Interpretation of the energy savings for ESD end-use and sub-sectors in relation with the energy consumption variation

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Enerdata

47, Avenue Alsace-Lorraine
38000 Grenoble
France

www.enerdata.net

s.a.s au capital de 100 000 euros
RCS Grenoble 381 703 859

Table of contents

1. INTRODUCTION 2
   1.1. Energy savings according to ODEX 2
   1.2. Energy savings according to ESD recommended method 3
2. DECOMPOSITION OF THE ENERGY CONSUMPTION IN INDUSTRY 3
   2.1. Methodology 3
   2.2. Application to the EU industry sector 5
3. DECOMPOSITION OF THE ENERGY CONSUMPTION IN TRANSPORT 6
   3.1. Methodology 6
   3.2. Application to the EU transport sector 7
4. DECOMPOSITION OF THE ENERGY CONSUMPTION FOR HOUSEHOLDS 9
   4.1. Methodology 9
   4.2. Application to the EU household sector 10
5. DECOMPOSITION OF THE ENERGY CONSUMPTION IN TERTIARY SECTOR 12
   5.1. Methodology 12
   5.2. Application to the EU tertiary sector 13
6. DECOMPOSITION OF THE ENERGY CONSUMPTION IN AGRICULTURE 14
   6.1. Methodology 14
   6.2. Application to the EU agriculture sector 15
7. DECOMPOSITION OF THE FINAL ENERGY CONSUMPTION 16

1. Introduction

This report provides guidelines for member countries on how to link the variation of the final energy consumption by sector to the energy savings as calculated with top-down methods for the monitoring of the Energy Service Directive (ESD)[1].

Therefore, this report presents a methodology of decomposition of the variation of the final energy consumption by sector into different explanatory factors, among which energy savings based on top-down indicators. Examples are given for EU as a whole to illustrate the methodology. The reason for this analysis is that although ESD is focusing on the measurement of energy savings, there is also a need to monitor the amount of energy consumed by sector as it will be the main driver of CO2 emissions in these sectors. Therefore it is important to understand the factors behind the variation of the final energy consumption.

The report is a deliverable of the task 4.2 ("Interpretation of the energy savings for ESD end-use and sub-sectors in relation with the energy consumption variation")[2].from the Work package 4 "Monitoring of EU and national energy efficiency targets"

Calculations related to the decomposition of the final energy consumption are integrated in the ODYSSEE data file as a new sheet and linked directly to the ODYSSEE data provided by national teams. Calculations and results can be used by national teams to improve the understanding of the variation of the final energy consumption.

Calculations are automatic without additional data input from national teams. The sheet contains all the detailed calculations for more transparency and a better understanding. Calculations are available since 2000 to the most recent year (2009 or 2010). When the data will be updated, the calculations will be updated automatically.

The following sections will present the decomposition of the final energy consumption sector by sector into several effects, expressed in Mtoe, of which energy savings. These savings will refer to the calculation according to either the ODYSSEE method, based on ODEX, or the method proposed by the European Commission for ESD. These methods are actually very close as explained below.

1.1. Energy savings according to ODEX

In ODYSSEE, energy savings are derived from ODEX, an indicator that measures the energy efficiency progress by main sector (industry, transport, households) and for the whole economy (all final consumers). ODEX for services is not performed for the moment because of lack of relevant data for several countries.

For each sector, the index is calculated as a weighted average of sub-sectoral indices of energy efficiency progress; sub-sectors being industrial or service sector branches or end-uses for households or transport modes.

The sub-sectoral indices are calculated from variations of unit energy consumption indicators, measured in physical units and selected so as to provide the best "proxy" of energy efficiency progress, from a policy evaluation viewpoint. The fact that indices are used enables to combine different units for a given sector, for instance for households kWh/appliance, koe/m2, toe/dwelling…

[1] Directive 2006/32/EC

[2] Deliverable D4.2" Guidelines and Excel template for the interpretation of the top-down energy savings for ESD in relation with the energy consumption variation"

The weight used to get the weighted aggregate is the share of each sub- sector in the total energy consumption of the sub –sectors considered in the calculation.

Energy savings by sector in absolute values (ktoe, GWh) can be directly calculated from the ODEX. Indeed, ODEX can also be defined as the ratio between the energy consumption at year t (E) and a fictive consumption that would have happened without energy savings (ES). Therefore, energy savings are equal to E x ((100/ODEX)-1)[3]. :

The weighting method has been defined in such a way that the calculation of energy savings is strictly equal to the sum of energy savings by end-use[4], with energy savings obtained by multiplying the variation in unit energy consumption by an indicator of activity. For instance, energy savings for refrigerators are equal to the variation in kWh per refrigerator multiplied by the number of refrigerators.

1.2. Energy savings according to ESD recommended method

The proposed method for ESD is based on a summation of energy savings by end-use or sub-sector. The final energy savings for each end-use equipment or sub-sector are calculated from the variation of the relevant energy efficiency indicator between 2007 and the year of reporting multiplied by an indicator of activity in the final year at the time of reporting as required by Directive 2006/32/EC.

The indicators have been classified by the Commission in three types, as follows:

- **Preferred** energy efficiency indicators **(P)** to be used wherever practicable to measure energy savings at the sub-sectoral level
- **Alternative** energy efficiency indicators **(A)** to be used when a lack of data impedes the use of the preferred energy efficiency indicators
- **Minimum** energy efficiency indicators (**M)** to be used when the preferred and alternative indicators cannot be applied[5].

