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Report No ECHOES 5.1 – Comparative Assessment Report on European Energy Lifestyles

Report: A Detailed Methodology for the Calculation of Cumulative Energy Demand per Survey Respondent

Comparative Assessment of European Energy Lifestyles

Report

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ABSTRACT

This report provides the technical backstop to the ECHOES 5.1 – Comparative Assessment Report on European Energy Lifestyles. The document presents in detailed the methodology, assumption and data sources used for the calculation of cumulative energy demand per survey respondent. The calculation of cumulative energy demand by respondents is based on a limited number (roughly 40) questions. It is a mixture of bottom-up evaluation from the survey with top-down control from other statistics (mostly from EUROSTAT). As quality control we find that the ECHOES results for Austria compare closely (±15%) to the results from another project, ClimAconsum, in the lifestyle areas mobility and heating. The ECHOES estimate for diet is higher than from ClimAconsum, because in ClimAconsum organic and conventional food production were considered and in ECHOES we have included food waste. The "goods" lifestyle area is significantly lower in ECHOES than in ClimAconsum, but that is to be expected considering the limited number of questions asked (i.e. only about clothing and electronics). In ClimAconsum, the lifestyle areas "leisure" and "information" were part of the general energy consumption and so were not calculated.

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Country	Consortium partner	Name
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EXECUTIVE SUMMARY

This report provides a technical backstop to the ECHOES 5.1 – Comparative Assessment Report on European Energy Lifestyles. The document presents in detailed the methodology, assumptions and data sources used for the calculation of the cumulative energy demand per survey respondent. The calculation of cumulative energy demand by respondents is based on a limited number (roughly 40) questions. It is a mixture of bottom-up evaluation from the survey with top-down control from other statistics (mostly from EUROSTAT). As quality control we find that the ECHOES results for Austria compare closely (±15%) to the results from another project, ClimAconsum, in the lifestyle areas mobility and heating. The ECHOES estimate for diet is higher than in ClimAconsum, because in ClimAconsum organic and conventional food production were considered and in ECHOES we have included food waste. The "goods" lifestyle area is significantly lower in ECHOES than in ClimAconsum, but that is to be expected considering the limited number of questions asked (i.e. only about clothing and electronics). In ClimAconsum, the lifestyle areas "leisure" and "information" were part of the general energy consumption and so were not calculated.

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1. INTRODUCTION

1.1. Aim of the report

This report provides a technical backstop to the ECHOES 5.1 – Comparative Assessment Report on European Energy Lifestyles. The aim of this document is to present in detail the methodology, assumptions and data sources used for the calculation of cumulative energy demand per survey respondent.

1.2. General methodology

In general, the following methodology was followed:

1) Estimate the amount of a service or commodity required by the respondent in a year (e.g. passenger-km in a private vehicle, bus, train, airplane, etc., heat for housing or electricity for lighting, etc., g of beef, milk, vegetables, etc., g of clothing, electronic goods, etc.); and

2) Multiply this estimate by a factor for the cumulative energy per amount of service or commodity extracted from a life-cycle assessment (LCA) database, namely either:
    a. Ecoinvent (Wernet et al., 2016); or
    b. GEMIS (IINAS, 2018)

The survey data provide a bottom-up estimate of the amount of service or commodity. After conversion to energy demand, this may not correspond to top-down estimates from other sources (e.g. EUROSTAT). Hence in many cases a correction (scaling) is applied so that the mean values of the bottom-up and top-down estimates match. This scaling does not affect the distribution of the values within a category, upon which the energy lifestyle categorisation is built.

1.3. Disclaimer

The energy calculation used in ECHOES should not be considered an estimate of the total energy demand per capita. The questions posed in the survey were limited in number and although more questions could have been asked, we selected questions that we thought were representative of an energy lifestyle. This is especially true for energy demand for goods and leisure. For example, the national per capita consumption of some materials (e.g. aluminium, steel, and plastics other than for packaging) is a significant portion of a country's consumption-based energy demand. However, it may be very difficult for for an individual to limit her/his per capita consumption of these goods since they are essentially part of infrastructure. Hence, even though they are significant, they are not really indicative of an individual's energy lifestyle.

For the more important lifestyle sectors (mobility and housing) the respondents were asked detailed quantitative questions. Here, the energy estimates are representative of the total energy demand per capita in the lifestyle sector. However, we purposely did not ask respondents questions with quantitative answers for all lifestyle sectors. For example, we could have asked "how often do you change your cell phone?" but that may not be pertinent for the frequency at which flat panel monitors are changed. Instead, we asked a qualitative question which then required us to give a value based on literature or our subjective assessment.

1.4. Definitions

The following definitions are used in this report:

Table 1: A list of definitions used in the report

Term	Definition
End energy $Energy_{end}$	End energy is the energy delivered by the consumption of an energy-carrier (e.g. gasoline, diesel, electricity). It is directly controlled by the user (e.g. when he/she turns on a light or drives a car).
Primary energy $Energy_{prm}$	Primary energy is the energy required to deliver an amount of end-energy. It occurs in the process chain prior to the end-user
Cumulative energy $Energy_{cum}$	The sum of end and primary energies.
Life-cycle assessment LCA	Life-cycle assessment is a technique to assess environmental impacts associated with all the stages of a product's life from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance, and disposal or recycling.
Question numbers (Qyy)	Question numbering referred to in this report is based on survey V6_10072018
Colour coding of data in tables	The following colour coding for data in tables is used throughout this report: Original values from the referenced source are in black. Interpolated, assumed or calculated values are in blue.
Pkm	Passenger-km, a unit of service for mobility
[ ]	Square brackets are used to denote the units in equations

2. METHODOLOGY

In the following section the methodology for the evaluation of the cumulative energy demand for the energy lifestyle research in the ECHOES project is described in more detail. The section is ordered by energy lifestyle area as discussed in the sister report (ECHOES 5.1 – Comparative Assessment Report on European Energy Lifestyles).

2.1. Housing

The housing lifestyle area is composed of four services:

1. Room temperature management (heating and cooling)
2. Hot water,
3. Cooking[1], and
4. Electricity for lighting and appliances.

2.1.1.Heating (Q94-101)

The estimate for heat demand make extensive use of the Tabula Web Tool (Loga et al. (2016) and TABULA and EPISCOPE. (2017)). This tool provides a value of energy demand per sq. meter for a specific type of housing, for a specific range of year of construction, with a three levels of renovation. The survey questions were designed to correspond to the classification criteria in the Tabula Web Tool and it is used as a country-specific look-up table to select the energy demand per sq. meter that corresponds to the reply from the respondent.

The year ranges in TABULA vary by country and they do not always correspond to the year ranges in the survey. As a result the values for the years in the survey are interpolated from the TABULA data. For countries without TABULA data, values from a neighbouring country with similar economic conditions adjusted for a difference in heating-degree-days were used. For Turkey, there is no TABULA entry. So that we are consistent in our methodology we have used the TABULA information for Greece Zone C (Thessaloniki region) based on maps in Dascalaki et al. (2012) and Spinoni et al. (2018) as a replacement.

If the respondent did not know the age of her/his dwelling then “1961-1980” was assumed as the year the dwelling was built. The amount and type of renovations to the home were converted to the appropriate TABULA renovation level assuming that cellar and wall renovations are half as effective as window replacements and increasing attic insulation. If the sum of the number of renovations was greater than 1 then TABULA renovation category two (i.e. more renovations) was assumed.

An example is shown in Table 2.

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[1] Cooking could have been assessed as a component of diet. However, we chose to include cooking as a component of housing so that the impacts of diet (i.e. amount of meat and milk products consumed) would be more transparent

Table 2: A comparison of TABULA and interpolated energy demand values [kWh/m2/a] for Austria

Start	End	SFH	SFH_reno1	SFH_reno2	TH	TH_reno1	TH_reno2	MFH	MFH_reno1	MFH_reno2	AB	AB_reno1	AB_reno2
1900	1919	135.8	87.5	64.8	127.0	85.9	64.9	125.7	90.9	84.7	108.9	74.4	67.1
1920	1944	153.1	84.1	57.5	130.8	77.1	56.7	135.9	79.1	69.0	125.1	75.1	67.3
1945	1960	134.2	81.6	60.6	139.5	107.7	78.4	125.4	81.6	75.1	112.3	58.8	62.1
1961	1980	144.8	98.4	69.9	137.7	93.6	65.0	125.6	75.5	68.7	112.8	73.0	65.4
1981	1990	104.6	74.6	57.2	112.4	83.4	60.8	89.9	71.9	63.9	49.4	48.2	45.3
1991	2000	100.8	87.5	65.0	97.5	80.7	62.3	88.0	72.5	61.8	83.8	72.7	64.3
2001	2009	74.3	74.3	67.9	72.0	72.0	65.9	77.9	77.9	80.5	68.8	68.8	70.8
2010		92.6	50.9	55.4	82.0	54.3	51.3	91.9	41.6	59.9	78.4	47.8	57.1

