Enerdata

Energy Efficiency Trends in Buildings in the EU

Lessons from the ODYSSEE MURE project

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Didier Bosseboeuf

Project leader

[1] Alphabetic order of countries

Key Messages

Buildings

- Buildings consume 41% of total final energy consumption in Europe in 2010. It is the largest end-use sector, followed by transport (32%), and industry (25%).
- Final energy consumption of buildings has increased by around 1%/year since 1990 and by 2.4%/year for electricity at EU level.
- At EU level residential buildings represent around 76% of the building floor area, of which 65% for single family houses.
- Annual unit consumption per m^2 for buildings at EU level is around 220 kWh/m^2 in 2009, with a large gap between residential (200 kWh/m^2) and non-residential (around 300 kWh/m^2)

Households

- The energy consumption trend varies among European countries; two thirds reduced their average consumption per dwelling, and in particular some new member states show a considerable decline.
- In 2009, energy consumption decreased with the global economic crisis by 1.6% (at normal climate) as a result of a decrease of income (-3%) and despite a drop in energy price (-9%).
- The fraction of energy devoted to space heating is decreasing, partly due to the relative growth in the consumption for electrical appliances. The highest fractions are not found in countries with severe winters but in countries with a moderate climate.
- Energy use for space heating per m^2 is decreasing almost everywhere, except in a few countries with mild winters where winter comfort is improving.
- About 20% of energy efficiency progress for space heating has been offset by dwellings becoming larger.
- The effect of efficiency standards for new dwellings on space heating consumption is hampered by the often limited volume of new construction (below 1% of the building stock every year in most EU countries).
- The Netherlands can be regarded as a benchmark for space heating as it shows the lowest specific energy use, thanks to the large diffusion of gas condensing boilers and a comprehensive thermal retrofitting of existing dwellings.
- The amount of dwellings with solar water heaters is only a few percent. Some countries with a sunny climate, such as Cyprus and Greece, score much higher than comparable countries like Italy and Spain. Austria is the benchmark for countries with medium solar radiation.
- Electricity consumption for appliances & lighting increased in all member states except Bulgaria and Slovakia. The strongest growth is recorded for small appliances.
- The, energy efficiency of large appliances has improved quite a lot over the last 20 years but most of the gains has been offset by an increase in equipment ownership.
- Most new refrigerators have label A or A+.

Services

- At EU level, energy consumption in the tertiary sector increased significantly in the early 2000s, and was then rather stable until 2008. In 2009, it decreased by 2.3% because of the economic downturn.
- There is no clear pattern for EU countries. Some new member states (e.g. Romania, Croatia and Bulgaria) show very high growth rates, but the same is true for some EU-15 countries (e.g. Greece). Various EU-15 countries show a decrease in energy consumption (e.g. UK and Germany), but again the same is true for some new member states (e.g. Slovakia and Slovenia).
- The decrease in energy use per employee (-3%) is in strong contrast with the substantial increase in electricity consumption per employee (+16%), which is mostly due to the diffusion of cooling in summer (all southern countries) or to strong economic growth (eastern European countries) and a large diffusion of IT appliances.
- However, for countries with a sustained high level of economic welfare, the electricity consumption per employee is either stable or even decreasing. This could signal that electricity use reaches a saturation level.

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1. Introduction

The aim of this report is to provide insight into past developments for energy use, energy efficiency trends for households and tertiary sectors in EU countries. This should help policy makers and other parties involved in energy efficiency and CO_2 emission reduction in adapting present policy and formulating new effective policy measures. The main issues in the analysis are energy efficiency improvement and the effect of various policy measures. However, energy trends including autonomous energy savings and the effect of other factors, such as the impact of economic growth, energy prices and behaviour, are also part of the analysis.

This publication relies on data contained in the **ODYSSEE** database on energy efficiency indicators, with data on energy trends, drivers for energy use, explanatory variables and energy-related CO_2 emissions.

Box 1: ODYSSEE database

The ODYSSEE database (www.odyssee-indicators.org) is used for the monitoring and evaluation of annual energy efficiency trends and energy-related CO_2 emissions. The energy indicators are calculated for the years from 1990 onwards (EU-15 countries) or from 1996 onwards (new Member States). The inputs for the indicators are provided by national energy agencies or institutes according to harmonized definitions and guidelines.

ODYSSEE encompasses the following types of indicators[2]:

- Energy/CO_2 intensities which compare the energy used in the economy or a sector to macroeconomic variables (e.g. GDP, value added).
- Specific energy consumption which compares energy consumption to physical indicators (e.g. specific consumption per tonne-km in transport, specific consumption per dwelling in households).
- Energy efficiency indices by sector (ODEX) to evaluate energy efficiency progress (in %).
- Energy savings to measure the amount of energy saved through energy efficiency improvements.
- Adjusted indicators to allow the comparison of indicators across countries (e.g. adjustments for differences in modal structure, in size of vehicles).
- Benchmark/target indicators by sector to show the potential improvement based on countries with the best performance (evaluation based on adjusted indicators).
- Diffusion indicators to monitor the market penetration of energy-efficient technologies (e.g. heat pumps, solar water heaters) and practices.

ODYSSEE indicators are now used to monitor trends in energy efficiency in a harmonised way among countries. It contributes to support energy efficiency policy formulation and evaluation by the European Commission and EU Member States, in particular as part of the monitoring and evaluation of the Energy Services Directive.

[2]The methodological issues and precise definitions of indicators and data are explained at the end of this brochure in a specific section, “Definitions and Glossary”.