The approach relying on the preferred indicators is very similar to the ODEX approach described above. The only difference may come from the indicator used to represent the unit consumption. For instance, for cars, ODEX used the specific consumption in litres/100 km whereas koe/passenger-km was proposed for ESD.

2. Decomposition of the energy consumption in industry

2.1. Methodology

The variation of the final energy consumption in industry can be explained by 4 effects:
An activity effect, measuring the effect of a change in the value added of industry,
Structural changes, measured by the change in the structure of the industrial value added by branch
Energy savings, measured by the ODEX, i.e. calculated from changes in specific energy consumption at branch level[6].
Changes in the value of product, i.e. in the ratio valued added over physical production or production index

[3] By definition: ODEX=E/(E+ES)*100 with ES >0; therefore it can be derived that ES= E x ((100/ODEX)-1
For instance, if energy consumption = 50 Mtoe and ODEX =80, energy savings are equal to 50*((100/80)-1)=12.5 Mtoe.

[4] A full description of ODEX methodology is given in http://www.odyssee-indicators.org/registred/definition_odex.pdf

[5] Minimum indicators can be calculated with Eurostat data.

[6] Specific consumption relating the energy consumption to a physical production (case of steel, cement and paper) and to industrial production index for the other branches.

The activity effect captures the changes in the value added and allows in particular to better understand and to measure the impact of the economic activity on the energy consumption. It is calculated by multiplying the energy intensity of the base year t_0 by the variation of the value added between t and t_0 .

Activity effect : $EQ_{t/t_0} = \Delta VA_{t/t_0} * (\frac{C_{t_0}}{VA_{t_0}})$

With:
EQ:activity effect
VA : value added of manufacturing
t=year t
t_0=reference year t_0
C : Energy consumption

The effect of structural changes is calculated as the difference between the actual energy consumption C_t and a fictive energy consumption calculated with an energy intensity at constant structure. This fictive energy consumption reflects the variation of the energy intensity assuming a constant structure of value added, between the various branches or sub-branches, for a reference year, so as to leave out the influence of structural changes.

Structural effect : $SE_{t/t_0} = \Delta Cf_{t/t_0} - \Delta C_{t/t_0}$,
with $C_f = IEc_t \quad * VA_t$

With:
SE: structural effect
Cf: fictive consumption based on the energy intensity at constant structure *IE c*
C : Energy consumption
IEc : Energy intensity at constant structure
VA : value added in constant prices
t=year t
t_0=reference year t_0

Energy savings[7] are based on ODEX, expressed in Mtoe.
Energy Savings: $ESI = C_t * (\left(\frac{100}{ODEX}\right) - 1)$
With:
C_t: Energy consumption
ODEX : Energy savings measured with ODEX

For industry, ODEX is carried out at the level of 12 branches (10 manufacturing branches, mining and construction if available)[8]:

- 4 main branches: chemicals, food, textile & leather and equipment goods (machinery and transport equipment);
- 3 energy intensive branches: steel, cement and pulp & paper
- 3 residual branches: other primary metals (i.e. primary metals minus steel), other non-metallic minerals (i.e. non-metallic mineral minus cement) and other industries.
- Mining industry
- Construction

[7] Energy savings calculated with ODEX similar to the method proposed to ESD; however, in ESD methodology, in principle, only the part of the consumption, and thus of savings, not covered by the Emission Trading Scheme is considered. In ODEX, all savings are considered.

[8] For ESDD, the calculation is made at the level of 13 branches :non energy mining (NACE 13-14); food, beverage, tobacco (NACE 15-16); textiles, clothing, leather (NACE 17-19); wood industry (NACE 20); paper, pulp and printing (NACE 21-22); chemicals (NACE 24); non metallic minerals (NACE 26), of which cement (NACE 26.51); iron and steel (27.1); non ferrous (27.2); machinery & metal products (NACE 28-32), of which fabricated metals (NACE 28); transport equipment (NACE 34-35); other manufacturing (NACE 25+33+36+37), of which rubber and plastics (NACE 25); construction (NACE 45)

The unit consumption is expressed in terms of energy used per ton produced for energy intensive products (steel, cement and paper) and in terms of energy used related to the production index for the other branches[9].