Age_desc	SFH	SFH_reno1	SFH_reno2	TH	TH_reno1	TH_reno2	MFH	MFH_reno1	MFH_reno2	AB	AB_reno1	AB_reno2
<1900	135.8	87.5	64.8	127.0	85.9	64.9	125.7	90.9	84.7	108.9	74.4	67.1
1901-1920	136.7	87.3	64.4	127.2	85.5	64.5	126.2	90.3	83.9	109.7	74.4	67.1
1921-1940	153.1	84.1	57.5	130.8	77.1	56.7	135.9	79.1	69.0	125.1	75.1	67.3
1941-1960	138.0	82.1	60.0	137.8	101.6	74.1	127.5	81.1	73.9	114.9	62.1	63.1
1961-1980	144.8	98.4	69.9	137.7	93.6	65.0	125.6	75.5	68.7	112.8	73.0	65.4
1981-2000	102.7	81.1	61.1	105.0	82.1	61.6	89.0	72.2	62.9	66.6	60.5	54.8
>2000	83.5	62.6	61.7	77.0	63.2	58.6	84.9	59.8	70.2	73.6	58.3	64.0
I don't know	144.8	98.4	69.9	137.7	93.6	65.0	125.6	75.5	68.7	112.8	73.0	65.4

Notes: SFH = single family home, TH = terraced housing, MFH = multi-family housing, AB = apartment block. Reno1 and reno2 are two different levels of renovation.

For the energy demand per respondent assuming average interior temperature (*Ti_mean*),

$$Energy_{Ti\_mean}[MJ] = \frac{Living\ Space\ (Q95)[m2]}{Household\ size\ (Q8)}\ x\ F_{en}[\frac{MJ}{m2}](lookup\ table, Q94, Q100, Q101) \text{(h.1)}$$

where F_{en} is the value from the TABULA lookup table.

With a correction for different interior temperatures (Stanciu et al., 2016).

$$Energy_{end}[MJ] = Energy_{Ti_{mean}}[MJ]\ x\ \left(1 + \frac{\Delta T\ (Q98)}{Te_{mean} - Ti_{mean}}\right) \qquad \text{(h.2)}$$

Where Te_{mean}=mean exterior temperature during the heating season [°K], where the heating season is all days with mean temperature less than 15.5°C, the base temperature for the European definition of heating degree-days (EEA, 2016). Ti_{mean}=mean interior temperature (assumed 21°C or 293°K), and ∆T is the change interior room temperature setting.

Based on OVO Energy (2018), we have converted the responses to ∆T (Q98) as follows:

What do you think about your preferred room temperature setting compared to other people you know in your country?	
a) Much cooler	- 2°C
b) Slightly cooler	1°C
c) About average	No change
d) Slightly warmer	+ 1°C
e) Much warmer	+ 2° C

Population-weighted mean temperatures, heating and cooling-degree days were self-calculated using NOAA city specific temperature data for the period 1990 – 2017 (NOAA, 2018). For the population weights the 10 largest cities in each country were used (EUROSTAT, 2018a). The values used in this report and a comparison to official values from EUROSTAT (2018b) are shown in Table 3.

Table 3: Population weighted heating degree-days (HDD), cooling degree-days (CDD), average temperature on days with less than 15°C and more than 24°C.

			Calculated from 1990 - 2017			
Country	**HDD_EUROSTAT**	**CDD_EUROSTAT**	**HDD**	**CDD**	**tavg_le_15**	**tavg_ge_24**
EU						
Belgium	2,580.0	16.9	2,610.8	15.9	7.7	25.3
Bulgaria	2,532.6	207.0	2,698.1	87.5	5.8	25.3
Czech Republic	3,310.5	22.3	3,597.5	22.2	4.9	25.3
Denmark	3,117.5	0.0	3,236.1	1.4	6.5	24.4
Germany	2,964.3	8.8	2,994.0	22.2	6.7	25.3
Estonia	4,208.2	0.0	4,254.3	5.1	3.5	24.7
Ireland	2,670.2	0.0	2,509.2	0.0	9.4	24.0
Greece	1,657.7	349.6	890.0	598.1	11.0	27.6
Spain	1,597.9	306.9	1,286.7	381.5	10.4	26.4
France	2,338.0	66.4	2,141.8	74.1	8.4	25.5
Croatia	2,330.6	206.7	2,039.4	239.6	7.1	26.2
Italy	1,878.2	295.4	1,618.4	248.8	8.9	26.3
Cyprus	720.7	702.6	789.3	1,022.4	11.5	28.3
Latvia	4,016.2	0.6	3,924.3	8.6	4.1	24.9
Lithuania	3,830.4	4.6	3,990.0	11.6	3.7	25.0
Luxembourg	2,869.5	23.1	3,096.9	23.5	6.6	25.3
Hungary	2,742.1	142.9	2,783.3	114.6	5.4	25.8
Malta	485.2	673.3	604.0	484.3	12.7	26.3
The Netherlands	2,544.1	5.8	2,777.7	8.5	7.7	25.0
Austria	3,503.3	34.9	2,939.7	52.1	5.8	25.3
Poland	3,290.0	19.6	3,398.7	22.2	5.0	25.3
Portugal	1,054.6	269.4	732.4	97.8	12.1	26.1
Romania	2,916.5	131.3	2,867.1	138.6	5.0	25.6
Slovenia	2,832.8	87.4	2,757.1	61.1	6.1	25.3
Slovakia	3,280.4	59.9	3,165.5	47.9	5.2	25.3
Finland	5,524.3	0.0	4,695.8	2.9	2.5	24.9
Sweden	5,219.9	0.0	3,539.4	5.2	5.1	24.6
United Kingdom	2,864.8	0.2	2,654.0	5.4	8.6	24.9
Iceland			4,668.2	0.0	5.1	24.0
Norway	5,529.8	0.0	4,098.7	0.7	4.9	24.6
Switzerland	3,735.5	14.5	2,933.8	22.5	6.4	25.0
Turkey			1,414.7	383	9.2	26.5

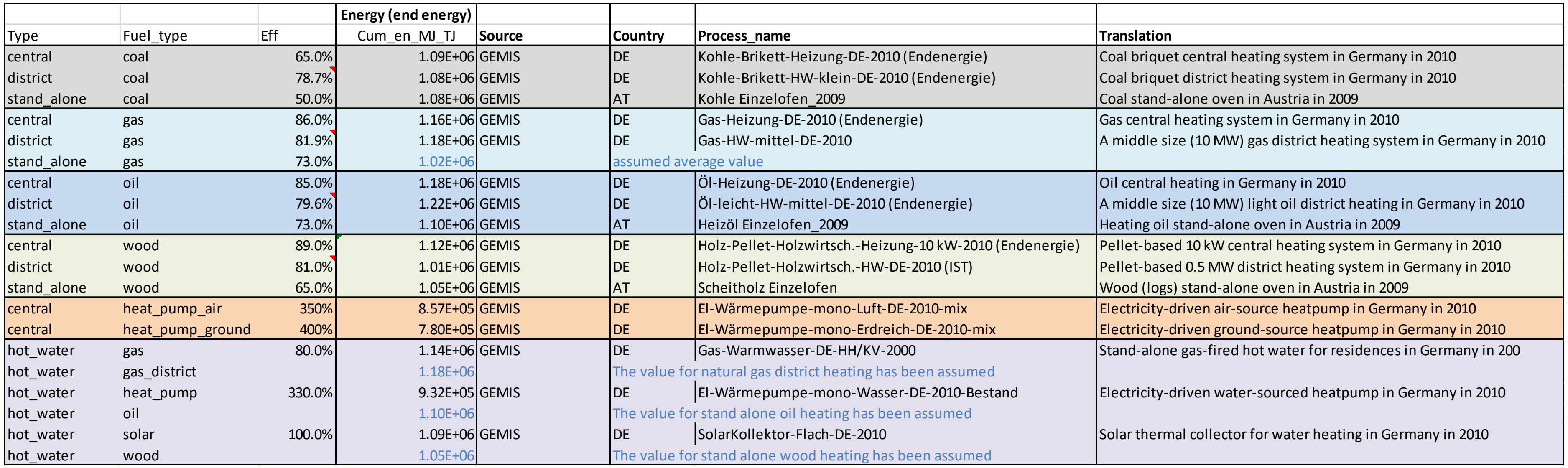
The $Energy_{end}$ per respondent per land were first calculated and then scaled so that the country mean demand (bottom-up) equalled the top-down country mean demand as estimated by EUROSTAT (2018c and 2018d).

