and a convergence to 10 and 5% of the diet in Levels 3 and 4 respectively. These are further converted into the respective values of kcal.

For each lever we sum up the calories of the food groups “red-meat ruminants, “red-meat non-ruminants”, “white meat non-ruminates”, “fruits and vegetables” and “sugars and sweeteners” and determine the difference to the total calories in the current diet of the country. We call the result of this difference Rest of Food Groups (RoFG). Following, the calorie fraction of each food group (except those bounded to healthy diet recommendation, see above) is determined using the RoFG total. This guarantees that the diet lever can be combined with the calorie requirements determined in Section 8.1.1. First the calories for the food groups with dietary recommendations are fulfilled from the total calorie requirements lever. Then, the calories for the remaining food groups are simply a multiplication of the fractions determined in diets lever with the amount of calories available in the calorie requirements after the subtraction of the calories for “red-meat ruminants, “red-meat non-ruminants”, “white meat non-ruminates”, “fruits and vegetables” and “sugars and sweeteners”.

8.1.3 Level definition (consumer food waste)

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) (pp 112). 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. As reflection of this grand challenge, there has been an explicit accounting of reducing food waste and loss in the Sustainable Development Goals (SDGs) agenda[22].

The SDGs have set the 2030 agenda to transform the world by ensuring, simultaneously, human well-being, economic prosperity, and environmental protection. Comprising of 17 goals and 169 targets, SDGs aim at tackling multiple and complex challenges faced by humankind. Of the many goals and targets composing the SDGs, Goal 12 (responsible consumption and production) and target 12.3 (food loss and waste) are of particular relevance for this deliverable.

> *SDG 12 (Responsible consumption and production) seeks to “ensure sustainable consumption and production patterns.” The third target under this goal (Target 12.3) 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.*
>
> **Box 1**

[22] http://www.un.org/sustainabledevelopment/development-agenda/

Under the SDG mandate, countries are asked to half their current values of food waste by 2030 (see Box 1). The target is explicit in mentioning that the cuts in waste should take place across the entire agricultural and supply system. According the FAO loss and food waste are defined as the decrease of food in subsequent stages of the food supply chain intended for human consumption. Food is lost or wasted throughout the supply chain, from initial production down to final household consumption (FAO, 2017).

In this deliverable we differentiate food waste taking place at the consumer level from food waste taking place elsewhere in the agricultural and supply chain system. We define consumer food waste as the difference between the biophysical calorie requirements the population (see section 8.1.1) and those available for consumption, following the definition of food surplus outlined in (Hiç et al., 2016). Operationally, we equate food waste to the difference between the biophysical calorie requirements (those determined in Section 8.1.1) and the amount of food available in the marketplace in a country. Accordingly, our approach does not capture food loss taking place during the "production", "supply chain" or "post-harvest". It does capture the waste at the "consumer level", which is arguably more relevant to be framed as a lifestyle lever. In addition, for Europe the food waste at the consumer lever is responsible for about 40% of the total loss and wasted food calories (FAO, 2017). For the OECD countries, Hiç et al (2016) has estimated an increase of food surplus (the difference between the biophysical calorie requirements the population and those available for consumption) is increasing globally and most pronouncedly in most of the OECD countries. According to the authors in the United States alone, food surplus has increased from 400 to 1050 kcal/cap/day between 1965 and 2010. Underpinning this increase is the evidence that food availability has increased over the last few decades, whereas biophysical food requirements have remained almost constant (Hiç et al., 2016).

Table 9 - Suggested definition of levels for the consumer-level waste lever.

Level 1	Level 2
By 2050 food waste at the consumer level evolves following historical patterns. This implies an average food waste for EU28+Switzerland of 1000 calories, an increase of 25% in relation to 2015 levels.	By 2050 countries achieve food waste reductions at the consumer level of 15%, a quarter of that proposed in the SDG target 12.3 (originally set by 2030). This translates to an average food waste for EU28+Switzerland of 620 kcal.
Level 3	**Level 4**
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 410 kcal.	By 2050 countries achieve food waste reductions at the consumer level of 75%, thus overcoming the SDG target 12.3 by 2030. This translates to an average food waste for EU28+Switzerland of 200 kcal.

For the definition of consumer food waste levels we scale the food surplus calculation in (Hiç et al., 2016) in the light of the published SDGs. We take country specific kcal of food waste for 2015 and linearly decline these in order for the target 12.3 to be achieved by 2030 or 2050 (see Table 9). The calories trajectories implied in the levels definitions are shown in Figure 15 (left panel).

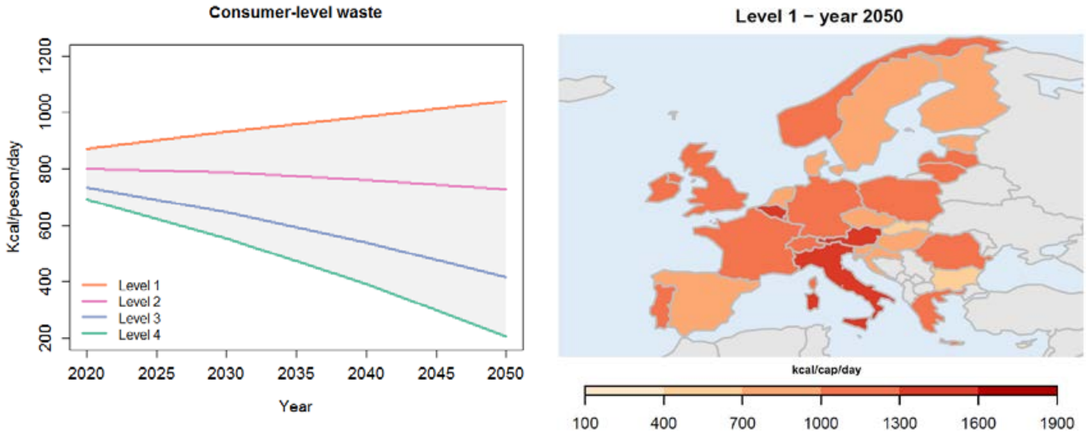


Figure 15 - Development of EU28+Swizerland kcal/cap/year associated with consumer-level waste (left). Spatial distribution implied by Level 1 for the year 2050 (right).