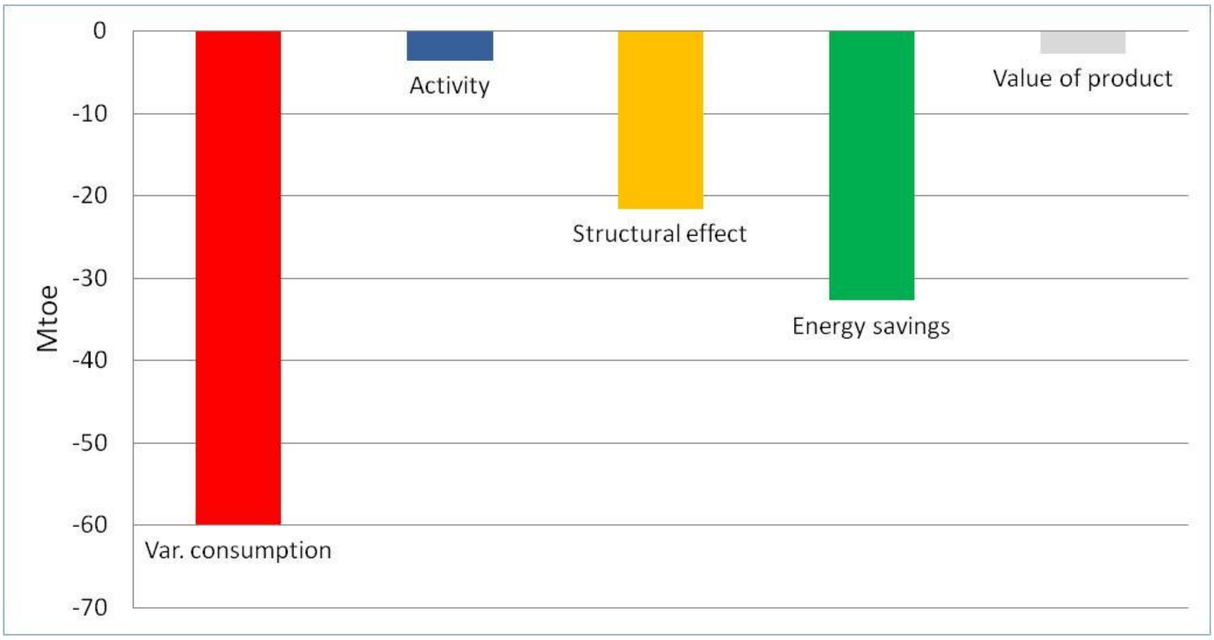
The last effect (residual) represents the influence of changes in the value of products measured by the ratio of the value added by production index or physical production of the year t divided by this ratio for the base year t_0. It can also be calculated by difference between the total energy variation and the sum of the other effects.

2.2. Application to the EU industry sector

Over the period 2000-2009 the energy consumption of industry has decreased by almost 60 Mtoe, or -2.2%/year.

This decrease of the energy consumption is due to the conjunction of three factors: a decrease of the value added by around 1%, of which 11% for the year 2009 (activity effect), a decrease of the share of energy intensive branches (structural effect) and energy savings (captured by the ODEX). Energy savings represent around 56% of the decrease of the energy consumption over the period 2000-2009, following by structural effects (36%), activity effect (6%) (**Figure 1**).

Figure 1: Drivers of the energy consumption in industry in EU (2000-2009)[10]



[9] For ESD only production index are used
[10] The values used here correspond to the data in the ODYSSEE data base as of November 2011. They are shown here to illustrate the methodology.

3. Decomposition of the energy consumption in transport

3.1. Methodology

The variation of the final energy consumption of transport is decomposed into three main factors:

An activity effect, measuring the impact of increasing traffic of passengers and goods by mode of transport;

- Energy savings, measuring the impact of the variation of the energy consumption per passenger kilometre or tonne-km for each mode of transport[11];
- A modal shift effect measuring the impact of changes in the distribution of each mode in total traffic of passenger and goods.

For cars, energy savings can be split into 4 effects:

- a technology effect due to a reduction in the specific consumption in l/100km[12]
- a kilometre effect, due to the evolution of the number of kilometer driven by car
- a substitution effect, due to a change in the average heat content of one litre of motor fuel with changes in fuel mix (gasoline/diesel and penetration of biofuels)
- an occupancy rate effect, linked to a variation in the average car occupancy rate

The activity effect is calculated for the different modes of transport separately and summed up. For passengers, it is calculated by multiplying the variation of the traffic measured in passenger kilometre for each mode (cars, bus, rail, tram and metro), by the specific energy consumption per passenger-km at base year. For goods, it is calculated by multiplying the traffic in tonne-km of each mode (road, rail, inland waterways) by the specific energy consumption per tonne-km at base year.

Activity effect (passenger): $EQT_{t/t_0} = \sum_{\mathrm{i}=0}^{n}(\Delta pkm_{n,t/t0} * CU_{n,t-1})$

Activity effect (good): $EQT_{t/t_0} = \sum_{\mathrm{i}=0}^{m}(\Delta tkm_{m,t/t0} * CUn,_{t-1})$

With
EQT:activity effect
CU : energy consumption per passenger or good kilometre by mode
t=year t
t_0=reference year t_0
n=cars, bus, rail for passengers
m= trucks and light vehicles, rail for goods, inland waterways
pkm : number of passenger kilometre by mode
tkm : number of ton kilometre for goods by mode

[11] Same definition as proposed to calculate energy savings for ESD.
[12] Corresponds to the definition of savings in ODYSSEE.

The savings effect is measured by multiplying the variation of the specific energy consumption per passenger-km or tonne-kilometre of each mode of transport by the number of passenger/ goods kilometre.[13]

Savings (passenger) : $EST_{t/t_0} = \sum_{\mathrm{i}=0}^{n}(\Delta CU_{n,t/t0} * pkm_{n,t})$
Savings (goods) : $EST_{t/t_0} = \sum_{\mathrm{i}=0}^{m}(\Delta \mathrm{CU}_{\mathrm{m,t/t0}} * tkm_{m,t})$

With
EST: savings effect
CU : energy consumption per passenger or good kilometre for all transport mode
t=year t
t_0=reference year t_0
n=cars, bus, rail for passengers
m= trucks and light vehicles, rail for goods, inland waterways
pkm : number of passenger kilometre by mode
tkm : number of ton kilometre for goods by mode

At an aggregate level (for passengers or for goods), an additional effect can be calculated, a modal shift effect, corresponding to difference between the sum of savings of each mode for passenger and goods respectively and the aggregate savings calculated directly for passenger or goods as a whole. Indeed modal shift illustrates a change in the distribution of each mode in terms of traffic (for example a decreasing share of public transport in passenger traffic contributed to increase the consumption).