Finally the cumulative energy $Energy_{cum}$ is calculated using the following formula:

$$Energy_{cum}[MJ] = Energy_{end}[MJ]\ x\ F_{en}[\frac{MJ}{MJ}] \qquad \text{(h.3)}$$

Where $F_{en}[\frac{MJ}{MJ}]$ is the amount of cumulative energy required per unit $Energy_{end}$. These values are heating technology and fuel dependent and are listed in Table 4.

Table 4: Cumulative energy [MJ] per unit end energy [TJ] factors (used in equation h.3) for various technologies and fuels



			Energy (end energy)				
Type	Fuel_type	Eff	Cum_en_MJ_TJ	**Source**	**Country**	**Process_name**	**Translation**
central	coal	65.0%	1.09E+06	GEMIS	DE	Kohle-Brikett-Heizung-DE-2010 (Endenergie)	Coal briquet central heating system in Germany in 2010
district	coal	78.7%	1.08E+06	GEMIS	DE	Kohle-Brikett-HW-klein-DE-2010 (Endenergie)	Coal briquet district heating system in Germany in 2010
stand_alone	coal	50.0%	1.08E+06	GEMIS	AT	Kohle Einzelofen_2009	Coal stand-alone oven in Austria in 2009
central	gas	86.0%	1.16E+06	GEMIS	DE	Gas-Heizung-DE-2010 (Endenergie)	Gas central heating system in Germany in 2010
district	gas	81.9%	1.18E+06	GEMIS	DE	Gas-HW-mittel-DE-2010	A middle size (10 MW) gas district heating system in Germany in 2010
stand_alone	gas	73.0%	1.02E+06		assumed average value		
central	oil	85.0%	1.18E+06	GEMIS	DE	Öl-Heizung-DE-2010 (Endenergie)	Oil central heating in Germany in 2010
district	oil	79.6%	1.22E+06	GEMIS	DE	Öl-leicht-HW-mittel-DE-2010 (Endenergie)	A middle size (10 MW) light oil district heating in Germany in 2010
stand_alone	oil	73.0%	1.10E+06	GEMIS	AT	Heizöl Einzelofen_2009	Heating oil stand-alone oven in Austria in 2009
central	wood	89.0%	1.12E+06	GEMIS	DE	Holz-Pellet-Holzwirtsch.-Heizung-10 kW-2010 (Endenergie)	Pellet-based 10 kW central heating system in Germany in 2010
district	wood	81.0%	1.01E+06	GEMIS	DE	Holz-Pellet-Holzwirtsch.-HW-DE-2010 (IST)	Pellet-based 0.5 MW district heating system in Germany in 2010
stand_alone	wood	65.0%	1.05E+06	GEMIS	AT	Scheitholz Einzelofen	Wood (logs) stand-alone oven in Austria in 2009
central	heat_pump_air	350%	8.57E+05	GEMIS	DE	El-Wärmepumpe-mono-Luft-DE-2010-mix	Electricity-driven air-source heatpump in Germany in 2010
central	heat_pump_ground	400%	7.80E+05	GEMIS	DE	El-Wärmepumpe-mono-Erdreich-DE-2010-mix	Electricity-driven ground-source heatpump in Germany in 2010
hot_water	gas	80.0%	1.14E+06	GEMIS	DE	Gas-Warmwasser-DE-HH/KV-2000	Stand-alone gas-fired hot water for residences in Germany in 200
hot_water	gas_district		1.18E+06		The value for natural gas district heating has been assumed		
hot_water	heat_pump	330.0%	9.32E+05	GEMIS	DE	El-Wärmepumpe-mono-Wasser-DE-2010-Bestand	Electricity-driven water-sourced heatpump in Germany in 2010
hot_water	oil		1.10E+06		The value for stand alone oil heating has been assumed		
hot_water	solar	100.0%	1.09E+06	GEMIS	DE	SolarKollektor-Flach-DE-2010	Solar thermal collector for water heating in Germany in 2010
hot_water	wood		1.05E+06		The value for stand alone wood heating has been assumed		

Electricity-based heating

For electric-based heating two factors were used: one for respondents who have purchased “green” energy and another for those who have not. The factor for “green” energy is 1.14 $Energy_{cum}$ / $Energy_{end}$, the value for non-alpine hydro power from Ecoinvent (Wernet et al., 2016). The factor for “regular” energy was calculated so that response weighted value equalled the national factor listed in Table 5.

2.1.2.Cooling (Q99)

For cooling we ask a very simple question on frequency of use. For the calculation we used the following approach:

From Stanciu et al. (2016) the heat transfer coefficient, k is given by:

$$k = \frac{Energy_{Ti\_mean}}{HDD} \qquad \text{(c.1)}$$

Where HDD = heating degree-days

Assuming the same heat transfer coefficient for cooling:

$$Energy_{cooling} = \frac{Energy_{Ti\_mean}}{HDD}\ x\ CDD \qquad \text{(c.2)}$$

Where CDD is calculated using 22°C as the base temperatures (EEA, 2016). For the different levels of air conditioner (AC) use we assume that the user turns on her/his AC unit at different temperature and we will estimate the CDD at different base temperatures based on the response to Q99 using the following:

$$Energy_{end}[MJ] = Energy_{cooling}[MJ]\ x\ \left(1 - \frac{Set\ Temperature\ (Q99)}{Te_{mean}(> 24°C) - Ti_{mean}}\right)$$

Table 5: National electricity cumulative energy [MJ] per unit end energy [MJ] factors for 2020. The value varies due to the assumed fuel mix (e.g. coal, oil, natural gas, renewable). Values highlighted in red are the highest 10%. Values highlighted in green are the lowest 10%.

Country	**cum_en_MJ_MJ**	**Source: system**
EU		
Belgium	3.41	GEMIS: El-KW-Park-BE-2020
Bulgaria	2.90	GEMIS: El-KW-Park-BG-2020
Czech Republic	3.01	GEMIS: El-KW-Park-CZ-2020
Denmark	2.85	GEMIS: El-KW-Park-DK-2020
Germany	2.22	GEMIS: El-KW-Park-DE-2020
Estonia	2.33	GEMIS: El-KW-Park-EE-2020
Ireland	1.78	GEMIS: El-KW-Park-IE-2020
Greece	2.27	GEMIS: El-KW-Park-GR-2020
Spain	2.21	GEMIS: El-KW-Park-ES-2020
France	3.34	GEMIS: El-KW-Park-FR-2020
Croatia	2.32	GEMIS: El-KW-Park-HR-2005
Italy	2.40	GEMIS: El-KW-Park-IT-2020
Cyprus	2.33	GEMIS: El-KW-Park-CY-2020
Latvia	1.79	GEMIS: El-KW-Park-LV-2020
Lithuania	2.75	GEMIS: El-KW-Park-LT-2020
Luxembourg	2.05	GEMIS: El-KW-Park-LU-2020
Hungary	3.69	GEMIS: El-KW-Park-HU-2020
Malta	2.51	GEMIS: El-KW-Park-MT-2020
The Netherlands	2.22	GEMIS: El-KW-Park-NL-2020
Austria	2.39	GEMIS: El-KW-Park-AT-2020
Poland	2.71	GEMIS: El-KW-Park-PL-2020
Portugal	2.59	GEMIS: El-KW-Park-PT-2020
Romania	2.31	GEMIS: El-KW-Park-RO-2020
Slovenia	2.47	GEMIS: El-KW-Park-SI-2020
Slovakia	2.84	GEMIS: El-KW-Park-SK-2020
Finland	2.93	GEMIS: El-KW-Park-FI-2020
Sweden	2.42	GEMIS: El-KW-Park-SE-2020
United Kingdom	2.41	GEMIS: El-KW-Park-UK-2020
Iceland		
Norway	1.21	GEMIS: El-KW-Park-NO-2020
Switzerland	2.25	GEMIS: El-KW-Park-CH-2020
Turkey	2.06	GEMIS: El-KW-Park-TR-2020
Hydro_runofriver	1.14	Ecoinvent
Hydro_alpine	1.14	Ecoinvent
Hydro_non_alpine	1.14	Ecoinvent

How often do you use air condition at home during the summer?

a) Almost never	Set temperature = +3°C
b) Rarely	Set temperature = +2°C
c) Sometimes	Set temperature = +1°C
d) Regularly	Set temperature = 0°C. This is the value for the standard CDDs.
e) Often	Set temperature = -1°C

We assume that all energy for cooling is provided from electricity (i.e. factors from Table 5).

2.1.3.Hot water (Q 107, 108, 109)

To calculate the energy required for hot water, we have assumed that a bath requires 175 litres and a shower uses 55 litres (EEA, 2015). For the respondents who answered that they have both, 115 litres was assumed. The end energy required for hot water is calculated using:

$$Energy_{end}\,[MJ] = \frac{Bath\ or\ Shower\ (Q109)}{Bath\ or\ Shower_{mean}}\ x\ Energy_{hot\_water}\,[MJ] \qquad \text{(hw.1)}$$

Where $Bath\ or\ Shower\ (Q109)$ is the amount of water used by the respondent, $Bath\ or\ Shower_{mean}$ is the country mean amount of water used by respondent and $Energy_{hot\_water}[MJ]$ is the mean energy used for hot water by country (EUROSTAT, 2018c and 2018d). This inherently assumes that all respondents bath or shower with the same frequency and for the same amount of time.