ODYSSEE indicators are more specifically used by the European Commission as well as by several international organizations, including:

- DG-Energy: the EC explicitly referred to the ODEX indicators in the Energy Services Directive as a way of contributing to the monitoring of the Directive in a so-called "top-down" approach. The EMOS (Energy Market Observatory) database includes about 40 ODYSSEE indicators. The Energy Demand Management Committee of ESD has proposed indicators similar to those used in ODYSSEE for the measurement of energy savings with top-down methods and several member states made use of such indicators to report their energy savings in the second NEEAP in June 2011.
- EEA (European Environmental Agency): uses data and indicators taken from the ODYSSEE database for their indicators factsheets as well as in different annual reports such as the Energy and Environment Report[3] and the TERM report[4]. ODYSSEE indicators were also used in the fourth pan-European environment assessment report (UNECE).
- IEA, the International Energy Agency: ODYSSEE data are used by the IEA to construct their own indicators for European countries. In addition, IEA has developed a questionnaire for the collection of the data necessary to calculate the indicators similar to the ODYSSEE data template.

[3]EEA (2008): Energy and environment report.
[4]EEA (2009): TERM monitors indicators tracking transport and environment integration in the European Union.

2. Energy efficiency in buildings

2.1. Introduction

Buildings consume about 40% of total final energy requirements in Europe in 2010. It is the largest end-use sector, followed by transport (32%), industry (24%) and agriculture (2%).

The building sector is one of the key consumers of energy in Europe, where energy use has increased a lot over the past 20 years. A wide array of measures has been adopted at EU level and implemented across individual Member States to actively promote the better energy performance of buildings. In 2002, the Directive on the Energy Performance of Buildings (EPBD)[5] was adopted and recast in 2010 with more ambitious goals. More recently in the Energy Efficiency Plan 2011[6], the European Commission states that the greatest energy saving potential lies in buildings[7].

2.2. Overview of the buildings sector

The buildings sector is composed of two main categories of buildings: residential buildings and non residential buildings. Residential buildings are composed from single family houses (detached and semi detached houses) and apartments blocks.

Compared to the residential sector, non residential buildings are more heterogeneous and refer here to buildings in the service or tertiary sector. They are usually classified by type and by branch of activity according to the following categories[8],: offices (private and public offices), health sector, education, hotels and restaurants, wholesale and retail trade and other types of buildings.

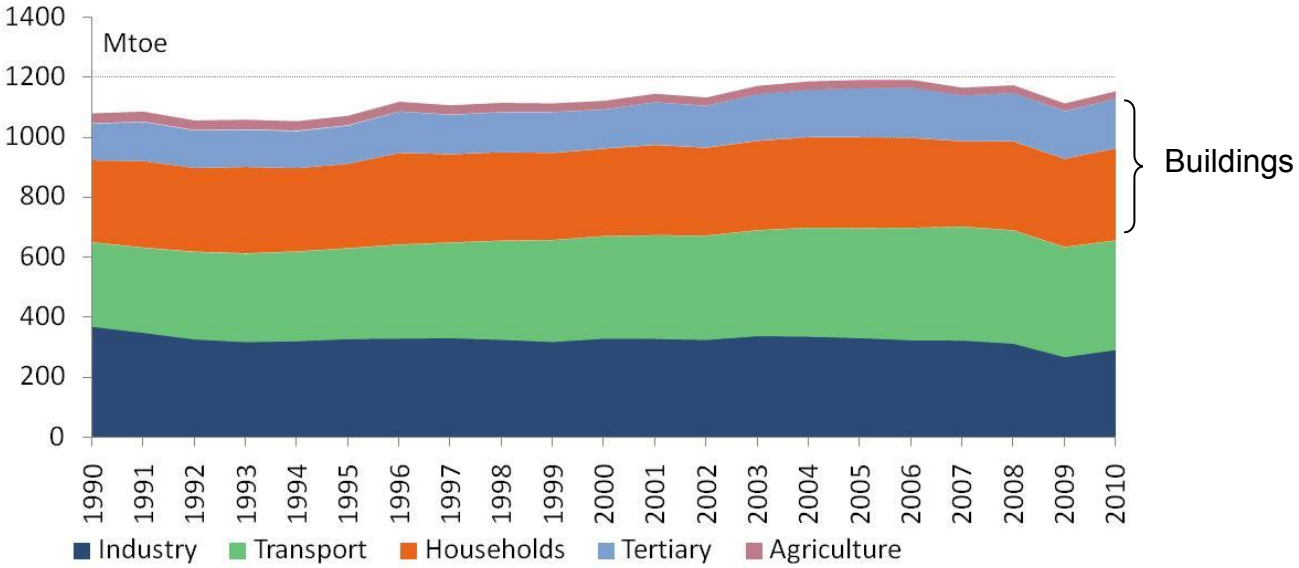
One statistical issue is that beyond the consumption in the above categories of buildings, other consumers are often included in a residual sector called “non specified”, which by definition includes all activities not included elsewhere (e.g. SME’s, military uses). It is obviously difficult to know precisely what is included in this but it is important to consider it as it represents around 7% of the total non-residential consumption in 2010 at EU level (10% in 1990)[9]. However it remains difficult to match activities variables or economic data to this consumption; for this reason indicators will exclude this “non specified” sector.

[5] Directive 2002/91/EC, recast Directive 2010/31/EU
[6] European Commission (2011), Energy Efficiency Plan 2011, COM(2011) 109 final
[7] Related documents MEMO 11-149
http://europa.eu/rapid/pressReleasesAction.do?reference=MEMO/11/149&format=HTML&aged=0&language=en&guiLanguage=en
[8] Eurostat nomenclature NACE Divisions 41,50,51,52,55,63,64,65,66,67,70,71,72,73,74,75,80,85,90,91,92,93 and 99).
[9] Source: Energy consumption from Eurostat

2.3. Energy consumption of the buildings sector

Energy consumption of the building sector has increased by around 1%/year since 1990, mainly in non-residential buildings (1.5%/year for non residential buildings compared to 0.6%/year for households) (Figure 1).