Modal shift : $MST_{t/t_0} = EST - (\Delta \mathrm{CU}_{\mathrm{t/t0}} * pkm_t)$ for passenger as a whole

Modal shift : $MST_{t/t_0} = EST - (\Delta CU_{t/t0} * tkm_t)$ for goods as a whole

3.2. Application to the EU transport sector

The energy consumption of transport has increased by 23 Mtoe over the period 2000-2009 mainly due to an increasing traffic of passenger and goods (activity effect) which contributed to increase the energy consumption by around 40 Mtoe.

The decreasing share of public transport in passenger traffic and the increasing share of road goods also contributed to increase the energy consumption by around 5 Mtoe since 2000. Cars represent around 83% of the passenger traffic in 2009 (+1 point compared to 2000); the share of rail, tram and metro is quite stable (8.5% in 2009); contrary to the share of bus which tends to decrease (8.8 % in 2009, 9.8 % in 2000). Concerning goods, road represent 78 % of the goods traffic (74% in 2000) following by rail (17% in 2009, 20% in 2000) and inland water ways (6% in 2009, 7% in 2000).

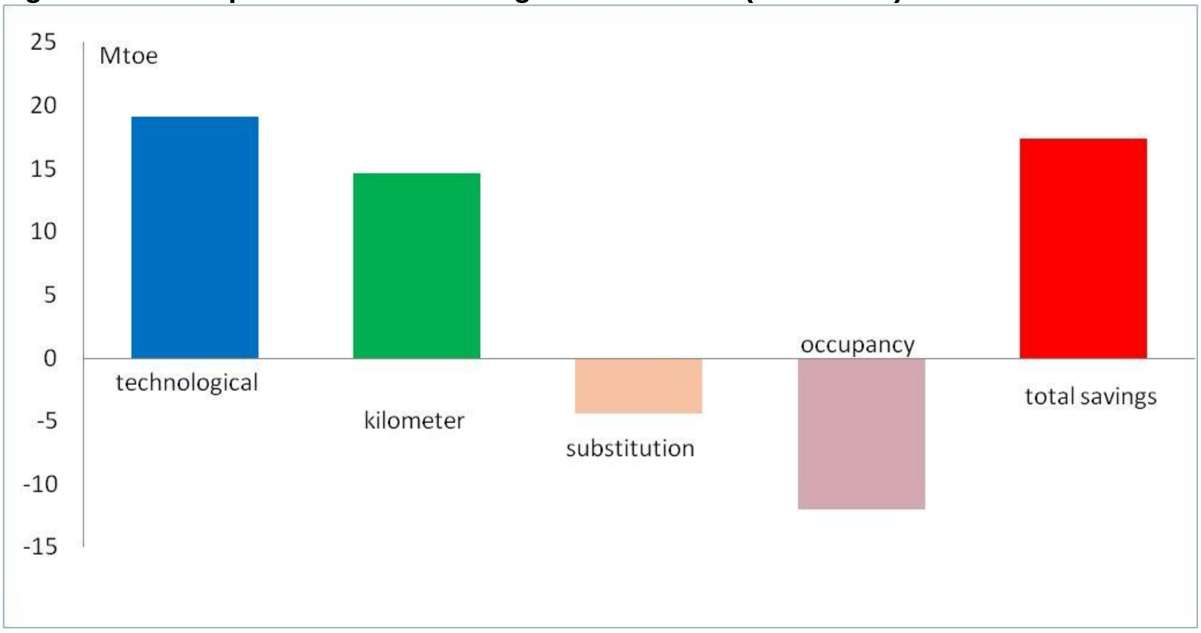
[13] This calculation is conformed to the methodology proposed by the Commission to calculate energy savings for the monitoring of the ESD in the top-down approach. It differs from the calculation used for the ODEX where the indicator used for cars is litre/100km instead of goe/pkm.

On the opposite energy savings have offset part of the impact of traffic increase and modal shift; indeed energy savings decreased the energy consumption by 22 Mtoe over the period 1990-2009 (**Figure 2**).

Figure 2: Drivers of the variation of the energy consumption in transport[14]

Savings from cars (around 17 Mtoe in 2009 compared to 2000) results from technical improvement due to a decrease of the specific consumption in litre per 100 km (from 7.9l/1000 km in 2000 to 7.1 l/100km in 2009), decreasing number of kilometre driven by cars (-755 km/year). On the other side, two effects contributed to increase the energy consumption: fuel substitution (more diesel cars and a higher share of biofuel), less person per car (from 1.69 person per car in 2000 to 1.67 in 2009) (**Figure 3**).

Figure 3: Decomposition of the savings of cars in EU (2000-2009)



[14] The values used here correspond to the data in the ODYSSEE data base as of November 2011. They are shown here to illustrate the methodology.

4. Decomposition of the energy consumption for households

4.1. Methodology

The variation of the final energy consumption of households can be explained by:

- A climatic effect, due to difference in the number of degree days between year t and the base year t_0.
- A demographic effect, due to the increasing number of dwellings,
- A lifestyle effect, due to the increase in the number of households equipment, to larger homes, and to the diffusion of central heating
- Energy savings (as measured from ODEX or ESD[15]).