The cumulative energy is then given by:

$$Energy_{cum}[MJ] = Energy_{end}[MJ]\ x\ F_{en}[\frac{MJ}{MJ}] \qquad \text{(hw.2)}$$

Where $F_{en}[\frac{MJ}{MJ}]$ are the technology and fuel dependent factors listed in Table 4.

2.1.4.Cooking (Q105)

Energy for cooking is calculated assuming that the average response per country causes the average energy for cooking for that country (EUROSTAT, 2018c and 2018d).

$$Energy_{end}[MJ] = \frac{No\_hot\_meals(Q105)}{No\_hot\_meals_{mean}}\ x\ Energy_{cooking}[MJ] \qquad \text{(c.1)}$$

Where $Energy_{cooking}[MJ]$ is the mean energy used for cooking in the country. Note: For countries where no data were available from EUROSTAT, the average EU value has been assigned.

The cumulative energy is then given by:

$$Energy_{cum}[MJ] = Energy_{end}[MJ]\ x\ F_{en}[\frac{MJ}{MJ}] \qquad \text{(c.2)}$$

For this equation, $F_{en}[\frac{MJ}{MJ}]$ are a usage-weighted sum of factors for different cooking energy sources (Table 6) based on the national percentage of cooking energy for various sources (EUROSTAT, 2018c and 2018d).

Table 6: Cooking cumulative energy [MJ] per unit end energy [MJ] factors

Item	EF_MJ_MJ	Ref_country	Ref_year	Ref_EI	Source
Gas	1.226	Germany	2010	0.1729	GEMIS: Gas-Kochen-DE-HH/KV-2010 (Endenergie)
Oil	1.289	Tanzania	2010	0.0873	GEMIS: LPG-Kochherd-TZ-2010
Coal	1.237	Germany	2010	0.1729	GEMIS: Braunkohle-Brikett-Heizung-DE-rheinisch-2010 (Endenergie)
Wood	1.005	Germany	2000	0.2123	GEMIS: Holz-Kochen-DE-2000 (Endenergie)

Notes: No data for LPG cooking systems were available in the databases in European countries. Hence we are using data from Tanzania as a replacement.

2.1.5.Lighting and appliances (Q102 - 104)

Energy for electricity, other than electricity for heating and cooling (see above), is calculated from two questions. We assume:

$$Energy_{end}[MJ] = Energy_{appl}[MJ] + Energy_{stand}[MJ] + Energy_{light}[MJ] \qquad \text{(la.1)}$$

and

$$Energy_{end}[MJ] = Energy_{LA\_mean}[MJ]\ x\ (0.65 + 0.15f_l + 0.05f_s) \qquad \text{(la.2)}$$

Where $\overline{Energy_{LAmean}}[MJ]$ is the country average electricity consumption of lighting and appliances (EUROSTAT, 2018c and 208d) and the values 0.65, 0.05 and 0.15 are the portions attributable to large appliances, lighting and stand-by respectively in Austria in 2016 (Statistics Austria, 2018) and f_l and f_s are factors that are applied in response to Q102 and Q103[2].

F_l will be assigned as follows. First we will assume that the replacement of a 60W incandescent with a 10W LED is (Q103):

What proportion of your light bulbs at home are energy saving varieties (e.g. LED, compact fluorescent, etc.)?

a) zero or only a few	10%
b) several	50%
c) most (around 75%)	75%
d) all (100%)	100%

We will calculate the survey average energy for lighting:

$$\overline{Energy_{light}} = \frac{1}{N}\sum_i(60 - 50xLED\%_i) \qquad \text{(la.3)}$$

then

$$f_{l,i} = \frac{(60-50xLED\%_i)}{\overline{Energy_{light}}} \qquad \text{(la.4)}$$

Answer *e) I don't know* is assigned the survey average response.

For stand-by energy the following scale was assumed:

How often do you disconnect electric appliances from the power supply when you are currently not using them? (Specifically TV, PC, Notebook, DVD-Player etc.)

a) never	0%
b) rarely	25%
c) occasionally	50%
d) often	75%
e) always	100%

We calculate the survey average energy for standby as:

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[2] The sum the portions does not equal 1 because energy for electronics is not included here. It is calculated under the information lifestyle category

$$\overline{Energy_{standby}} = \frac{1}{N}\sum_i Standby\%_i \tag{Ia.3}$$

then

$$f_{s,i} = 1 - \frac{Standby\%_i}{\overline{Energy_{standby}}} \tag{Ia.4}$$

Cumulative energy is given by:

$$Energy_{cum}[MJ] = Energy_{end}[MJ]\ x\ F_{en}[\frac{MJ}{MJ}] \tag{Ia.5}$$

As with electric-based heating, two factors were used: one for respondents who have purchased "green" energy and another for those who have not. The factor for "green" energy is 1.14 *Energy*$_{cum}$ / *Energy*$_{end}$, the value for non-alpine hydro power from Ecoinvent (Wernet et al., 2016). The factor for "regular" energy was calculated so that the response weighted value equalled the national factor listed in Table 5.

2.2. Mobility

2.2.1.Private vehicle use (Q75 - Q80)

Automobiles

The calculation of an individual's end energy for mobility would be quite simple.

$$Energy_{end}[MJ] = \frac{\frac{Q75[km]}{100}\ x\ Q79\left[\frac{l}{100km}\right] x\ Q78\ [\frac{MJ}{l} - fuel\ type]}{\overline{passengers}} \tag{m.1}$$

Where

$$\overline{passengers} = Q76\ [\%] + (1 - Q76[\%])\ x\ Q77 \tag{m.2}$$

However, the calculation is a little more complicated because the LCA energy factors are vehicle size specific and these do not match completely the respondent's vehicle. Instead a linear model relating vehicle efficiency and cumulative energy per passenger-km for diesel and gasoline vehicles was developed. In GEMIS there are three sizes of vehicle (small, medium and large) and the relationship between *Energy*$_{cum}$[MJ/p-km] and vehicle fuel efficiency [l/km] is shown in Figure 1.

With these relationships equation m.1 can be reformulated as

$$Energy_{cum}[MJ] = \frac{Q75[km] x \left(a + \frac{b}{100}\ Q79\left[\frac{l}{100km}\right]\right)}{\overline{passengers}} \tag{m.3}$$

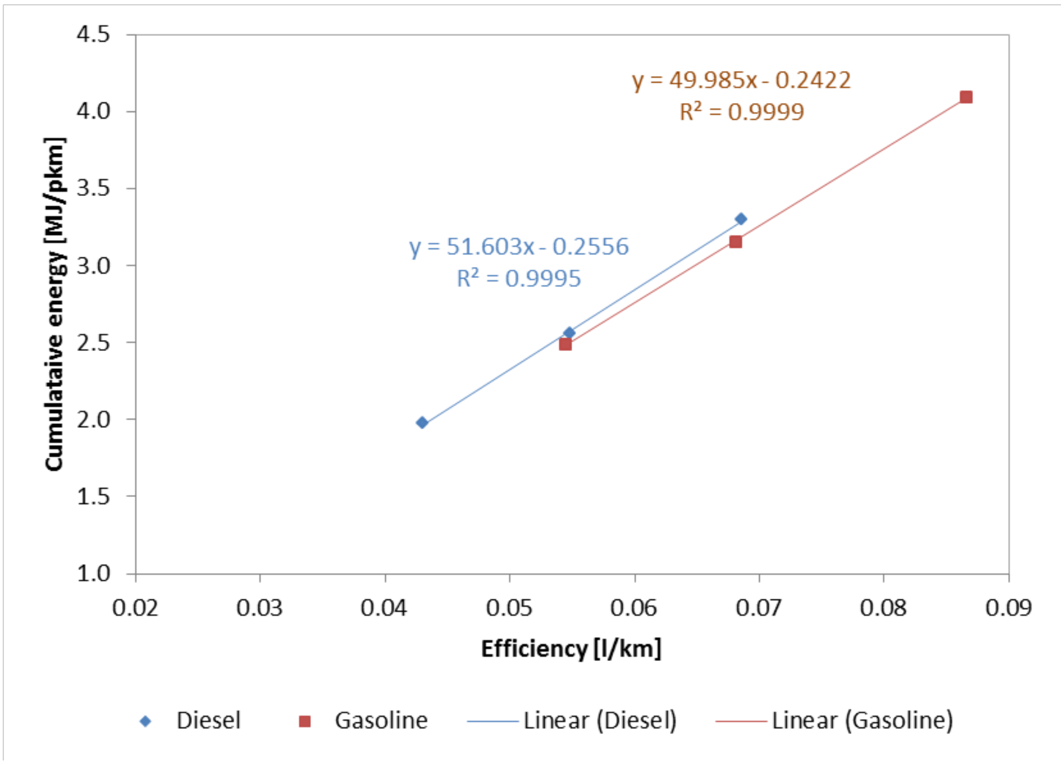

Figure 1: The linear relationships between vehicle efficiency and cumulative energy [MJ / p-km] for diesel (blue) and gasoline vehicles (brown)