8.1.4 Total calorie production and RoW disaggregation

As mentioned in section 8.1.3, the food waste approach adopted in this deliverable only captures food waste at the consumer level. There are other dimensions of waste taking place at the level of distribution, processing, post-harvest and agriculture that need to be quantified. The sum of all forms of food waste and the biophysical calorie requirements sets the amount of total calories demanded to the agricultural production system developed in WP4 (see Figure 16). Accordingly, for the purposes of model integration, we determine total calorie production that needs to be fulfilled by the supply side in WP4.

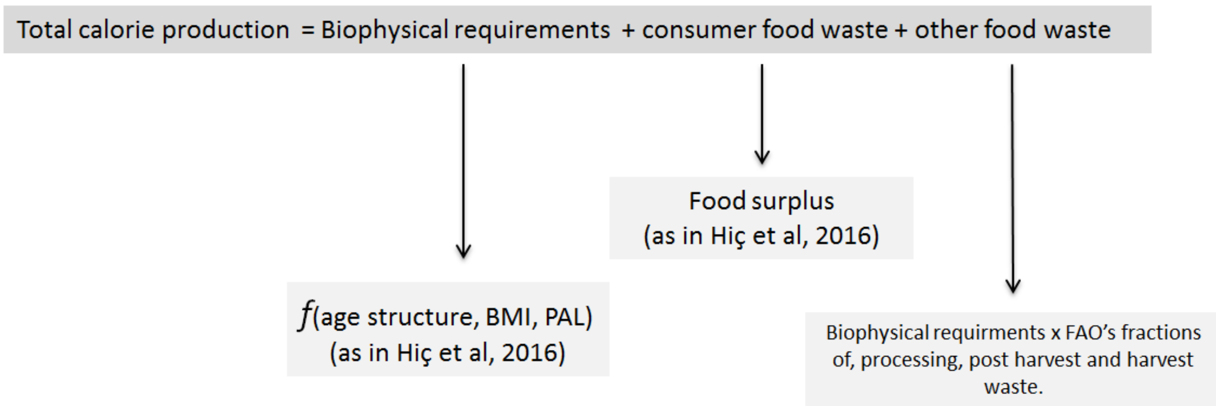


Figure 16 - Total calorie production to cover biophysical needs of the population and food waste.

The methods for estimating biophysical requirements and food waste at the consumer level are explained in sections 8.1.1 to 8.1.3. In order to obtain the amount of calories wasted elsewhere in the agricultural and supply chain systems we scale the biophysical requirements by all the waste factors (except the "consumption" factor in order to avoid double counting) determined in (FAO, 2017).

Given the global connections in the agricultural and food systems, information on the levers described in sections 8.1.1 to 8.1.3 need to be available not only for the EU28+Switzerland but also the world. When it comes to agriculture, lifestyle decision taking place in other parts of the globe can have repercussions for the food availability in Europe, be it in the form of price changes or physical availability. In order to reduce complexity to manageable levels we opt to treat the Rest of the World (RoW = World – (EU28+Switzerland)) as a limited set of macro regions. We opted to align these with the set of macro-regions used by FAO. Accordingly, we disaggregate the RoW as follows: North Africa, Sub-Saharan Africa, North America, Latin America and the Caribbean, Western Asia, Easter and South-East Asia, South Central Asia, Oceania and Rest of Europe (all countries not captured in the EU28+Switzerland). During the model set up we might opt to slightly re-arrange this division scheme in order to better exploit the interlinkages with WP7's GTAP modelling.

9 Data

9.1 Data intensity

The data intensity is usually expressed in terms of Gigabits per capita and/or country and per month (GB/month per capita). The worldwide internet traffic was about 33 Gigabits (GB) per month in 1985. Nowadays, this represents the average consumption per capita in Europe In 2021, it is forecasted to be the average worldwide volume consumed per capita (Cisco, 2017). Figure 17 presents the estimated data intensity trends for the different regions in the world. The Western Europe currently represents 14% of the worldwide data traffic, and should remain stable in the next few years (Cisco, 2017).

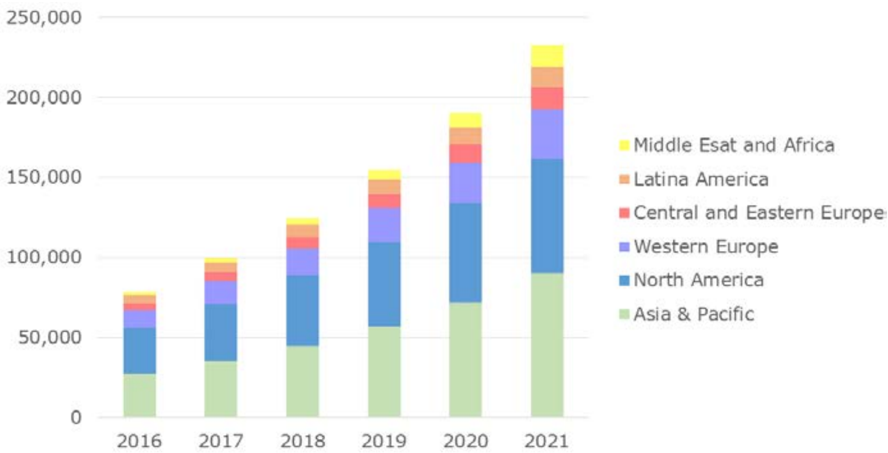


Figure 17 - Data volume of global consumer IP traffic by region (in petabytes per month)