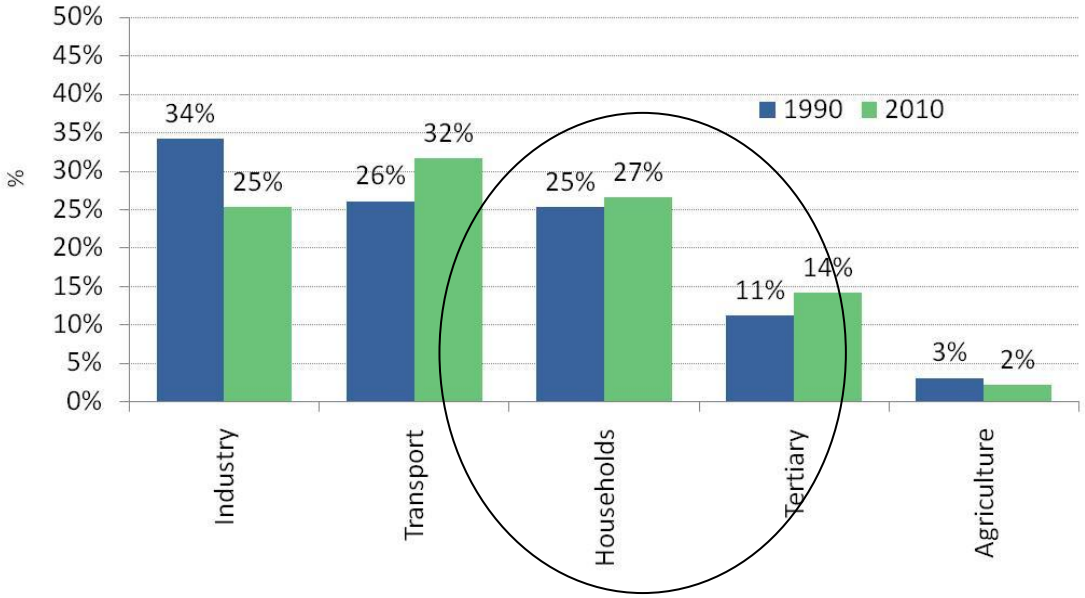
Figure 1 : Final energy consumption by sector (EU)



Source: Eurostat

Buildings energy consumption represented 41% of final energy consumption at EU level in 2010, up from 37% in 1990 (Figure 2), of which 27% for residential buildings (i.e. around 2/3 of total energy use in buildings) and 14% for the tertiary sector. Transport and industry consumed respectively 32% and 25% of final energy consumption in 2010 (26% and 34% in 1990).

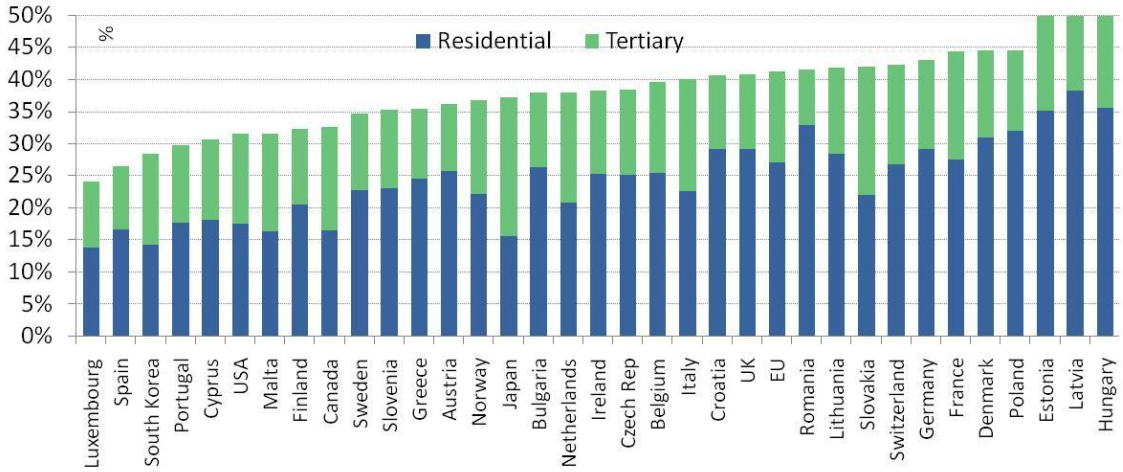
Figure 2 : Share of energy consumption by sector in EU



Source: Eurostat

Buildings represent less than 1/3 of total final energy consumption in 6 EU countries (Luxembourg, Spain, Portugal, Cyprus, Malta and Finland) and 3 non-OECD countries (USA, Canada and South Korea). On the opposite, buildings represent more than 45% of final energy consumption in countries such as Hungary, Latvia, Estonia, Poland, Denmark, Germany and France.