For natural gas and electric vehicles the following constant energy factors, independent of vehicle size were assumed:

- electric car - 1.3986 MJ / p-km (a small vehicle)
- natural gas car - 3.4819 MJ / p-km (a medium-size vehicle)

2.2.2.Mopeds, motorcycles (Q81 & 82)

For motorcycles, the respondents were asked their fuel efficiency. We assumed that the country average response required the cumulative energy from the LCA database. Hence:

$$Energy_{cum}[MJ] = Q81\ [km] x\ \frac{Q82\ [\frac{l}{100km}]}{Motorcycle\_efficiency_{mean}[\frac{l}{100km}]} x\ 1.626\ [\frac{MJ}{pkm}]\quad \text{(m.4)}$$

The energy factor 1.626 MJ/p-km is the value for Motorrad-4-Takt-AO-2010 in the GEMIS database.

2.2.3.Vehicle use as a passenger (Q83 – Q84)

The average distance travelled per trip as a passenger in a vehicle in Austria is 11.2 km (BMVIT, 2016), but in other European countries it is generally more (Pasaoglu et al., 2012; Ahern et al., 2013), however values for all countries are not available. Table 6 lists actual and assumed country-specific average trip distances. With this information, the energy required as a passenger is calculated using by assuming that they travel is in a country average car:

$$Energy_{cum}[MJ] = \frac{Average\ trip\ distance\left[\frac{km}{trip}\right] x\ Q83\ \left[\frac{trip}{week}\right] x\ 52\left[\frac{weeks}{year}\right]}{Q84\ [passengers]}\ x\ \overline{Energy_{cum}}[\frac{MJ}{pkm}]\text{(m.5)}$$

Table 7: Country specific support data for the calculation of energy demand for as a passenger and by public transportation. Values in black come directly from various sources. The red value is the EU average and blue values are assumed values which are usually the EU average but occasionally a neighbouring country.

Country	ave_vehicle_trip_km	bus_km_hr	train_km_hr	tram_km_hr	underground_km_hr
EU	19.8	19.0	29.4	16.3	32.0
Belgium	19.8	16.6	29.4	16.6	28.0
Bulgaria	25.0	18.6	38.4	12.5	38.4
Czech Republic	19.8	19.0	29.4	16.3	32.0
Denmark	19.8	19.0	29.4	16.3	32.0
Germany	19.8	19.0	27.8	16.3	31.9
Estonia	19.8	22.8	29.4	16.0	32.0
Ireland	19.8	19.0	29.4	22.5	32.0
Greece	19.8	17.9	29.4	21.0	33.0
Spain	29.6	12.1	28.9	18.0	28.9
France	19.0	19.0	29.4	16.3	25.0
Croatia	19.8	19.1	29.4	12.9	32.0
Italy	18.9	19.1	26.8	16.3	26.8
Cyprus	19.8	19.0	29.4	16.3	32.0
Latvia	19.8	21.0	29.4	16.0	32.0
Lithuania	19.8	22.8	29.4	16.0	32.0
Luxembourg	19.8	19.0	29.4	16.3	32.0
Hungary	19.8	19.0	29.4	16.3	32.0
Malta	19.8	19.0	29.4	16.3	32.0
The Netherlands	19.8	19.0	29.4	16.3	32.0
Austria	11.2	17.3	24.4	15.0	32.5
Poland	25.0	22.4	29.4	14.6	36.0
Portugal	19.8	14.0	29.4	16.3	32.0
Romania	19.8	13.3	46.0	12.6	36.0
Slovenia	19.8	11.0	29.4	16.3	32.0
Slovakia	19.8	19.0	29.4	16.3	32.0
Finland	19.8	19.0	29.4	16.3	32.0
Sweden	15.8	24.4	29.4	16.3	32.0
United Kingdom	19.1	19.0	29.4	16.3	32.0
Iceland	19.8	23.2	29.4	16.3	32.0
Norway	15.8	22.9	30.1	19.0	30.1
Switzerland	19.8	18.8	29.4	15.8	32.0
Turkey	19.8	23.8	29.4	16.3	38.1

Sources: Alexopoulos and Wyrowski (2015), *EMTA(2017)*, Lagzdons (2012), Madrid S.A. (2018), *New Statesman (2017)*, *Railway Technology (2017)*, Roads and (BDiK) (2010), *Romania Insider (2017)*, Ruter (2015), Wiener_Linien (2016)

2.2.4.Public transportation (Q85 – Q89)

The time travelled per day for the various transport modes must be converted to distances since the energy and emission factors are per passenger-km. For bus, tram and underground, the average speeds of Wiener Linien (Wiener_Linien, 2016) are 17.3, 15.0 and 32.5 km/hr respectively. A full list of average public transportation velocities by country is given in Table 6.

$$Energy_{cum}[MJ] = \sum\nolimits_{transport\ mode} F_{en-mode}[\frac{MJ}{pkm}]\ x\ \frac{time_{mode}[minutes]}{60}\ x\ V_{mode}[\frac{km}{hr}] \quad \text{(m.6)}$$

The energy factors used in equation m.6 are listed in Table 7.

Table 8: Cumulative energy [MJ/pkm] for various modes of public transport and aviation

Type	Energy Cum_en_MJ_pkm	Source	Country	LCA system
bus	0.833	GEMIS	DE	Bus-Linie-Diesel-DE-2010
train	1.237	GEMIS	DE	Zug-Personen-Nah-Diesel-DE-2010
tram	1.782	GEMIS	DE	Strassenbahn-D-Darmstadt 2000
underground	1.074	GEMIS	DE	SSU-Elektrisch-Zug-DE-2010
short haul flights	3.158	GEMIS	DE	Flugzeug-Passagiere-Inland-DE-2010
long haul flights	2.047	GEMIS	DE	Flugzeug-Passagiere-internantional-DE-2010

Notes: The specific energy factors for each country are calculated by adjusting the electricity portion by the specific countries electrical energy mix.

2.2.5.Aviation (Q92 & 93)

Non-business flights

For non-business aviation the respondents have answered how much time was spent flying in the past year. The time needs to be converted to distance by multiplying by a velocity. For answers less than 10 hours, we assume that they are short haul flights. For answers, greater than 10 hours, we assume that a percentage of the time is short haul.

Q92 < 10 hours

$$Energy_{cum}[MJ] = Q92[hrs]\ x\ V_{short}\ \left[\frac{km}{hr}\right] x\ \ F_{en-short}[\frac{MJ}{pkm}] \qquad \text{(m.7)}$$

Q92 > 10 hours

$$Energy_{cum}[MJ] = Q92[hrs]\ x$$
$$\left(\%_{short}\ x\ V_{short}\ \left[\frac{km}{hr}\right] x\ F_{en-short}\left[\frac{MJ}{pkm}\right] + (1-\%_{short}) x\ V_{long}\ \left[\frac{km}{hr}\right] x\ F_{en-long}\left[\frac{MJ}{pkm}\right]\right) \qquad \text{(m.8)}$$

Where V_{short} = 523 km/hr[3], V_{long} = 750 km/hr[4].

Business flights

The survey asks for the number of business trips in a year. This value needs to be partition between short and long haul flights and an average distance for short and long haul flights needs to be calculated. For this purpose, we have assumed average one-way distances for short haul flights, D_{short}, are estimated for flights to Brussels from the country capital. Average one-way distances for long haul flights, D_{long}, are calculated as the average of flights to Johannesburg, New York City and Singapore.

$$Energy_{cum}[MJ] = Q93\ x$$
$$\left(\%_{short}\ x\ 2D_{short}\ [km] x\ F_{en-short}\left[\frac{MJ}{pkm}\right] + (1-\%_{short})\ x\ 2D_{long}[km] x\ F_{en-long}\left[\frac{MJ}{pkm}\right]\right)$$

(m.9)

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[3] The distance between Vienna and Brussels is 915 km, with a flight time of 1 hr 45 min.

[4] The distance between Vienna and Beijing is 7,456 km, with a flight time of 9 hrs 30 minutes.

The supporting data for the calculation of energy demand from aviation are shown in Table 9.