Data demand can be split into four applications: gaming (1%), file sharing (8%), web-data (18%), and video (73%). The current trends suggest an increasing share of video and gaming consumption implied by the deployment of ultra-high definition footage. By 2021, video and gaming are expected to represent 86% of the global internet traffic (Cisco, 2017). The video footage quality is also critical regarding the data intensity as the bit rate for a Standard Definition (SD) and Ultra Hight Definition (UHD) 2 to 18 Mbps (Megabytes per second) respectively. As a comparison, the current available high-quality footage on YouTube requires a bit rate up to 80 Mbps. In other words, watching 7 minutes of such video footage is equivalent to the average European data consumption per capita for a month.

Data intensity will also increase through the development of the Big Data and the Internet of Things (IoT), i.e. the network of connected devices such as vehicles, homes and cities. IoT will contribute to increase the machine to machine (M2M) data volume traffic. The data generated as well as the need for storage will thus be considered across the calculator though the deployment of connected technologies and smart devices.

Over the years, the data intensity has been increasing at a two, even at three-digit growth depending on the country. Focusing on the European countries Figure 18 the average expected growth rate per year is assumed to be about 22% between 2016 and 2021 (Cisco, 2017), but it widely differs from one country to another. For example, the data volume consumed in 2016 in France through mobile increased by nearly 100% and through fixed internet by 30%, compared with, respectively, 45% and 35% for the UK.

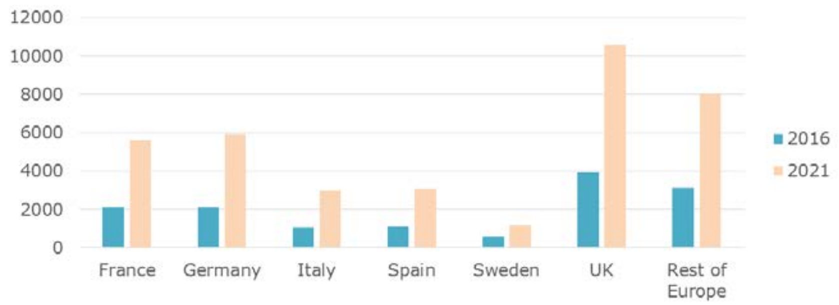


Figure 18 - Data volume traffic forecast in European countries (TB/month), based on the VNI Forecat Widget, Cisco systems.

Various factors may affect the data intensity ranging from techno-economic to socio-cultural drivers. The network access, coverage and average speed are critical drivers for data intensity as they condition the scope of the available internet services. The World Bank provides several data (World Bank, 2017) including the share of individuals using the internet, the broadband speed and penetration, the mobile phone subscriptions and so on. The range of devices own by the end-users also drives the data intensity (Cisco, 2017), for example, through the deployment of smartphones, tablets and smart TVs against non-smartphones and regular TVs. Literature also points out the correlation between internet penetration, connected devices ownership and the GDP[23] (as illustrated in Figure 27 of the Annex). Data intensity will thus be correlated with the GDP scenarios of the calculator, as well as the ICT jobs.

Socio-cultural drivers also influence the data intensity. As an illustration, Sweden and the Netherlands have equivalent network access but the Swedish data intensity per capita is nearly two times higher compared with the Dutch[24,25].

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[24] World Bank – World Development Indicators: International Telecommunication Union, World Telecommunication/ICT Development Report and database (per country, from 1960 to 2016).
[25] Ofcom - Average monthly fixed broadband data volume per capita in 2008 and 2014 (in GB), International Communications Market Report 2015, December 2015.

Data intensity is also observed to vary according to age and gender.[26] The proportion of individuals using internet is significantly higher for the young population (aged 15-24), with 71% compared with 48% for the total population at the World level. Focusing on Europe, rates are 80% and 96% for the total population and young people respectively. Focusing on the gender issues, the gap[27] is currently ranging from -3 to +33%[28]. The gender gap is increasing in the World (11% in 2013 against 11.6% in 2017) while slightly decreasing in Europe (9.4% in 2013 against 7.8% in 2017). The data intensity will thus be correlated to the demography settings (Lever 1.5).

9.2 Electricity intensity of data

ICT products and services accounted for 3.9% of the worldwide electricity in 2007, 4.6% in 2012, 7% in 2017 and it is expected to represent 13% by 2030 (Avgerinou et al., 2017; Aslan et al., 2017). The data generation and traffic induce a demand for data centres, servers and network infrastructure (see Figure 19).