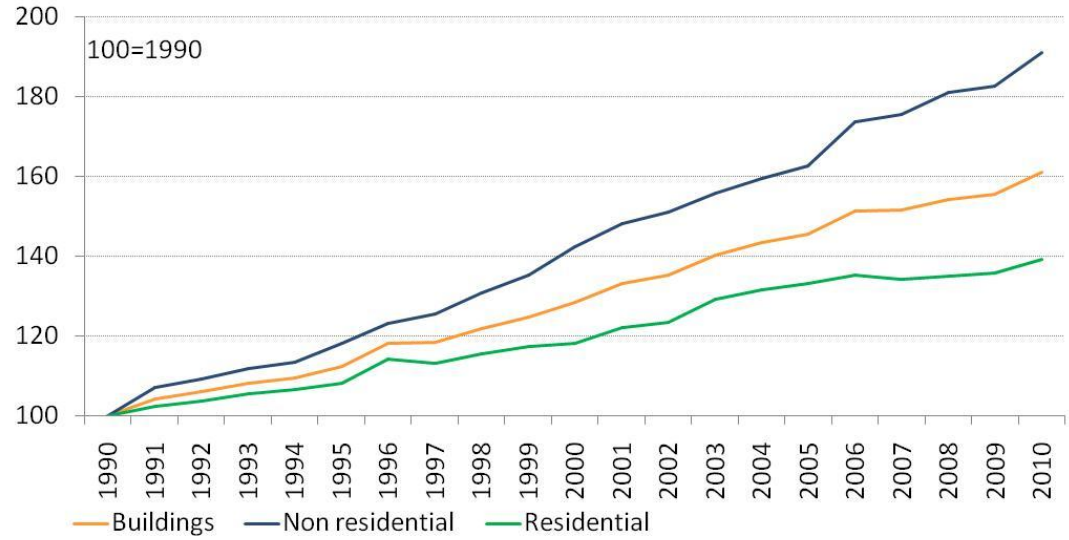
Figure 3 : Share of energy consumption for buildings in final consumption (2009)



Source: Eurostat

Electricity consumption in buildings has increased very rapidly since 1990, by 2.4%/year (+60%). This increasing trends is rather marked for non residential buildings, with an increase of 3.3%/year, while the rate of progression for households is twice lower (1.7%/year) (Figure 4). Understanding energy uses in the buildings sector is complex because of a lack of reliable data on the energy consumption by end-use in service sector buildings (e.g. heating, cooling, lighting, IT equipment and appliances), and because of the large variety of building categories in this sector.

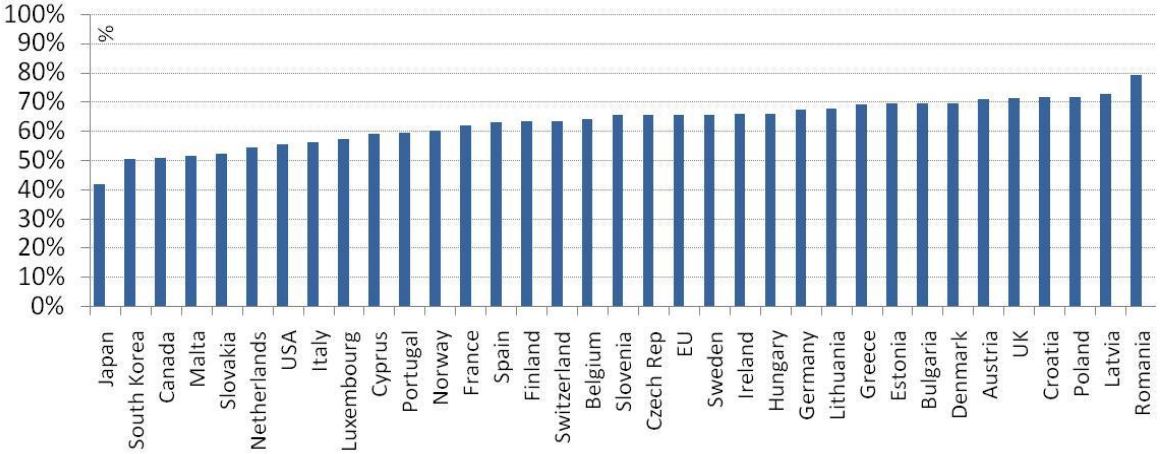
Figure 4: Electricity trends in the building sector



Source: Eurostat

The distribution of buildings consumption between residential and non residential buildings depends on the country. In the majority of countries, residential buildings represent more than 60% of buildings energy use. This share is above 70% for UK, Poland, or Latvia and even reaches 80% for Romania (Figure 3).

Figure 3 : Share of residential buildings in total buildings consumption (2009)

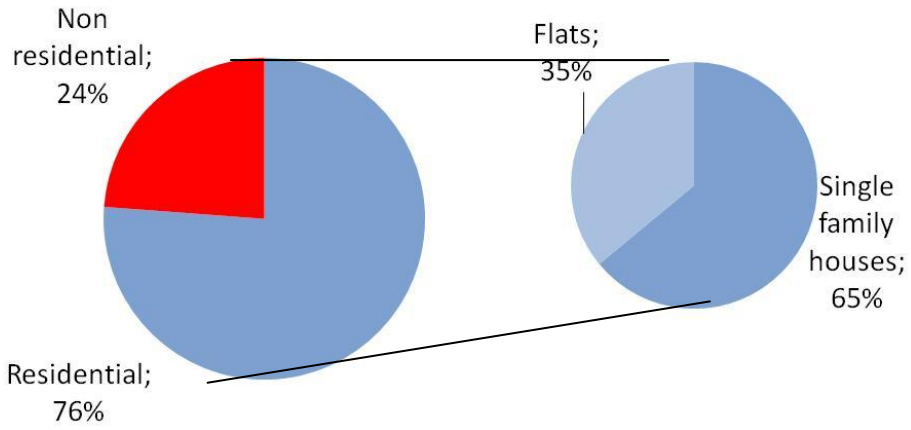


Source: Eurostat

2.4. Overview of the building floor area

The total floor area of buildings represents around 24 billion m^2 in the EU, of which around ¾ for residential buildings. Single family houses represent 65% of residential floor space, against 35% for apartments (Figure 4). At EU level the average floor area is around 87 m^2 per dwelling (2009).