Table 9: The fraction of short haul private and business flights in 2016 and the geographical coordinates of the capital cities by country. The red values are the EU means. There are no data for the entries in blue. They are assumed to be the EU mean, with the exception of Turkey, for which we assumed the Greek values. For business flights in Turkey, we assumed that the point of departure was Istanbul and not the capital, Ankara.

Country	priv_short_haul_frac	bus_short_haul_frac	capital	lat	long
EU	0.74	0.65			
Belgium	0.74	0.59	Brussels	50.85	4.35
Bulgaria	0.75	0.61	Sofia	42.70	23.32
Czech Republic	0.72	0.78	Prague	50.08	14.44
Denmark	0.74	0.63	Copenhagen	55.68	12.57
Germany	0.66	0.65	Berlin	52.52	13.40
Estonia	0.80	0.70	Tallinn	59.44	24.75
Ireland	0.85	0.76	Dublin	53.35	-6.26
Greece	0.83	0.83	Athens	37.98	23.73
Spain	0.86	0.83	Madrid	40.42	-3.70
France	0.65	0.72	Paris	48.86	2.35
Croatia	0.74	0.74	Zagreb	45.82	15.98
Italy	0.81	0.74	Rome	41.90	12.50
Cyprus	0.66	0.78	Nicosia	35.19	33.38
Latvia	0.73	0.49	Riga	56.95	24.11
Lithuania	0.78	0.35	Vilnius	54.69	25.28
Luxembourg	0.90	0.68	Luxemburg	49.61	6.13
Hungary	0.81	0.63	Budapest	47.50	19.04
Malta	0.91	0.88	Valletta	35.90	14.51
The Netherlands	0.62	0.59	Amsterdam	52.37	4.90
Austria	0.70	0.62	Vienna	48.21	16.37
Poland	0.82	0.71	Warsaw	52.23	21.01
Portugal	0.74	0.81	Lisbon	38.72	-9.14
Romania	0.87	0.65	Bucharest	44.43	26.10
Slovenia	0.61	0.41	Ljubljana	46.06	14.51
Slovakia	0.85	0.65	Bratislava	48.15	17.11
Finland	0.76	0.76	Helsinki	60.17	24.94
Sweden	0.81	0.87	Stockholm	59.33	18.07
United Kingdom	0.70	0.56	London	51.51	-0.13
Iceland	0.00	0.00	Reykjavik	64.15	-21.94
Norway	0.82	0.87	Oslo	59.91	10.75
Switzerland	0.74	0.65	Zurich	47.38	8.54
Turkey	0.83	0.83	Istanbul	41.01	28.98

Sources: Calculated from EUROSTAT (2018e), Statistics Norway (2018)

2.3. Goods

As an indicator of the energy required for the consumption of goods, we have focused on two commodities: clothing and electronics. They were chosen due to experience gained in the Austrian project ClimAconsum (Windsperger et al., 2017, 2018). The goal of this project was to estimate the consumption-based greenhouse gas emissions of Austria using a bottom-up approach by tying LCA emission factors to national consumption statistics. This study found that goods composed 43% of consumption emissions. However, the majority of these were due to commodities over which the individual has little control (e.g. aluminium – 22%, cement – 6%, plastic – 14%, and steel – 22% of goods). The commodities are consumed by the society for buildings. Two commodities over which an individual has control are clothing (9% of emissions) and electronics (11% of emissions).

2.3.1.Clothing (Q111)

For clothing we asked the respondent a very simple question (Q111) which is repeated here. This was transferred into a scale indicating the amount of clothing the purchased relative to the average.

Please choose the answer that best describes your preferences in fashion.

a) Modest	1/3 as much
b) Long use, also second hand	2/3 as much
c) About average	The same as average (1)
d) New clothes quite often	2 time as much
e) Highly fashionable, always the latest style	3 times as much

This breakdown was based on a paper by Scheerder et al. (2011). Their study, based on sporting apparel purchases in Belgium found that, in comparison to the amount the average person spent: 10% of the population spent less than 0.3, 20% of the population spent between 0.3 and 0.6, 20% of the population spent between 1.6 and 3.0 and 10% of the population spent more than 3 times. With this information:

$$Energy_{cum}[MJ] = \frac{Clothing\ fraction\ (Q111)}{Clothing\ faction_{mean}}\ x\ Clothing_{amount}[\frac{g}{cap}]\ x\ F_{en}[\frac{MJ}{g}] \qquad \text{(g.1)}$$

Where *Clothing*$_{amount}$ is the national average clothing consumption per capita and F_{en} is the cumulative energy factor. The national average clothing consumption per capita are listed in the last column of Table 10. The energy factor for clothing is 0.3615 MJ/g and is the average of a value from GEMIS (system: Veredlung-IT\Baumwolle-US-I-2000) and Ecoinvent (system: market for textile, knit cotton, alloc. default, U).

2.3.2.Electronics (Q112)

For electronic equipment the following question was asked in the survey:

Please choose the answer that best fits your preferences in purchasing electronics (PC, Notebook, Tablet, Smartphone, TV, Hi-Fi Equipment)

a) I do not need most of it	2 times the average lifetime
b) Long use, replace only if broken	1.5 times the average lifetime
c) About average	The same as average (1)
d) New equipment regularly	0.75 times the average lifetime
e) I like to always have the latest technology	0.5 times the average lifetime

The average lifetimes for cell phones, computers and flat screen monitors were modelled from consumption information (EUROSTAT, 2018f).

Table 10: Average lifetimes of electronic goods and clothing consumption per capita (2016) used for calculating the cumulative energy demand for goods. The red values are the EU mean values. Values in blue are assumed values usually the EU mean, but sometimes a value from a neighbouring country. Highlighted cells are the top 10% (red) or bottom 10% (green) used a quality control

Country	Cell_phone_life_yr	Computer_life_yr	FP_monitor_life_yr	Clothing_g_cap
EU	3.4	5.0	3.0	11,512
Belgium	3.4	5.0	1.4	9,800
Bulgaria	3.9	10.3	3.5	5,771
Czech Republic	3.4	2.8	3.0	7,454
Denmark	3.4	5.0	3.7	10,906
Germany	3.4	3.9	1.9	12,311
Estonia	3.4	5.0	3.0	8,678
Ireland	3.4	5.0	2.8	14,176
Greece	3.2	4.7	2.9	6,022
Spain	2.3	3.4	1.3	11,167
France	3.4	3.2	1.7	10,182
Croatia	3.4	8.4	5.2	17,129
Italy	3.3	5.2	3.0	11,095
Cyprus	3.4	5.0	1.7	9,922
Latvia	3.4	5.0	3.0	5,137
Lithuania	3.4	5.0	1.1	8,857
Luxembourg	3.4	5.0	1.4	10,894
Hungary	3.4	6.3	3.0	5,680
Malta	3.4	5.0	1.7	6,002
The Netherlands	3.4	2.7	1.9	24,313
Austria	5.1	6.0	4.0	11,725
Poland	3.4	7.5	3.0	7,377
Portugal	3.4	3.4	1.3	15,129
Romania	3.4	5.0	3.5	6,166
Slovenia	3.4	5.0	2.7	5,236
Slovakia	3.4	5.0	2.7	8,807
Finland	3.4	5.1	1.0	8,625
Sweden	2.5	3.0	3.1	11,488
United Kingdom	3.4	3.0	2.8	13,922
Iceland	3.4	5.0	3.0	10,057
Norway	2.5	3.0	3.1	11,488
Switzerland	3.4	5.0	3.0	12,018
Turkey	3.5	7.5	3.2	5,897

Sources: Product lifetimes are self-calculated. Clothing are calculated based on the number of products from EUROSTAT (2018f) and assuming an average mass of 290 g/piece

For cell phones, we assumed that the market is saturated. In this case, any new purchases are replacement phones only and are a fraction of the total number of phones in the market which is calculated from World Bank (2018) indicator - Mobile cellular subscriptions (per 100 people). We found that the average cell phone lifetime in the EU is 3.4 years.

For computers, the model is a little more complicated. EUROSTAT has information on the percentage of employees with access to a computer (EUROSTAT 2018g and 2018h) and percentage of households with computer access (EUROSTAT 2018i), and data on the amount of computers consumed per year (EUROSTAT, 2018f). Assuming exponential decay the average lifetime is calculated by:

$$T_{ave} = \frac{-1}{ln\left[1 - \frac{(C_{y1} - S_{y1} + S_{y0})}{S_{y0}}\right]} \qquad \text{(g.2)}$$

Where C_{y1} is the consumption of computers in year y1, and S_{y1} and S_{y0} are the stocks of computers in the market. S_{y1} and S_{y0} are calculated from a polynomial fit to the data on percentages of employees and households with computer access, and the total number of employees and households in the country. We found that the average lifetime of a computer in the EU is 5.0 years.