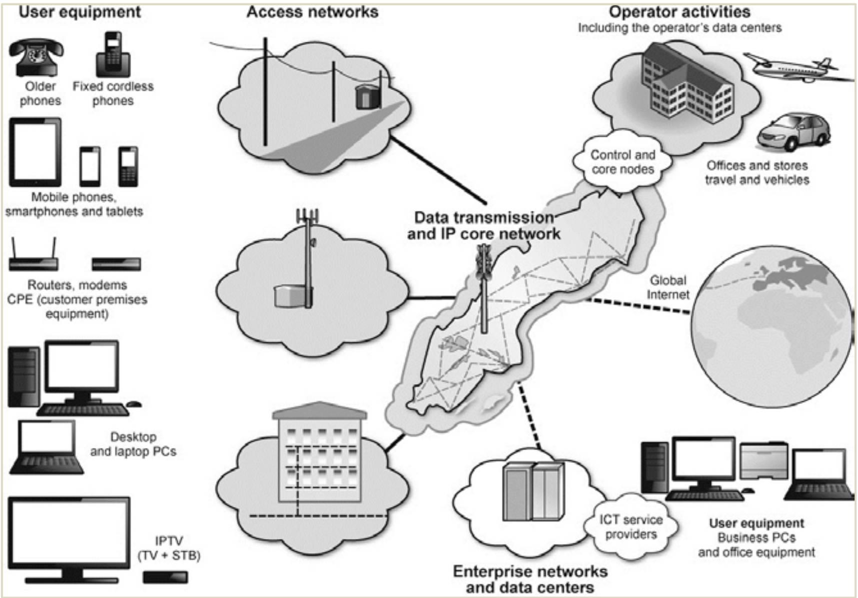


Figure 19 - Internet system LCA boundaries (extracted from Malmodin et al., 2014)

The electricity intensity of the data will thus focus on the "the megawatts behind the megabytes" of the internet system (Costenaro and Duer, 2012), i.e. the electricity demand resulting from data traffic expressed in kWh/GB. This electricity demand can be divided into different internet sub-system (based on Malmodin et al., 2014):

1. **End-users:**

[26] International Telecommunication Union: ICT statistics, ICT facts & Figure 2017, 2017.
[27] Definition: the gender gap represents the difference between the Internet user penetration rates for males and females relative to the Internet user penetration rate for males, expressed as a percentage.
[28] Meaning that the gap between the penetration rate of men against women is ranging from -3% to 33%.

The user equipment: the connected devices such as smartphones, PCs, TVs, etc. and the network equipment such as modems, routers, set-top boxes, etc.; The end-user networking equipment: the broadband, the GSM network (2G, 3G, 4G and incoming 5G), the cables, the public network, etc.;

2. **Data transport / Networking equipment:**
   Control and core nodes: Public Switched Telephone Network (PSTN), mobile core networks, voice over IP; Other operations and maintenance of the ICT networks; IP core network: A wide range of transmission link elements (copper, fiber-optic, radio links, etc.), IP edge, metro, core, switches, routers, including all supporting infrastructure for cooling, power, international data transport (submarine cable systems), etc.

3. **Data-centers:**
   Including data centers, enterprise networks and all supporting infrastructure for cooling, rectifiers, and back-up systems.

Based on the last decade literature (since 2008, Table 10) and depending on the considered system boundaries, the electricity intensity of Internet may range from 0.052 to 7 kWh per GB (Aslan et al., 2017; Coroama and Hilty, 2014).

Table 10 - Literature review of electricity intensity of the data.

Reference	Historical data	Data center	Networking equipment	End-user device	Intensity
Koomey et al. (2004)	2000	√	√	√	136 kWh/GB
Taylor and Koomey (2008)	2000	√	√		92-160 kWh/GB
Taylor and Koomey (2008)	2006	√	√		9-16 kWh/GB
Baliga et al. (2009)	2008		√		0.179 kWh/GB
Lanzisera et al. (2012)	2008		√		0.39 kWh/GB
Weber et al. (2010)	2008	√	√		7 kWh/GB
Pickavet et al. (2008)	2008		√		1.8 kWh/GB
Coroama and Hilty (2014)	2009		√		0.2 kWh/GB
Williams and Tang (2011)	2010	√	√		0.3 kWh/GB
Malmodin et al. (2014)	2010	√	√	√	2.48 kWh/GB
Baliga et al. (2011)	2011		√		0.06 kWh/GB
Costenaro and Duer (2012)	2011	√	√	√	5.12 kWh/GB
Shehabi et al. (2014)	2011		√		0.29 kWh/GB
Schien and Preist (2014)	2011		√		0.02 kWh/GB
Krug et al. (2014)	2012	√	√	√	7.2 kWh/GB
Schien et al. (2014)	2014		√		0.052 kWh/GB
Aslan et al. (2017)	2014		√		0.06 kWh/GB

Based on Table 10, the estimated electricity intensity in terms of kWh/GB is widely decreasing over the years. Nevertheless, there is still an important gap between the different studies, especially for end-user devices and data centres. Based on Malmodin et al. (2014)[29], who provides the most optimistic values while including the 3 sub-systems, the data traffic may have represented a

[29] 2.48 kWh/GB at the overall level, 0.87 kWh/GB when excluding the end users' equipment

consumption of 330 TWh in 2016, i.e. the equivalent of 10% of the European electricity consumption [30] (EURSOTAT); 115 TWh when excluding the energy associated with the end-user's equipment. Depending on the carbon emission factor of electricity (i.e. the location of consumption, data centres, etc.), the European data traffic may have led to emit from 10 (Sweden[31]) to 110 $MtCO_2eq$ (China) regardless to the end-user's equipment (up to 3% of the UE emission, which fits with Avgerinou et al., 2017).