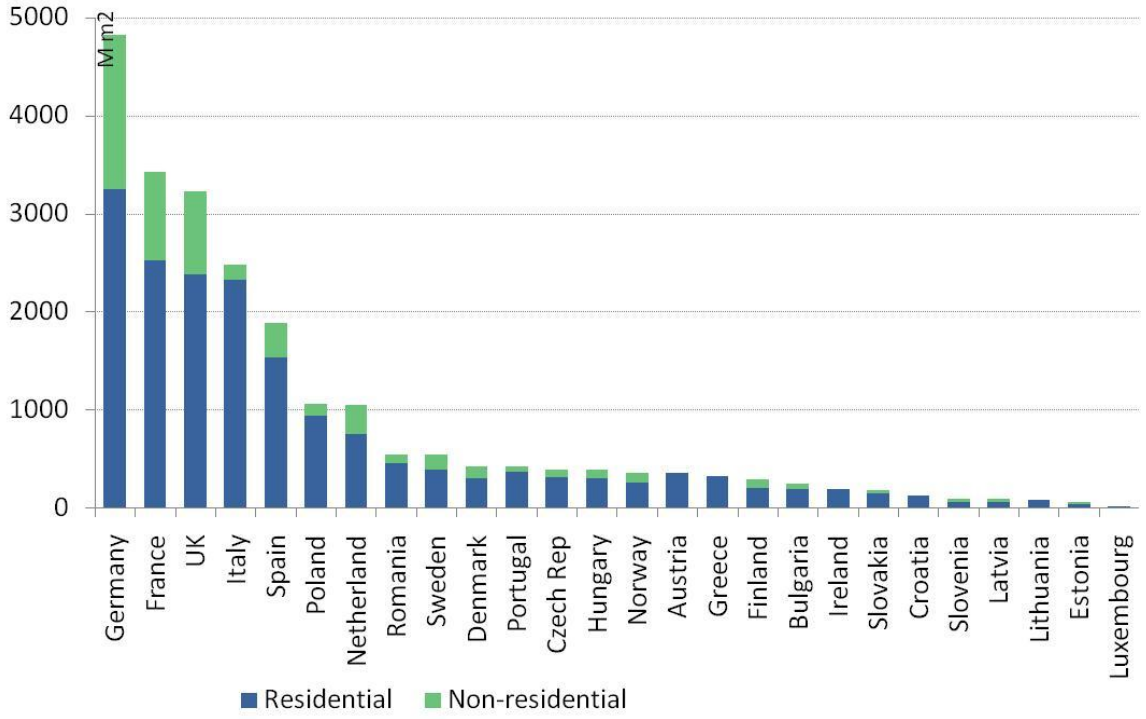
Figure 4 : Floor area by type of building at EU level



Source: ODYSSEE

Five large countries (Germany, France, UK, Italy and Spain) account for approximately 70% of the total floor space of buildings (Figure 5). The share of non residential buildings in the total floor area is higher than for the EU average in 5 countries (Germany, Finland, Slovenia, Latvia and Estonia) where it accounts for more than 1/3 of the total building floor area.

Figure 5 : Floor area distribution per country (2009)



Source: ODYSSEE and BPIE

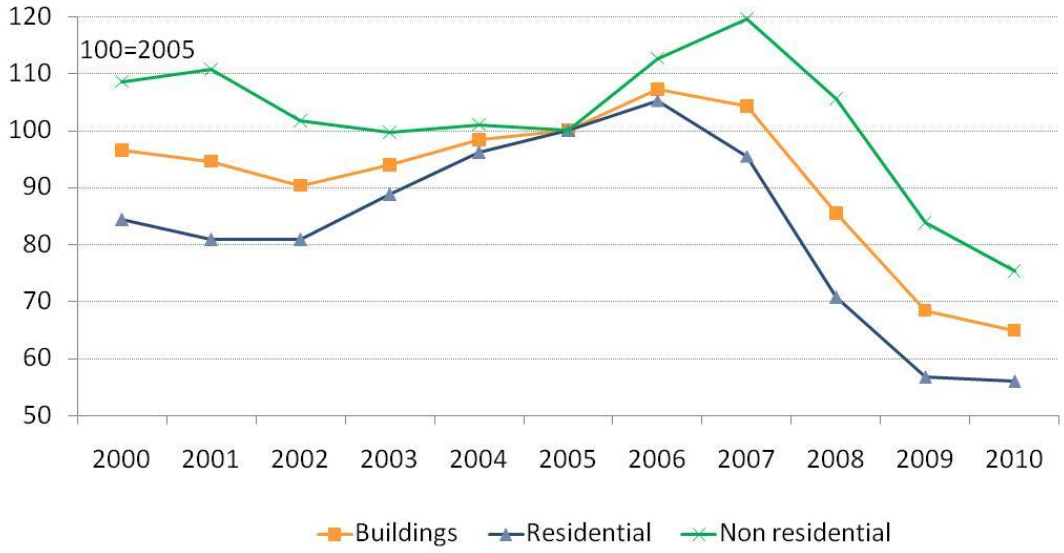
Retail and wholesale trade represent the largest proportion of non residential buildings with 28% of non residential floor space. Office buildings are the second largest category with around ¼ of the total non-residential floor space, followed by education represents (around 20%), hotels and restaurants (11%), hospitals (7%), sport facilities (4%) and others buildings (11%)[10].