The demographic effect due to the increasing number of dwellings is calculated as the variation in the number of dwellings multiplied by the energy consumption per dwelling (with climatic corrections):

Demographic effect : $DEH_{t/t_0} = \Delta nbrlpr_{t/t0} * CU_{t_0}$

With:
nbrlpr : number of permantly occupied dwellings
CU : Energy consumption per dwelling with climatic corrections
t=year t
t_0=reference year t_0

Two lifestyle effects may also influence the energy consumption of households: the increase in the household equipment ownership (electrical appliances and central heating) and in the increasing size of dwellings (i.e. larger homes).

The increasing number of equipment per households is due on one hand to the increasing number of electrical appliances (ICT, small electrical appliances, air conditioning in Southern countries), larger homes which requires more energy and central heating which requires around 25% more energy compared to single room heating[16].

The increasing number of electrical appliances is approximate with the electricity consumption of large appliance (refrigerators, freezers, TV, washing machine, dish washers) per dwelling in relation with the overall index for electrical appliances (based on the evolution of the electricity consumption per appliances weighted by their energy share). For small appliances and lighting, we take into consideration the energy consumption per dwelling.

The “central heating’ effect is calculated as a ratio between the unit consumption per m2 (with climatic corrections) and the unit consumption per equivalent dwelling[17] (with climatic corrections).

[15] For households the calculation of savings is the same with ESD or ODEX.
[16] The penetration of central heating was mainly significant in the southern European countries and in Ireland. Central heating (around 85% of EU dwellings in 2009) , which includes district heating, block heating, individual boiler heating and electric heating, implies that all the rooms are well heated, as opposed to room heating, where generally a stove provides heat to the main room only.
[17] The unit consumption per equivalent dwelling considers the number of dwellings with central heating (a correction factor of 0.75 is applied to take into account that a dwelling with room heating consumes 25% less than a dwelling with central heating)

Energy savings are based on ODEX, expressed in Mtoe.

Energy Savings: $ESI = C_t * (\frac{100}{ODEX} - 1)$

For ODEX, the following indicators are considered to measure efficiency progress:

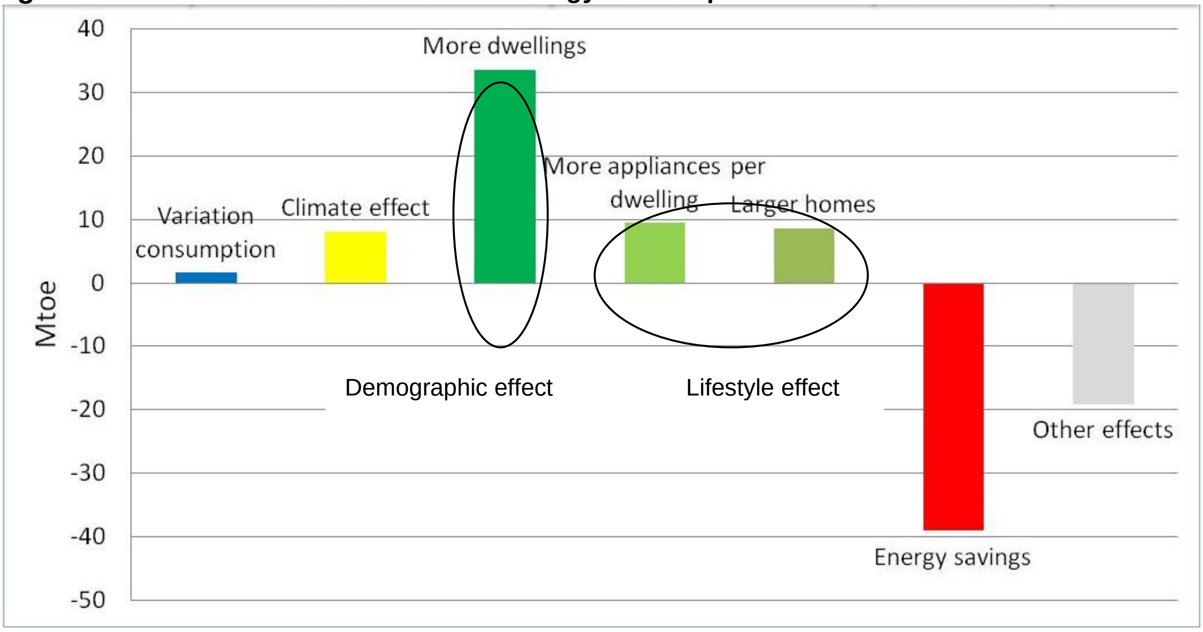
- Heating: unit consumption per m2 at normal climate (toe/m2)[18]
- Water heating: unit consumption per dwelling with water heating
- Cooking: unit consumption per dwelling
- Large electrical appliances: specific electricity consumption, in kWh/year/appliance

4.2. Application to the EU household sector

The variation of the energy consumption of households (+1.6 Mtoe or 0.6%) over the period 2000-2009 can be explained by three factors which increase the consumption: a demographic effect due to the increasing number of dwellings (around 34 Mtoe), an increase in the number of household's equipment (9.4 Mtoe) and larger homes (8.7 Mtoe). Climatic corrections have a negative impact on the energy consumption and participate to increase the consumption by 8 Mtoe over the period 2000-2009.

On the other side, energy savings, mainly due to better thermal performance of buildings, more efficient large electrical appliances (cold and washing appliances) and heating systems (condensing boilers and heat pumps), tend to decrease the energy consumption of households (these savings correspond to 40 Mtoe from 2000 to 2009). Without savings the energy consumption of households should be 40 Mtoe higher (**Figure 4**).