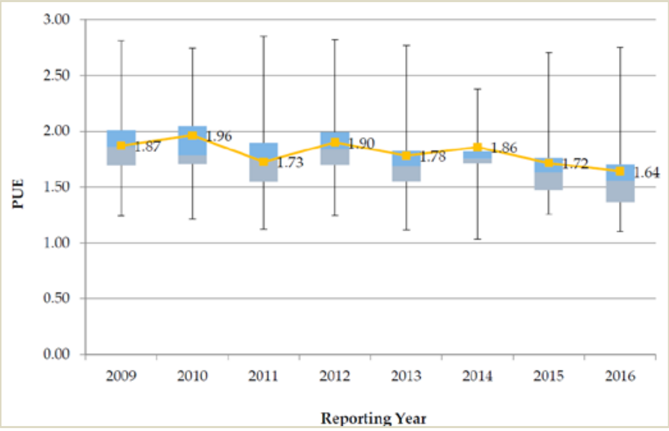


Figure 20 - Average PUE per year in Europe (extracted from Avgerinou et al., 2017)

Focusing on data centres, the evolution of the Power Usage Efficiency (PUE) (see Figure 20) and its reciprocal the Data Centre infrastructure Efficiency (DCiE), will be critical in the assessment. PUE informs about the data centre energy efficiency by computing the ratio between the overall data centre energy input compared with the power used by the IT equipment (Avgerinou et al., 2017); for example, a PUE of 2 means that each kWh consumed by the equipment will require 2 kWh for the whole facility, which means a DCiE of 50%. The evolution of the PUE will mainly depend on the renewal rate of equipment and thus its life time, the new capacity implemented each year, the technology efficiency and the energy management of the data centres (Avgerinou et al., 2017). Between 2015 and 2020, the compound annual growth rate of European data centres capacity is expected to be about 4.2% [32], i.e. much higher than the global electricity demand growth (2.1%) estimated by the International Agency of Energy from 2012 to 2040 (Avgerinou et al., 2017; Tatchell-Evans et al., 2017).

Depending on the energy type, electricity consumption of ICTs may lead to major GHG emissions, already estimated to represent 2% in Europe (Avgerinou et al., 2017). Good practices in terms of energy management[33] (Avgerinou et al., 2017; Tatchell-Evans et al., 2017) and even dedicated renewable energy deployment will be considered in the different levels of the lever. One may recall that, for example, Google and Apple data centres runs 100% renewable since 2017.

[30] The electricity consumed is divided between European and non-European consumption depending on the servers locations (mainly shared between US, Europe and Asia, see: *La documentation française: La répartition mondiale des serveurs hôtes en 2010*, 2011);

[31] Considered emission factors: 0.079 tCO_2eq/MWh for Sweden, 0.950 tCO_2eq/MWh for China.

[32] New technologies and architectures for efficient data center report, July 2015, Yole Développement

[33] The E-Server Consortium: Energy efficient servers in Europe: Energy consumption, saving potentials and measures to support market development for energy efficient solutions

Given that the cooling represents from 30 to 50% of the data centres systems energy-use, energy management through free-cooling will also be considered, i.e. using natural cooling pathways such as using outside air/cold water (see: Zhang et al., 2014 for a review of the possible alternatives). As another example, data centre waste heat can be used to supply district heating (Wahlroos et al., 2017), allowing to improve the energy efficiency.

9.3 Level definition

Defining the trends of data intensity and its associated electricity demand is by nature challenging given that ICTs deployment historical data is very limited compared with the required forecast 2050-time horizon. The different levels will be refined regarding the previously mentioned factors (Table 11) based on further modelling work and stakeholders' and experts' consultation.

Table 11- Drivers of data-intensity and data-electricity intensity.

Factors influencing data intensity (GB/cap/month or day)	Factors influencing electricity/carbon intensity (kWh/GB)
Type of the data consumed (video, gaming, web, M2M, etc.);	Data volume;
Broadband and mobile network penetration;	Data centers, connected devices, networking equipment capacity, load factors and efficiency (GW/GWh)
Average network speed and coverage;	PUE dynamics;
Quantity and types of connected devices own by end-users;	Deployment of energy management good practices;
Population demography (age & gender);	Share of renewable energy providing electricity to data centers (yielding a specific demand for renewables);
Deployment of Big Data and IoT;	Waste heat supply of data centers for heating district systems;
[Time spent on internet][34];	

[34] Depending on the data availability

10 Conclusions

This deliverable provides the first quantification of levels for a total of 6 levers covering demographics and lifestyles. Underlying the estimates of the levels are both semantic definitions of levers and the description of methodologies used in their quantification. This deliverable constitutes a fundamental step forward in establishing the EU-calculator model given that it supplies the consortium with the first estimates of the levers shaping the demand side of energy and materials. Furthermore, it provides the basic information (that is, levers definitions and levels) for stakeholder feedback in the upcoming sector-specific expert consultation workshops. Importantly, the deliverable anticipates a number of interrogations regarding the methodologies proposed for which expert feedback can provide some clarification. A summary of the main discussion points can be consulted in Table 12.

Table 12 - Summary of critical aspects requiring expert consultation.

Lever	Criticalities	Comment
Population	The need to align our level 1 with WP7 baseline data poses an “upper” limit to the growth of population in Europe.	To be discussed internally.
Fraction of urban population	Given the current global megatrends an inversion of growth of population in the urban areas in Europe seems unlikely. Furthermore, 4 levels of ambition appear to be redundant given that they would only differ marginally from each other.	To be discussed internally.
Passenger travel distance	We observed a high sensitivity of our passenger travel distance model to the variable daily travel speed. Given the lack of a consistent database of travel speeds across Europe we had to approximate this variable indirectly and noted that its future evolution substantially affects the levels of ambition. In addition, speed might be dependent on future degrees of automation. Furthermore, consistency checks of our level 1 estimates (namely with travel distance in the Reference scenario 2016) hinted at the possibility of a too “optimistic” level1 of ambition.	Discuss with experts in April’s 2018 transport workshop.
Building use intensity	The future evolution of household size has been identified as a crucial determinant of building use intensity. An empirical model has been established allowing simulating its effect in building use intensity at the country-scale. Most importantly, levels 3 and 4 imply an increase in household size, which might raise doubts on the individual acceptance of these levels.	Discuss with experts in June’s 2018 buildings workshop.
Calorie requirements	Because we thigh calorie requirements to the theoretic biophysical needs of the population (depending mostly on the age structure and physical activity), level 1 has been identified as potentially to low. The lack of a good database of physical activity lifestyles in Europe made us assume that these remain constant, which might not be the case. This needs further discussion.	To be discussed internally and in the September’s 2018 agriculture expert workshop.
Diets	We assumed that the best way to bring change into human diets is via the argument of gains in health. Accordingly, levels 3 and 4 simulate the adoption	To be discussed internally and in the September’s 2018 agriculture expert