The model for flat screen monitors is even more complicated because there is no information on the amount of market penetration. To model these data, we have assumed a Bass penetration model (Bass, 1969) with exponential decay after the Bass peak annual consumption has been reached. Figure 2 shows the model results for Austria. The average lifetime of a flat panel monitor in the EU is 3.0 years.

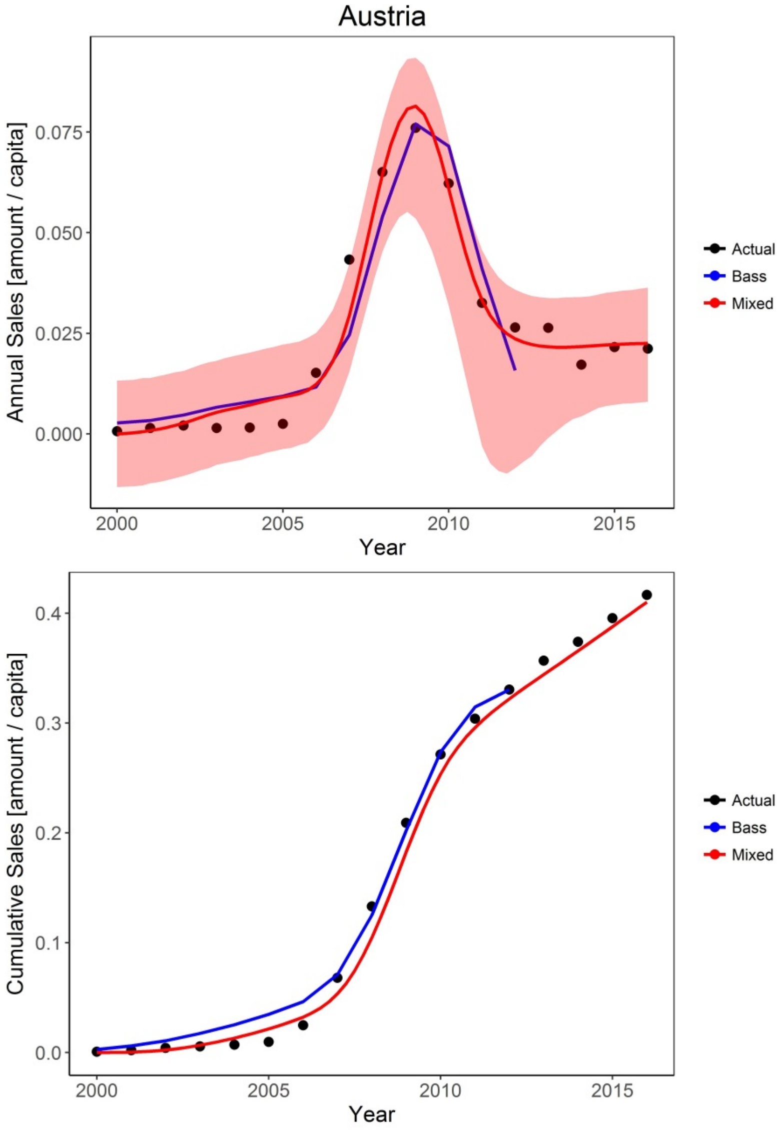

Figure 2: Modelled annual sales of flat panel monitors in Austria from 2000 to 2015

With this information, the cumulative energy from the consumption of electronics goods is

$$Energy_{cum}[MJ] = \sum_{product}\left(1 - e^{-1/T_{product}}\right) F_{en}[\frac{MJ}{unit}] \qquad \text{(g.3)}$$

Where the cumulative energy factors for cell phones, computers and flat panel monitors are 880, 2549, and 4503 MJ/unit respectively. The first value is taken from Quariguasi-Frota-Neto and Bloemhof (2012) and the other values are from Ecoinvent (systems: market for computer, laptop, alloc. default, U and market for display, liquid crystal, 17 inches, alloc. default, U).

2.4. Diet (Q106)

For estimating the cumulative energy demand from diet, we have relied on per capita national food consumption data with discards from FAOSTAT (2019). These are listed in Table 11. As shown we have only the national average consumption however we have made a calculation based on Q106:

Please choose the answer that best describes your diet.

a) Meat in most meals	
b) Meat in some meals	67% of "meat in most meals" Meat replaced by equally by nuts, oils and pulses on a caloric basis
c) Meat very rarely	33% of "meat in most meals". Meat replaced by equally by nuts, oils and pulses on a caloric basis
d) No meat, but fish	All meat replaced by fish on a caloric basis
e) Vegetarian	No meat. Meat replaced by equally by nuts, oils and pulses on a caloric basis
f) Vegan	Recommended vegan diet

The vegan diet uses the values listed in Table 10 as they are. For the other diets we have converted this scale into a scale of varying food consumption. First we assumed that the national average diet is representative of answer a - *Meat in most meals*. For the fish diet (d) we assumed that all meat was replaced on a caloric basis by fish. For the three remaining diets we assumed that answer b - *Meat in some meals* eats 67% of the average meat consumption; answer c - *Meat very rarely* eats 33% of the average meat consumption; and answer e – *Vegetarian* eats no meat products. In all cases the missing calories from meat are assumed to be compensated equally on a caloric basis by nuts, oils and pulses (legumes). Finally, the estimated amounts per food type are scaled to the national average again. In this manner, the *meat in most meals* person ends up eating more than the national average but the ratios to other diets remain the same, and the total amount of each food equals the national average. Hence:

$$Energy_{cum}[MJ] = \sum_{food\ type}\frac{Food_i[\frac{g}{person-day}]}{\sum_i Food_i[\frac{g}{person-day}]} x Food_{national}\left[\frac{g}{person-day}\right] x 365 x\, F_{en,food}[\frac{MJ}{g}]$$

(d.1)

Where i = respondent number.

The values for $F_{en,food}$ are listed in the bottom row of Table 11.

Table 11: National per capita consumption of food for human consumption including waste [g/person/day]. Values highlighted in red are the upper most 10% while those highlighted in green are the lower most 10%