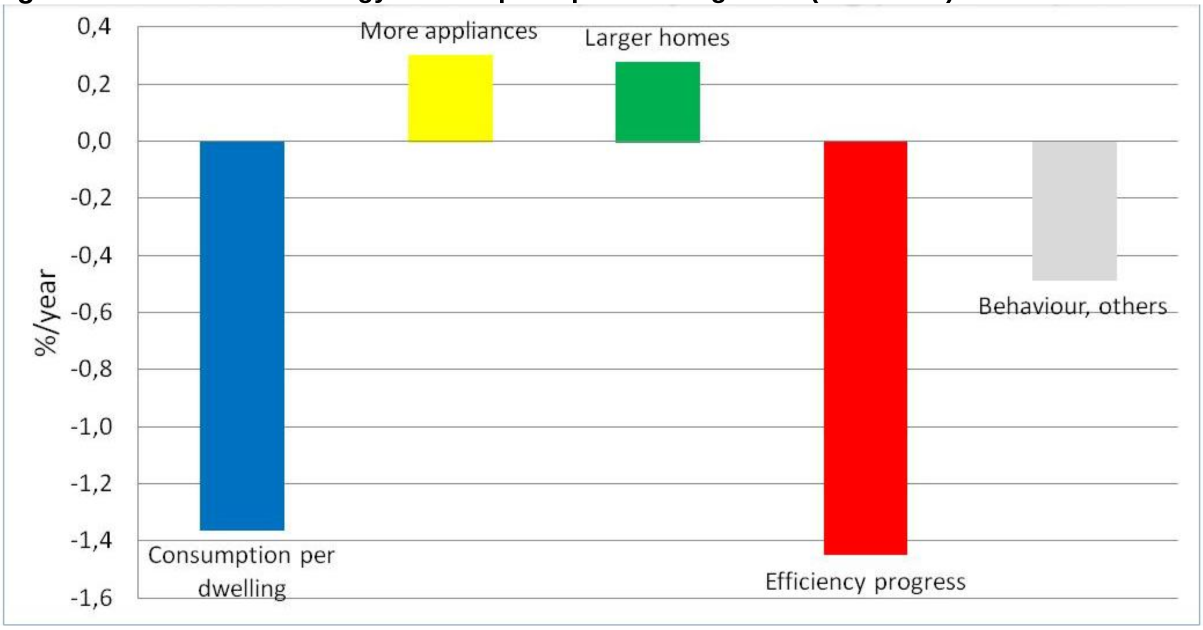
Figure 4: Drivers of the variation of the energy consumption in households[19]



[19] The values used here correspond to the data in the ODYSSEE data base as of November 2011. They are shown here to illustrate the methodology.

As a result, consumption per dwelling (climate corrected) has decreased by around 1.4%/year since 2000, mainly due to energy efficiency progress (measured by ODEX). On the opposite, the increasing number of appliances and larger homes contributed to increase the unit consumption by around 0.8 %/y (**Figure 5**).

Figure 5: Drivers of the energy consumption per dwelling in EU (2000-2009)[20]



20 The values used here correspond to the data in the ODYSSEE data base as of November 2011. They are shown here to illustrate the methodology.

5. Decomposition of the energy consumption in tertiary sector

5.1. Methodology

The variation of the final energy consumption in the tertiary sector (i.e. services) can be explained by:

- An activity effect, measuring the effect of a change in the value added of tertiary
- Structural changes, measured by the change in the structure of the value added by branch
- Productivity effect, measured by the change in the ratio of the value added per employment
- Energy savings, due to a decrease in the energy consumed per employee by branch

The activity effect in tertiary is measured by the variation of the value added multiplied by the energy intensity by branch

Activity effect : $EQT_{t/t_0} = \sum_{\mathrm{i}=0}^{n} \quad \Delta VA_{\,i,t/t_0} * I_{\ \mathrm{i},t_0}$

With
EQT: activity effect
VA: value addby by branch i
I : Energy intensity by branch i
i: hotel-restaurant, health, education, public, private offices, wholesale and retail trade
t=2009
t_0=2000

The energy savings are calculated by multiplying the number of employees by the variation of unit consumption per employee by branch.

Energy savings : $ESH_{t/t_0} = \sum_{\mathrm{i}=0}^{n} \quad \Delta CU_{\,i,t/t0} * \mathrm{EMP}_{\mathrm{i,t}}$

With:
ESH: energy savings
EMP: number of employees
CU_i : Energy consumption per employee in branch i
i: electric, non electric or by branch (hotel-restaurant, health, education, public, private offices, wholesale and retail trade)
t=year 2009
t_0=reference year 2000

The productivity effect is calculated by difference between the energy consumption variations, the activity effect and energy savings effect.