	of WHO guidelines on healthy food. The feasibility of achieving this conversion in the narrow time frame between 2015 and 2050 needs to be further discussed. Doubts were raised to what extent having health as the main guiding principle in defining diets is adequate for a tool looking mostly and environmental gains.	workshop.
Data intensity	This lever has been proposed in this deliverable as relevant and extensive documentation of that factor influencing its levels has been achieved. Details on the quantification of the levels still need to be undertaken. Further discussion is needed to what extent on the long-run inequality rather than demographic factors influence data consumption.	To be discussed internally.

Despite the apparent large number of interrogation to be addressed it should be said that this is a mere reflection of philosophy being the design of the EU-calculator, that is, a co-design effort between the scientific team and sectoral expert.

Importantly, the deliverable achieves an alignment of levers and disaggregation-level of information with, respectively, WP 7's socio-economic baselines, and the needs of WP 2, 4 and 6. Nevertheless, one issue regarding the need of having additional GDP projections additional to the baseline provided by WP7 has not yet been solved. This discussion will continue with WP's 6 and 7 in the next general assembly (May 2nd 2018). There is some further work to do regarding the integration of the Data intensity lever. For now, this has been admittedly an exploratory exercise but the preliminary results indicate that the electricity needs to run the server infrastructure to satisfy our "always connected" lifestyle can be about 10% of total demand. In the coming months more effort will be dedicated into better defining the levels of this lever.

As outcome of this deliverable 6 .csv files are made available to the consortia. These include the values of population, fraction of urban population, passenger travel distance, calorie requirements, diet composition and floor space usage. The data is structured in columns; the first column contains the iso3 identifier code for each of the EU28 member states + Switzerland, the second column contains an identifier ("*l1*" to "*l4*") of the respective level, the third column contains information of the year (2015 to 2050) and finally the fourth column contains the value of the respective level for a respective year. All files are structured in this way except the one regarding the diet composition. In this particular case an extra column is added with the identification of a particular food group for the purposes of future integration of this lever with WP4 and WP6. In addition, 6 .xlsx files are provided containing the metadata details of each .csv file. The data and respective metadata can be accessed, by request, following this link: www.european-calculator.eu/?cdm_linkout=NzU5.

11 Annex

11.1 Passenger travel demand

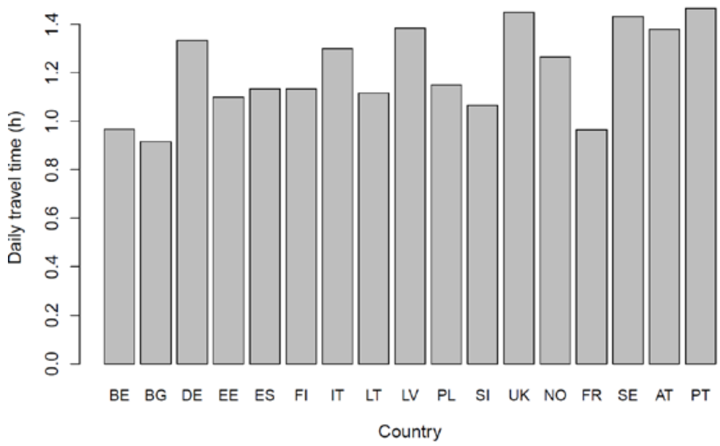


Figure 21 - Daily travel times for European countries for circa year 2000 unless specified. Source (Eurostat, 2003). For SE (Sweden), NO (Norway) and FR (France) data refers to year 2007[35], for PT (Portugal) to 1998[36] and for AT (Austria) 2008[37].

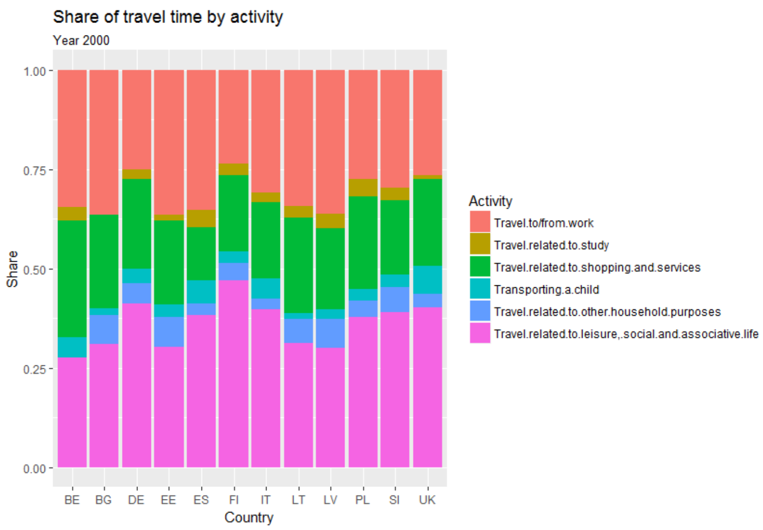


Figure 22 - Travel time by activity as share of total travel time for European countries. Source (Eurostat, 2003).