Country	Beer	Cheese	Coffee	Eggs	Fish	Fruit	Grains	Meat_beef	Meat_chicken	Meat_pork	Milk	Nuts	Oil	Potatoes	Pulses	Sweets	Vegetables	Wine
EU	259.6	93.5	26.8	54.0	90.4	636.9	1,046.9	92.5	96.6	140.7	841.9	20.1	177.7	406.3	103.6	1,080.4	501.9	88.5
Belgium	205.9	71.2	22.6	35.2	68.6	237.7	1,501.7	61.0	35.2	105.5	640.7	22.1	385.0	279.6	30.5	1,498.2	401.3	75.0
Bulgaria	205.0	44.0	21.1	24.5	18.8	309.0	1,146.0	31.6	56.8	71.5	396.5	9.0	56.8	88.2	9.4	86.9	204.3	31.6
Czech Republic	389.7	61.0	15.6	33.3	24.0	211.9	919.4	43.8	53.1	114.9	548.7	7.8	84.4	213.6	18.3	1,147.6	208.1	41.7
Denmark	169.2	79.8	38.1	40.5	99.8	368.1	686.5	102.6	73.8	142.3	718.3	17.1	228.9	683.7	3.5	1,479.7	303.3	77.8
Germany	264.5	77.9	23.6	34.6	35.4	302.4	760.9	48.7	53.4	145.8	701.2	22.9	165.6	253.5	116.7	939.8	286.5	66.2
Estonia	284.3	77.0	31.1	35.3	39.4	220.0	524.4	31.1	56.0	88.0	692.9	12.5	27.0	237.4	24.9	85.1	313.4	41.5
Ireland	413.1	124.3	12.5	26.7	72.5	493.2	482.4	78.5	77.3	89.1	1118.3	11.3	140.9	362.7	12.5	164.0	276.9	45.2
Greece	100.1	75.7	26.4	28.9	53.5	1001.7	560.5	102.3	46.1	81.4	681.6	32.6	141.4	230.8	85.6	176.8	728.8	80.2
Spain	205.4	49.4	20.9	37.4	117.4	1173.9	483.3	58.3	79.7	134.6	445.0	20.6	159.1	197.7	213.0	238.5	380.9	103.4
France	64.0	68.7	26.2	36.0	93.0	594.4	866.6	98.7	64.6	88.7	618.2	14.5	151.6	204.9	26.6	1570.1	296.2	138.9
Croatia	214.7	65.0	25.7	23.8	52.1	390.8	501.1	64.3	23.8	118.3	584.8	10.9	95.1	123.8	60.6	973.2	231.9	37.9
Italy	77.9	72.3	21.3	37.5	71.7	829.4	523.7	77.3	52.8	112.8	650.5	22.2	169.7	120.7	89.8	194.5	404.1	105.4
Cyprus	151.9	56.6	31.6	34.2	82.3	357.9	406.0	57.0	107.3	179.7	510.7	15.8	82.3	126.9	9.5	136.1	382.9	57.0
Latvia	211.2	55.1	20.3	39.3	62.3	159.6	585.5	33.8	56.9	97.5	495.3	10.8	158.4	400.3	2.7	136.7	321.9	9.5
Lithuania	285.8	85.6	15.7	36.9	150.3	177.0	917.1	26.7	74.7	129.9	770.4	5.5	166.9	291.5	10.8	1100.7	319.9	36.9
Luxembourg	234.7	71.4	81.6	40.8	81.6	637.2	389.8	102.0	56.1	117.3	642.8	-29.6	45.9	161.7	0.0	142.8	301.0	137.7
Hungary	189.4	51.1	5.0	37.0	18.5	317.3	953.6	22.1	74.3	103.1	460.2	0.0	73.0	153.2	28.8	334.6	245.7	73.8
Malta	110.2	64.2	32.4	38.9	90.8	259.4	663.4	84.3	84.3	103.8	580.4	19.5	58.4	155.0	6.5	252.9	658.2	45.4
The Netherlands	146.3	92.4	9.6	38.6	85.6	508.8	762.7	82.5	70.5	99.4	831.6	45.7	423.2	341.0	403.3	1068.3	265.1	56.3
Austria	294.3	77.9	31.4	40.5	38.9	570.4	825.2	58.0	54.8	144.9	700.9	22.0	146.2	209.7	22.3	1338.4	316.7	90.1
Poland	270.2	64.6	8.6	20.5	29.4	214.2	771.6	15.7	77.6	128.9	581.1	7.5	97.0	325.8	9.2	947.8	329.9	7.7
Portugal	133.5	61.4	22.2	24.7	149.4	757.6	571.4	70.3	85.9	108.9	553.0	12.0	154.7	214.5	202.9	87.8	480.8	125.6
Romania	242.4	71.4	11.8	41.8	18.5	378.2	855.0	37.3	45.7	76.1	642.6	5.3	59.8	309.2	22.0	221.7	556.4	63.2
Slovenia	215.0	70.3	27.9	25.3	27.9	414.5	577.4	63.9	66.5	77.2	632.4	14.6	69.2	160.1	7.6	123.8	246.1	31.0
Slovakia	81.8	26.7	10.6	9.6	10.6	157.7	219.7	24.3	25.3	29.4	240.6	5.6	26.3	60.9	2.9	47.1	93.6	11.8
Finland	220.1	122.8	40.9	26.2	100.0	275.6	564.9	62.6	57.6	99.0	1105.5	9.1	79.3	315.0	24.2	369.6	257.1	32.3
Sweden	152.2	98.9	35.0	37.2	87.7	393.3	484.3	78.0	51.0	101.5	890.5	17.2	173.5	279.8	11.1	762.6	277.8	57.1
United Kingdom	190.2	68.0	21.2	30.3	56.7	355.9	558.1	71.0	89.6	70.1	611.8	11.5	96.1	306.4	38.4	502.5	283.0	50.8
Iceland	204.3	68.1	34.0	25.5	476.7	366.0	442.6	127.7	76.6	59.6	612.9	8.5	59.6	93.6	0.0	195.8	204.3	34.0
Norway	137.8	78.4	36.9	31.9	142.6	395.2	465.1	77.6	57.5	70.5	705.5	17.4	240.8	160.4	248.3	123.7	226.6	44.5
Switzerland	154.7	110.0	21.8	29.6	48.7	341.0	362.7	77.4	45.0	86.6	989.8	26.6	76.3	148.3	12.3	647.2	308.1	100.2
Turkey	32.4	57.0	10.4	23.8	16.8	473.2	814.0	47.5	51.0	-0.9	512.9	23.3	89.2	122.3	85.0	684.1	773.0	1.1
Vegan	*260*	0.0	*26.8*	0.0	0.0	390.8	202.5	0.0	0.0	0.0	0.0	47.0	45.1	386.0	470.9	*1080.4*	1075.8	*88.5*
EF_food_MJ_g	0.0063	0.0338	0.0216	0.0099	0.0167	0.0051	0.0027	0.1169	0.0371	0.0303	0.0084	0.0243	0.0104	0.0021	0.0243	0.0044	0.0019	0.0244

Sources: All data except consumption for a vegan lifestyle come from FAOSTAT (2019). The estimate of vegan consumption comes from Proveg International (2019) adjusted for waste using FAOSTAT (2019). The cumulative energy factors [MJ/g] come from GEMIS with the exception of coffee which comes from Domínguez et al. (2014)

2.5. Leisure (Q110)

EU Commission, DG ENER, Unit A4 has provided an estimate of the energy consumption in each EU country in various sectors including services (EU Commission, 2018). For an estimate of the cumulative energy for leisure we have used this value, converted it to a per capita value and multiplied by a factor based on the respondents answer to Q110.

Please choose the answer that best fits your hobbies and leisure activities.

- *a) Very little equipment and infrastructure needed (e.g. playing board games, reading, …)*
- *b) Little equipment and infrastructure needed (e.g. playing music, hiking, cycling ...)*
- *c) Moderate amount of equipment and infrastructure (e.g. computer games, photography, …)*
- *d) More equipment and infrastructure needed (e.g. skiing, team sports, …)*
- *e) A lot of equipment and infrastructure needed (e.g. motorsports, heli-skiing, …)*

The factors used are: a) 50%, b) 75%, c) 100%, d) 150%, and e) 200%. After the initial calculation of the cumulative energy, the results are scaled so that the sum of the average cumulative energy demand per capita equals the energy demand per capita as calculated by DG ENER.

2.6. Information (Q113)

For information, one question (Q113) was asked.

Please choose the answer that best describes your private usage of electronics. (PC, Notebook, Tablet, Smartphone, TV, Hi-Fi Equipment)

- *a) I use electronics very little*
- *b) I use electronics less than most others*
- *c) I use electronics about average*
- *d) I use electronics quite intensively*
- *e) I use electronics very intensively.*

This was converted into a linear scale where answer "a" had a value 0% and answer "e" has the value 100%. Unfortunately, the EUROSTAT table Energy consumption in households (EUROSTAT, 2018d) does not record the amount of electricity used for electronics. It does record the total amount of energy used by a household and the percentage of energy used for lighting and appliances though. For example, the total amount residential energy per capita for Austria is 30,431 MJ of which light and appliances comprise 10.1 %. Statistics Austria (2018) does, however, record the amount of electricity used for computers, phones, TVs, etc. In 2016, this was 14.6% of the total electrical energy not used for heat and hot water. Hence the electricity used for computers, phones, TVs, etc. was 449 MJ.

$$Energy_{end}[MJ] = Energy_{LA\_mean}[MJ]\ x14.6\% \qquad \text{(i.1)}$$

$$Energy_{cum}[MJ] = Energy_{end}[MJ]\ x\ F_{en}[\frac{MJ}{MJ}] \qquad \text{(i.2)}$$

Where $\overline{Energy_{LA}}[MJ]$ is the country average electricity consumption of lighting and appliances (EUROSTAT, 2018d).

We are aware that most of the energy used for communication is not electricity use at home but it is embedded in building and running the infrastructure. Based on the annual reports of 18 wireless network operators around the world the average energy use per 0.245 kWh per Gb data transferred. The CISCO (2019) estimates that in Western Europe average internet traffic for all users (commercial and households) in 2017 was 43.8 Gb per capita per month. Meaning that the per capita electricity demand from the wireless operators for all users was 465 MJ. Unfortunately, it is difficult to estimate the amount which for household individual use.

Jones (2018), on the other hand, estimated that worldwide, the internet in 2017 required 2500 TWh and internet traffic totalled 1.1 x 10^{21} bytes. Of this, 37% was due to consumer devices. These estimates suggest that total electricity demand for internet use in 2017 was 2.2 x 10^{-9} kWh / byte. Using the CISCO average internet traffic value we calculate that internet use in 2017 was 98.3 kWh or 354 MJ per capita. This value was not included in our energy estimates.

3. CONCLUSION

The methodology for the calculation of cumulative energy demand by respondents based on a limited number (roughly 40) questions has been presented. It is a mixture of bottom-up evaluation from the survey with top-down control from other statistics (mostly from EUROSTAT). As quality control we find that the ECHOES results for Austria compare closely (±15%) to the results from ClimAconsum (Bird et al., 2017; Windsperger et al., 2017, 2018) in the lifestyle areas mobility and heating. The ECHOES estimate for diet is higher that ClimAconsum, because in ClimAconsum organic and conventional food production were considered and organic food production tends to have a lower energy factor than does conventional food production. In addition, The “goods” lifestyle area scores significantly lower in ECHOES than in ClimAconsum, but that is to be expected considering the limited number of questions asked (i.e. only about clothing and electronics). In ClimAconsum, the lifestyle areas, “leisure” and “information” were part of the general energy consumption and so were not calculated.

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