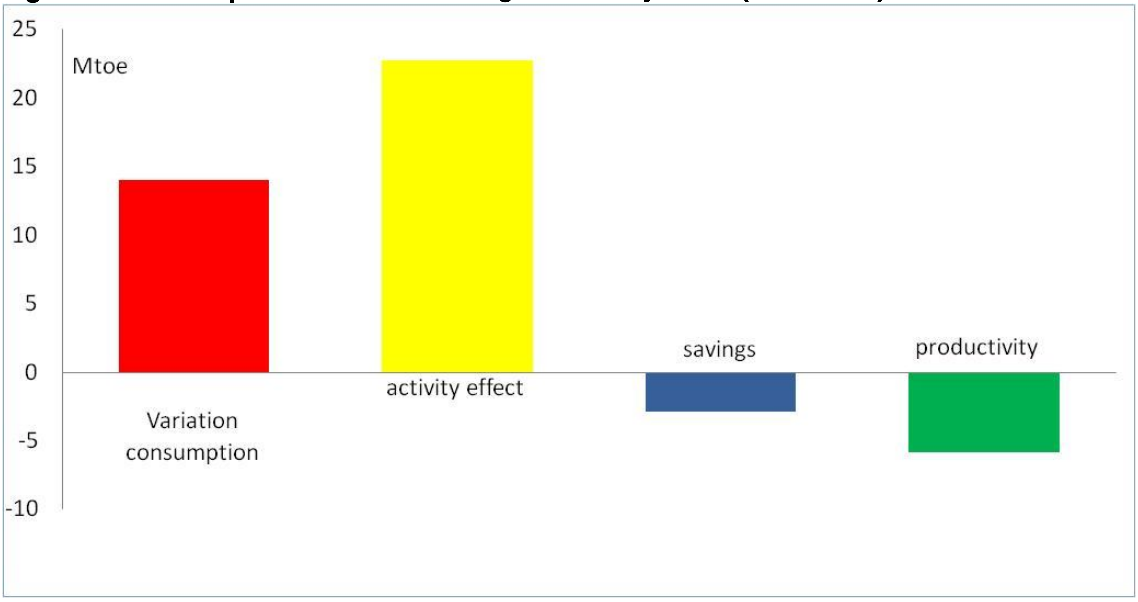
As proposed by the Commission for ESD, the calculation can be done at an aggregate level if detailed data by branch are not available (case of EU presented below); in this case we consider the evolution of the unit consumption of the tertiary sector, by separating fuel consumption (“non electricity”) and electricity[21] An additional effect can also be considered, corresponding to structural changes, i.e. the fact that branches with different energy intensities are not growing at the same rate[22]: if a branch with a low electricity intensity is growing much faster than the other branches, this will decrease the overall electricity of services all things being equal.

[21] This calculation corresponds to the use of the so called “minimum indicators” according to ESD.
[22] This effect can only be calculated for countries which provide energy consumption and value added by sub branches of tertiary.

5.2. Application to the EU tertiary sector

The energy consumption of tertiary increased by 14 Mtoe from 2000 to 2009 due to the conjunction of three effects, an activity effect which tends to increase the energy consumption by 23 Mtoe and energy savings and productivity which decreased the energy consumption by 3 Mtoe and 5.8 Mtoe respectively (**Figure 6**).

Figure 6: Decomposition of the savings in tertiary in EU (2000-2009)[23]



[23] The values used here correspond to the data in the ODYSSEE data base as of November 2011. They are shown here to illustrate the methodology.

6. Decomposition of the energy consumption in agriculture

6.1. Methodology

The variation of the final energy consumption in agriculture can be explained by:

- An activity effect (measured by the variation of the value added)
- Energy savings

The activity effect is calculated by multiplying the energy intensity of the base year by the variation of the value added between t and t_0.

Activity effect : $EQ_{t/t_0} = \frac{\Delta VA_{t/t_0}}{VA_{t_0}} * C_{t_0}$

With:
VA : value added of agriculture
t=2009
t_0=2000
C_0 : Energy consumption

The energy savings in agriculture are calculated by multiplying the value added of the year t by the variation of the energy intensity between the final year t and the base year t_0.

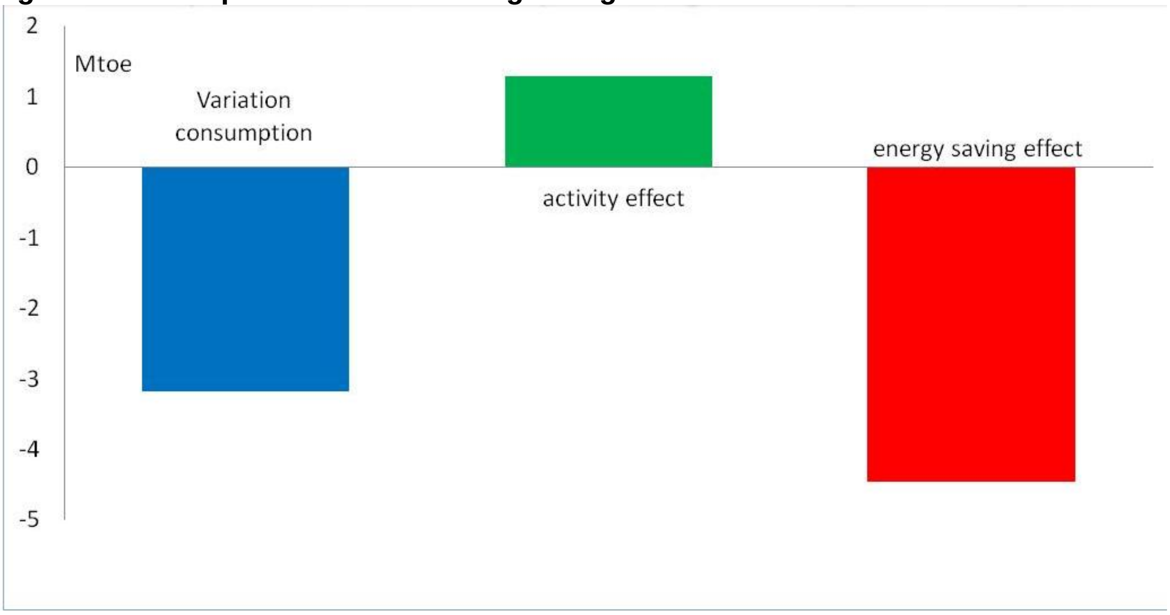
Energy savings : $ESH_{t/t_0} = \Delta \mathrm{I}_{\mathrm{t/t0}} * \mathrm{VA}_{\mathrm{t}}$