35 https://www.h6.scb.se/tus/tus/StatMeanMact1.html

36 http://cite.gov.pt/asstscite/downloads/Usos%20do%20tempo_Portugal_1999.pdf

37 http://www.oesta.gv.at/site/7232/default.aspx

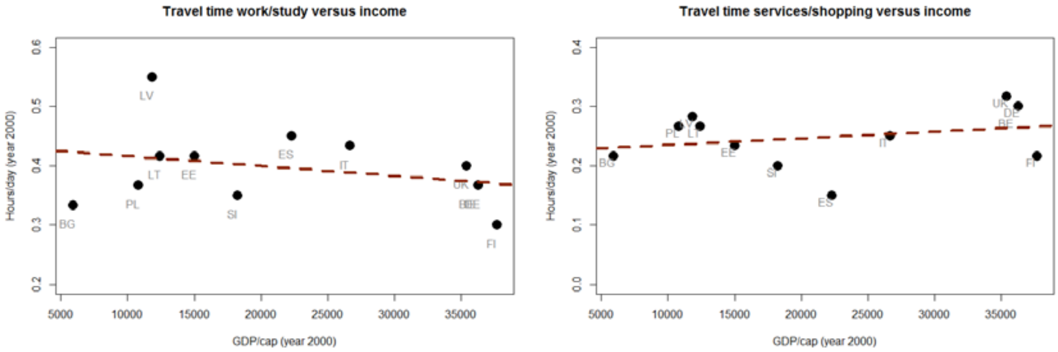


Figure 23 - Linear correlations between travel time for work/study (left) and services/shopping (right) vs GDP for the year 2000.

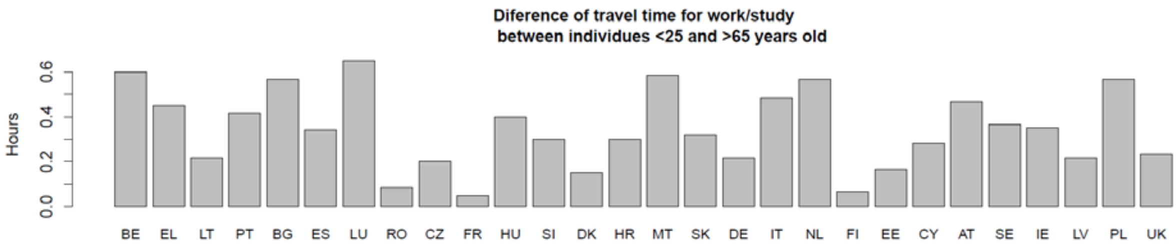
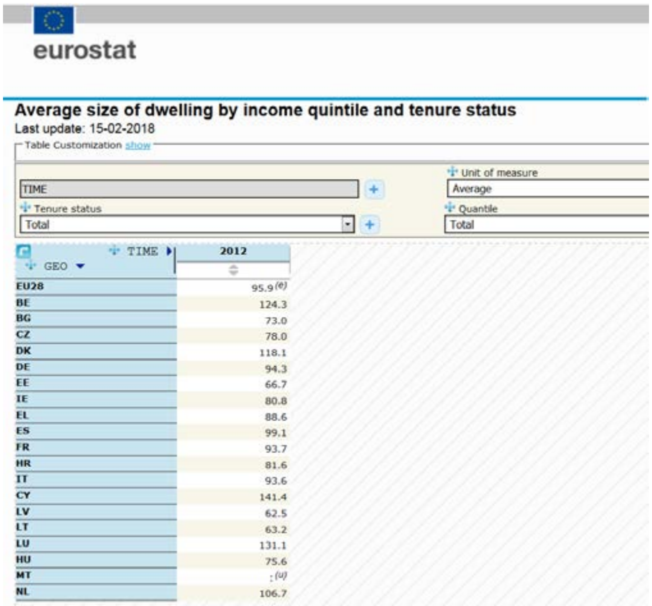


Figure 24 - Average difference (years 2003, 2011 and 2016) of travel time for work/study activities between the age groups <25 and >65 by country.

11.2 Buildings



eurostat

Average size of dwelling by income quintile and tenure status

Last update: 15-02-2018

Table Customization show

TIME

Tenure status: Total

Unit of measure: Average

Quantile: Total

GEO \ TIME	2012
EU28	95.9 (e)
BE	124.3
BG	73.0
CZ	78.0
DK	118.1
DE	94.3
EE	66.7
IE	80.8
EL	88.6
ES	99.1
FR	93.7
HR	81.6
IT	93.6
CY	141.4
LV	62.5
LT	63.2
LU	131.1
HU	75.6
MT	: (u)
NL	106.7

Figure 25 - Average size of dwellings in EU as retrieved from EUROSTAT[38]