2.5. Overview of buildings construction

The analysis of the building construction gives an interesting overview of the dynamics of the building sector. During the last ten years, the number of buildings permits[11] increased rapidly at EU level from 2002 to a peak in 2006 (+17% for all types of buildings and+24% for residential buildings), after which it fell dramatically and was in 2009 twice lower than in 2006 (Figure 6).

[10] Survey from BPIE (Buildings Performance Institute Europe) (2011).
[11] A building permit is an authorization to start work on a building project, and as such is the final stage of authorization prior to start work. The building permits indices assess trends in construction activity.

Figure 6 : Trends in buildings permits (indices)

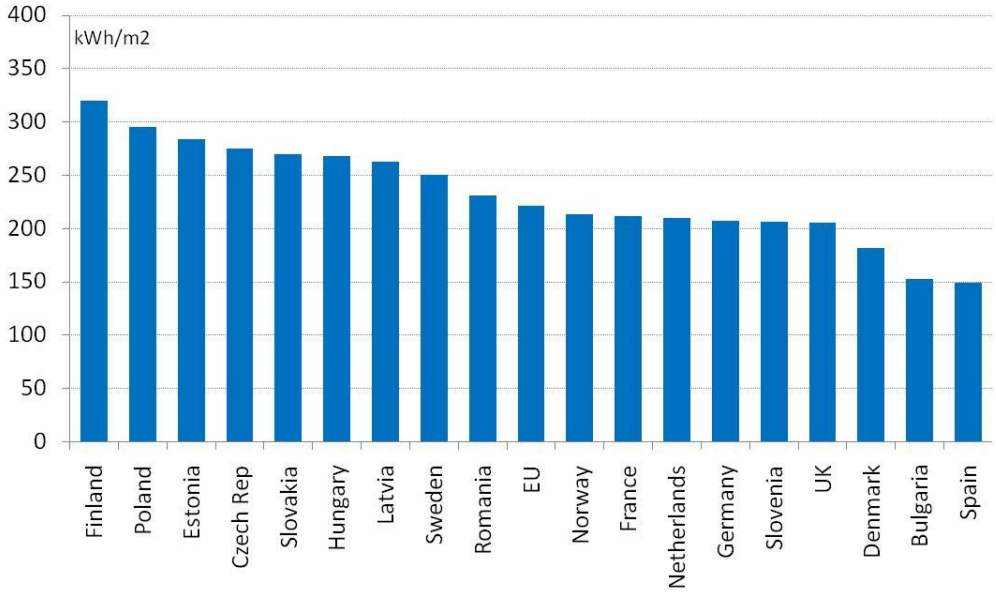


Source: Eurostat

2.6. Overview indicators

At EU level, the annual unit consumption per m^2 for buildings is around 220 kWh/m^2 in 2009, with a large gap between residential (200 kWh/m^2) and non-residential buildings (295 kWh/m^2) (Figure 7). This unit consumption is lower in Spain, Bulgaria compared to other countries such as Finland, Poland, Estonia, mainly for climatic reasons (factor 2 difference between these countries).

Figure 7 : Energy consumption in buildings [12](kWh/m^2) in 2009 (normal climate[13])



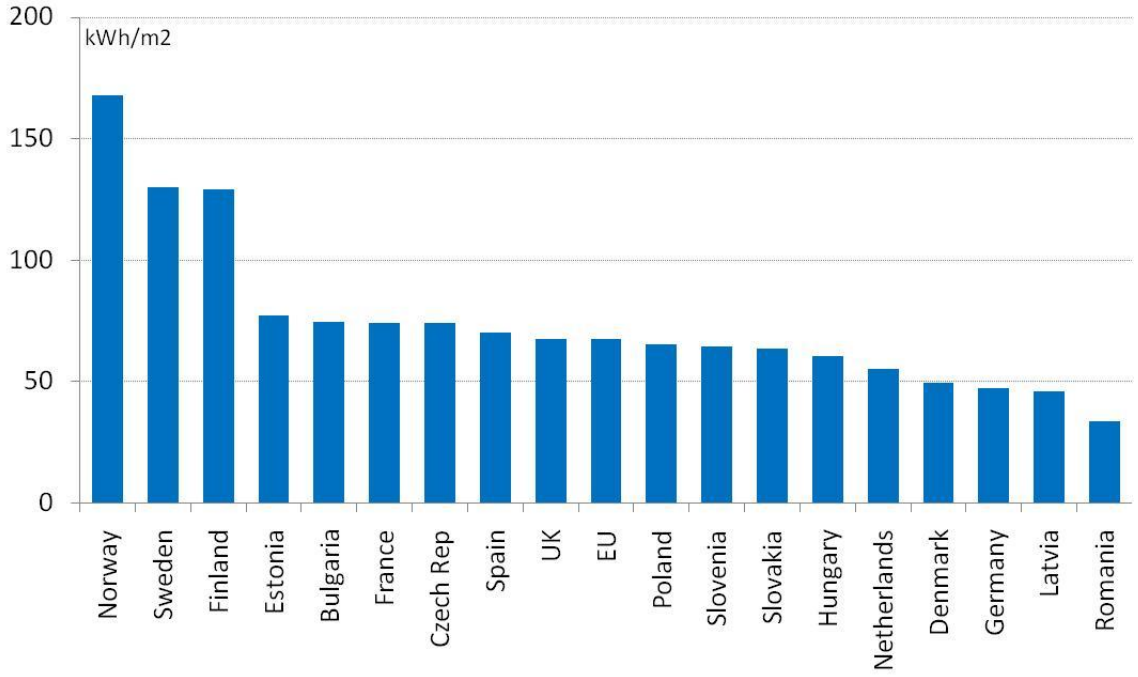
Source: ODYSSEE

[12] Average of a selection of 17 countries.