With:
VA : value added of agriculture
t=2009
t_0=2000
I : Energy intensity (ratio consumption and value added

6.2. Application to the EU agriculture sector

The energy consumption of agriculture decreased by 3.2 Mtoe from 2000 to 2009 due to the conjunction of two effects, an activity effect which tends to increase the energy consumption by 1.3 Mtoe and energy savings which decreased the energy consumption by 4.5 Mtoe (**Figure 7**).

Figure 7: Decomposition of the savings in agriculture[24]



[24] The values used here correspond to the data in the ODYSSEE data base as of November 2011. They are shown here to illustrate the methodology.

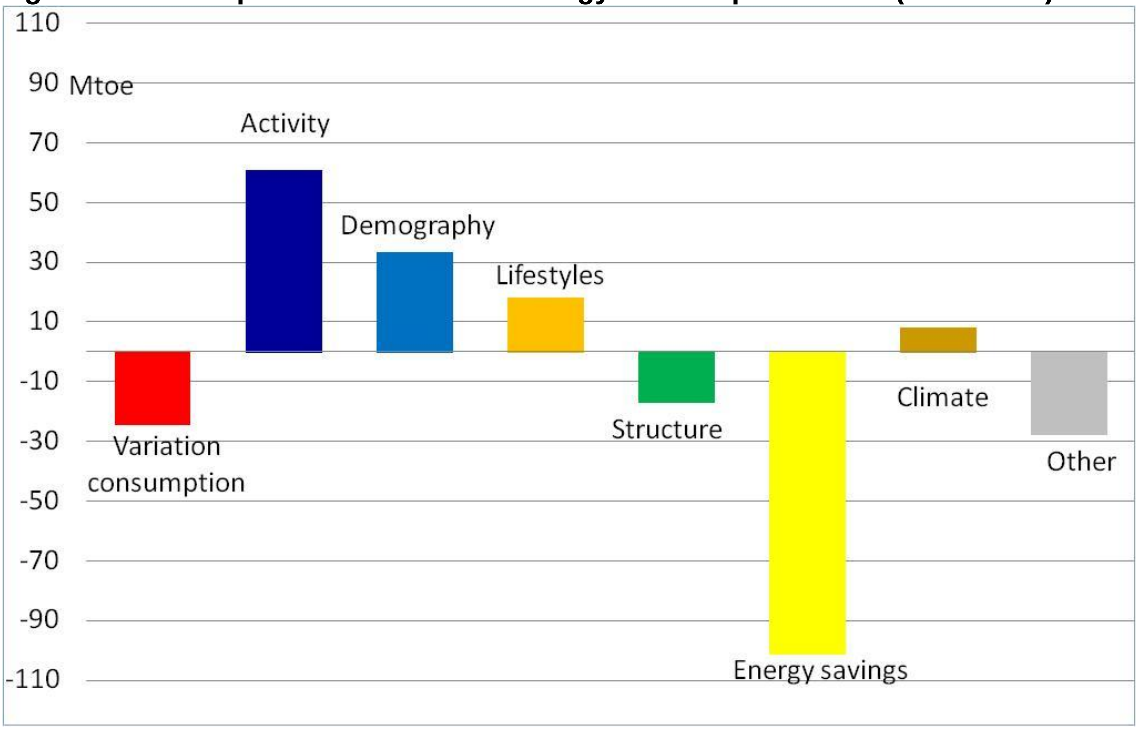
7. Decomposition of the final energy consumption[25]

The variation of the final energy consumption by sector can be split into different explanatory factors such as:

- activity effect due to an increase in the economic activity (value added in industry and agriculture, number of employees in services), in the number of dwellings, more traffic for passenger and goods in transport)
- structural effects due to a change in the structure of the value added in industry among the various branches, or due to modal shift in transport
- demographic effects (due to the increasing number of dwellings),
- lifestyle effect (due to the increase in the number of household equipment and cars, larger homes, change in car occupancy)
- energy savings (as measured from ODEX).
- climatic effect in households and tertiary

Over the period 2000-2009 the final energy consumption decreased by around 25 Mtoe, mainly due to a strong reduction in the energy consumption of industry (-60 Mtoe). On the opposite, energy consumption of transport has increased by 23 Mtoe and by 14 Mtoe for services. The activity effect, lifestyle, demography modal shift in transport and climatic effects contributed to increase the energy consumption by around 120 Mtoe; on the other hand energy savings, as well as, to a lesser extent, structural changes in industry contributed to decrease the energy consumption by around 125 Mtoe. Savings are mainly registered in the household and industry sectors (respectively 39% and 32% of total final savings); transport contributed to 22% of the savings, followed by agriculture (4%) and services (3%) (**Figure 8**).

Figure 8 : Decomposition of the final energy consumption in EU (2000-2009)[26]



[25] Here the final energy consumption exclude non energy uses (i.e. ODYSSEE definition)
[26] The values used here correspond to the data in the ODYSSEE data base as of November 2011. They are shown here to illustrate the methodology.