[38] http://appsso.eurostat.ec.europa.eu/nui/submitViewTableAction.do

11.3 Calories, diets and waste

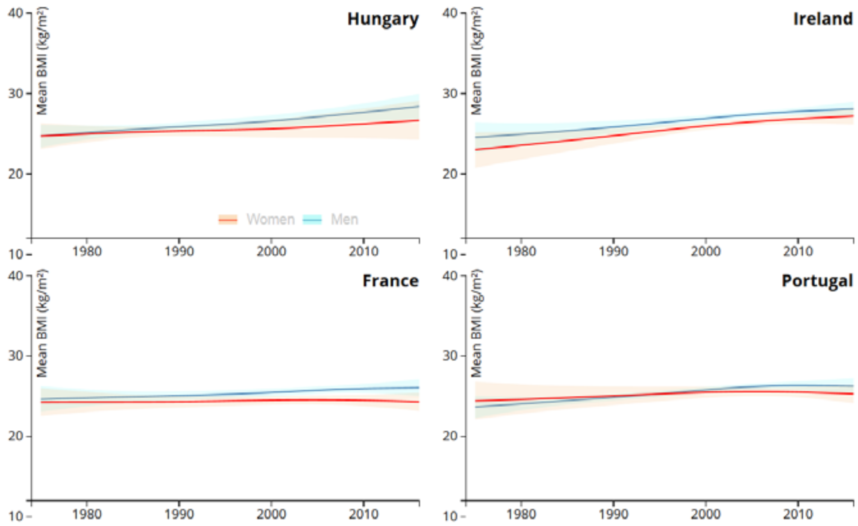


Figure 26 - Trends in BMI for selected countries, ranging from slight increase to stagnation. Source: http://ncdrisc.org/bmi-mean-line.html

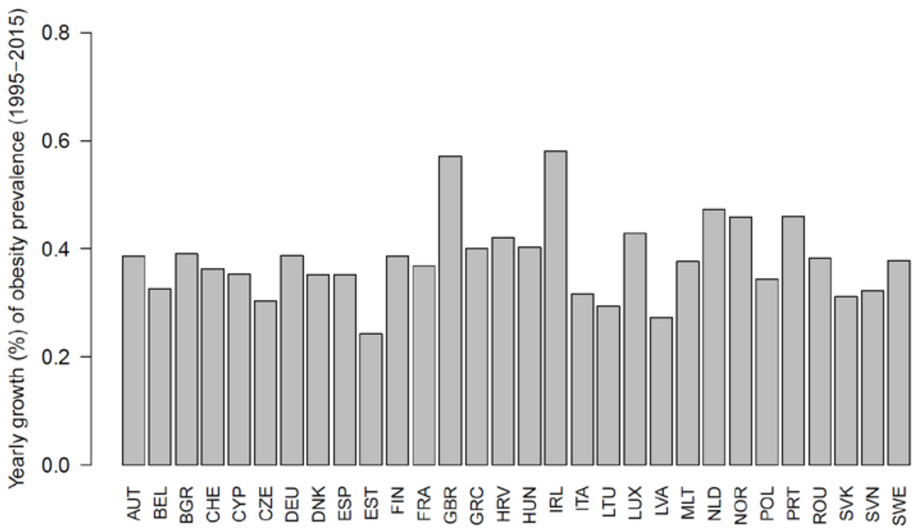


Figure 27 - Yearly changes of obesity prevalence (BMI>30) in European countries between 1995 and 2015 (values given in yearly % growth).

Table 13 - Considered food groups in the EU calculator, adapted from FAO.

Food groups considered in the EU calculator	Comments
Alcoholic Beverages	Including wine and beer
Cereals	Excluding those used for beer
Fruits	Excluding those used for wine
Oilcrops	
Pulses	
Starchy Roots	
Stimulants	
Sugar & Sweeteners	
Sugar Crops	
Vegetable Oils	
Vegetables	
Sea food	Composed of aquatic products, fish, body and liver oils
Eggs	
Milk products	Composed of cheese, butter, ghe, cream and milk excluding that used for butter
Red meat ruminants	Bovine, mutton and goat meat
Red meat non ruminants	Pigmeat
White meat non ruminants	Poultry meat
Animal products	Other types of meat, offals and fats
Others	Total of calories minus the sum of the EU calculator food groups

Table 14 - Healthy diet recommendations and respective source.

Food groups	Recommendations	Source
"Sugar & Sweeteners"	Minimum; <10% of daily calorie intake Best; < 5% of daily calorie intake	WHO, Fact sheet N°394, 2015 [39]
"Fruits & Vegetables"	Minimum; 400g daily intake Best; 600g daily intake	(World Cancer Research Fund International and American Institute for Cancer Research, 2007)
"Red meat ruminant", " Red meat non ruminant", "White meat non ruminant"	<= 90g daily intake	(FAO and United Nations University, 2007)
Red meat	Minimum; < 75g daily intake Best; < 45g daily intake	(World Cancer Research Fund International and American Institute for Cancer Research, 2007)

[39] http://www.who.int/mediacentre/factsheets/fs394/en/

11.4 Data intensity

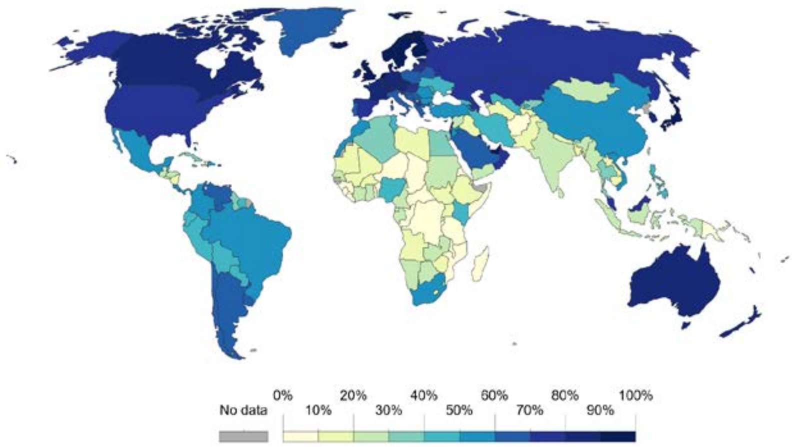


Figure 28 - World map of internet access (World Bank - ICT Development Report and database)

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