[13] The yearly energy consumption is corrected for variations in year-to-year average temperature and allows comparisons between countries without climatic effect on the energy consumption (see glossary for detailed information about the methodology).

Annual unit electricity consumption per m^2 varies significantly by type of buildings and countries (Figure 8). It is higher in Nordic countries (Norway, Sweden and Finland) due the use of electricity for space heating[14].

Figure 8 : Electricity consumption in buildings [15](kWh/m^2) in 2009 (normal climate)



Source: ODYSSEE

[14]Chapter 4 details further countries specificities related to climate for residential buildings.
[15] For a selection of countries. No information is available on the floor area of non residential buildings for Austria, Ireland, Greece, Croatia, Italy and Portugal.

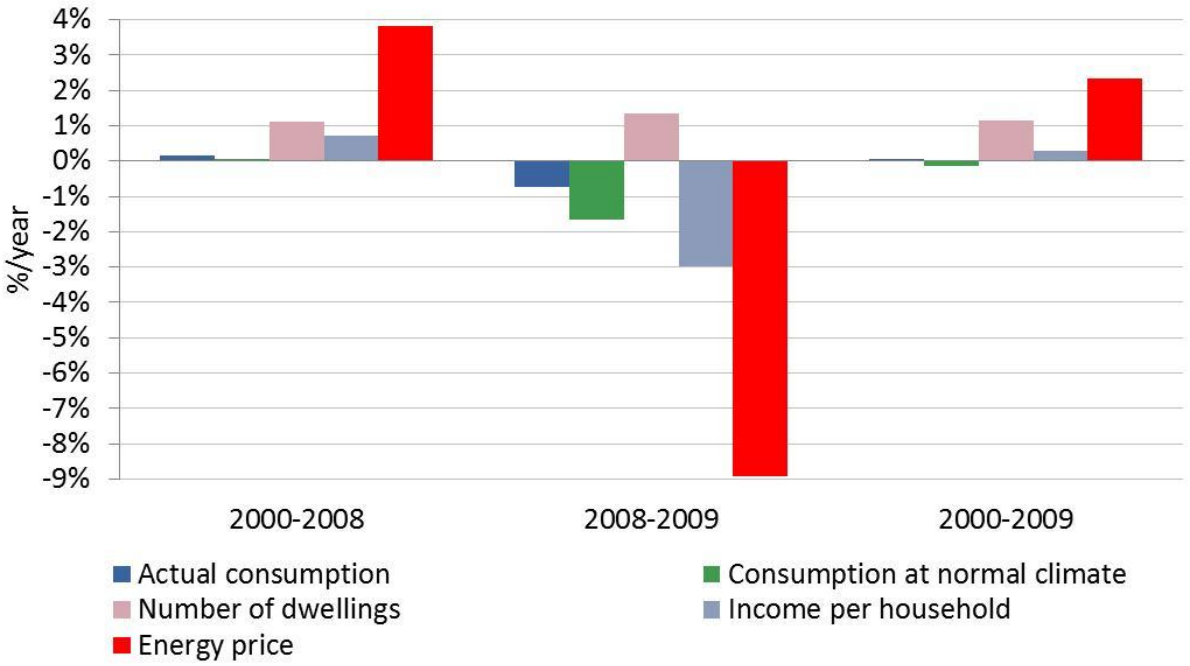
3. Total household energy consumption[16]

3.1. Introduction

Energy consumption, energy prices and income

In 2009, there was a decrease of the energy consumption by 1.6%[17] compared to 2008 as a result of a decrease of income (-3%) and despite a drop in energy price (-9%) (Figure 9). Energy consumption in 2009 (or 2008) is close to its 2000 level, despite a 1% growth in the number of dwellings and a slight progression of incomes.

Figure 9: Income, energy price and average energy use per household (EU-27)



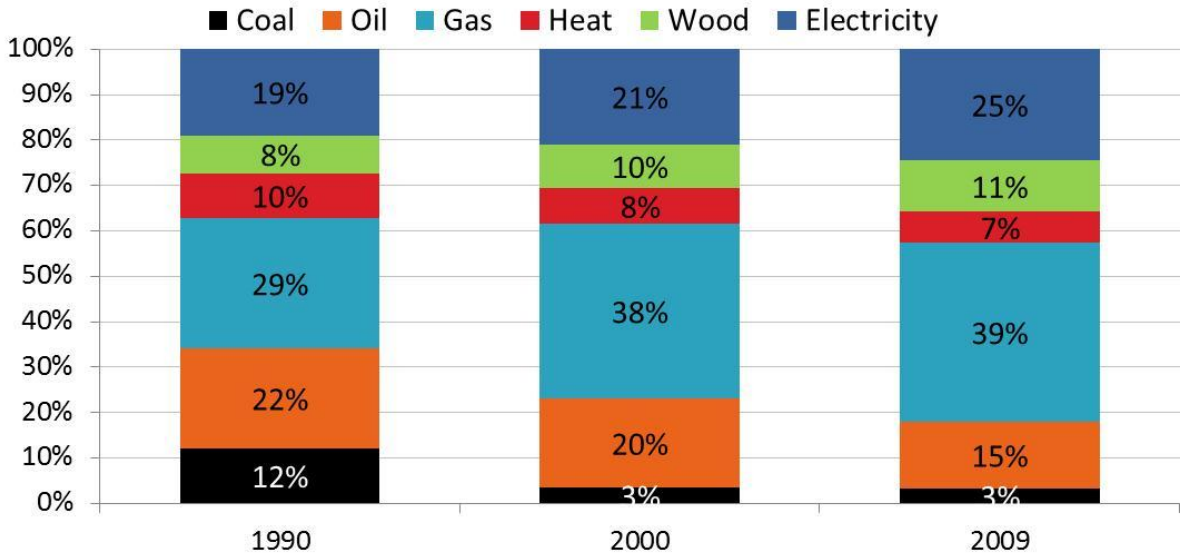
Source: Odyssee

Since 2000 the strongest increase is for electricity

Natural gas is the dominant source of energy for households in the EU with 39% of the market, up from 29% in 1990 (Figure 10). Electricity ranks second and its share is also increasing rapidly (from 19% in 1990 to 25% in 2009). Oil is slowly being phased out at EU average (from 22% in 1990 to 15% in 2009), but remains significant in island countries (Box 2).

[16]Unless otherwise specified, all indicators on total energy use or on heating shown in the report are temperature corrected, i.e. at normal climate (see glossary).
[17]0.7% at real climate.

Figure 10: Household energy consumption by energy source in EU



Source: Odyssee

The share of wood grew from 8 to 11% over the period, with very uneven role among countries. Coal has almost disappeared (except in some countries, 3% in 2009 down from 13% in 1990). Heat from district heating represents only 8% of the total although it plays an important role in many new member states. The diversity of fuel mix among countries and the extreme situations compared to the EU average are pinpointed in Box 2**.** Since 2000 the strongest penetration was for electricity (from 21% to 25%), while the share of gas almost did not change.

Box 2: Countries with extreme fuel mix for households

Natural gas: the countries with own gas reserves show the largest use of gas: the Netherlands (74% in 2009) and the UK (64% in 2009). Hungary and The Czech Republic have experienced the largest penetration of natural gas since 1990.

Coal, lignite and peat: Ireland had been strongly dependent on coal and peat but also has shown a very fast transition in recent years (down from 60% in 1990 to 17% in 2009). The same holds for coal in the Czech Republic (down from 53% in 1990 to 8% in 2009). Poland still holds the largest share for coal (30% in 2009 and 35% in 1990).

Liquid fuels: Island countries, e.g. Cyprus, Greece and Ireland, show the highest fractions for oil use, possibly due to the absence or limited gas grid.

District heating: large fractions are typically found in Eastern Europe and Baltic countries (about 50%). In Romania the share has been halved compared to 1990 (15% in 2009).

Wood/biomass: the largest shares are found in countries with a low GDP (Latvia 52% in 2009, Romania and Estonia 42%) and/or large wood resources (Austria 25%, Finland 21%).

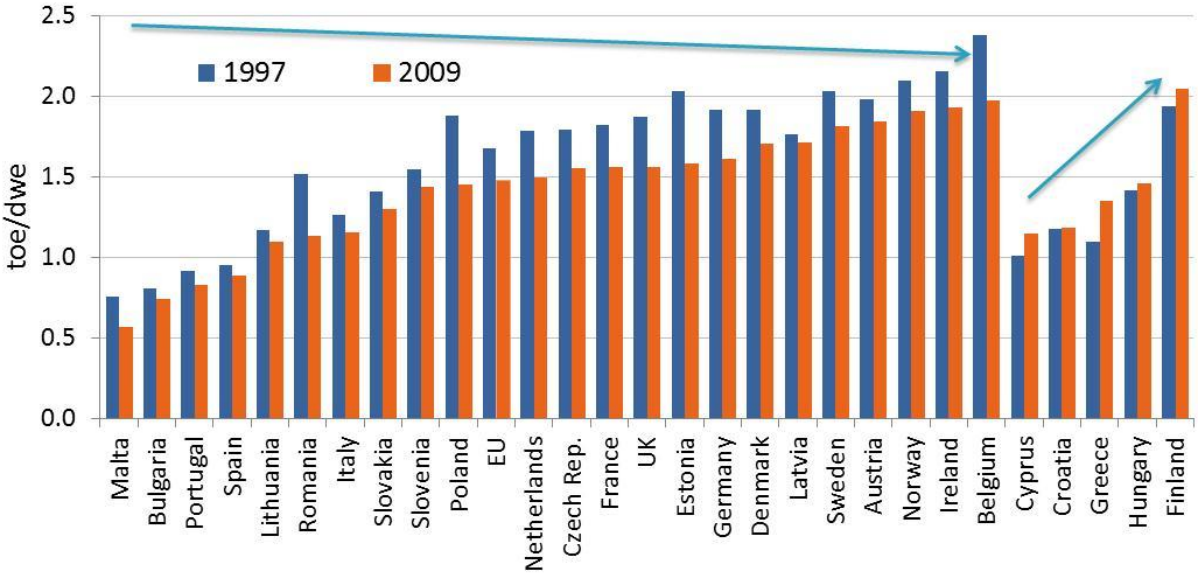
Electricity: high fractions for small islands (Cyprus and Malta), for countries with a lot of hydro, such as Norway, and for countries with nuclear electricity production (Sweden with 49% in 2009, France or Finland with 32% in 2009).

Energy consumption per dwelling is below its 1997 level in most countries

Energy consumption per dwelling is heterogeneous among countries: from 0.5 toe/dwelling in Malta to almost 2 toe/dwelling in Belgium (Figure 11). However, even for countries with similar climate, significant discrepancies exist (e.g. 1.5 toe/dwelling for The Netherlands compared to 2 toe/dwelling for Belgium).

Energy consumption per dwelling is below its 1997 level in about 80% of the countries in 2009, with a strong reduction (above 2%/year) in several new member countries (Romania, Poland and Estonia), while there is an increase in Cyprus, Greece, and to a lesser extent in Finland, Hungary and Croatia.

Figure 11: Household energy consumption per dwelling[18]

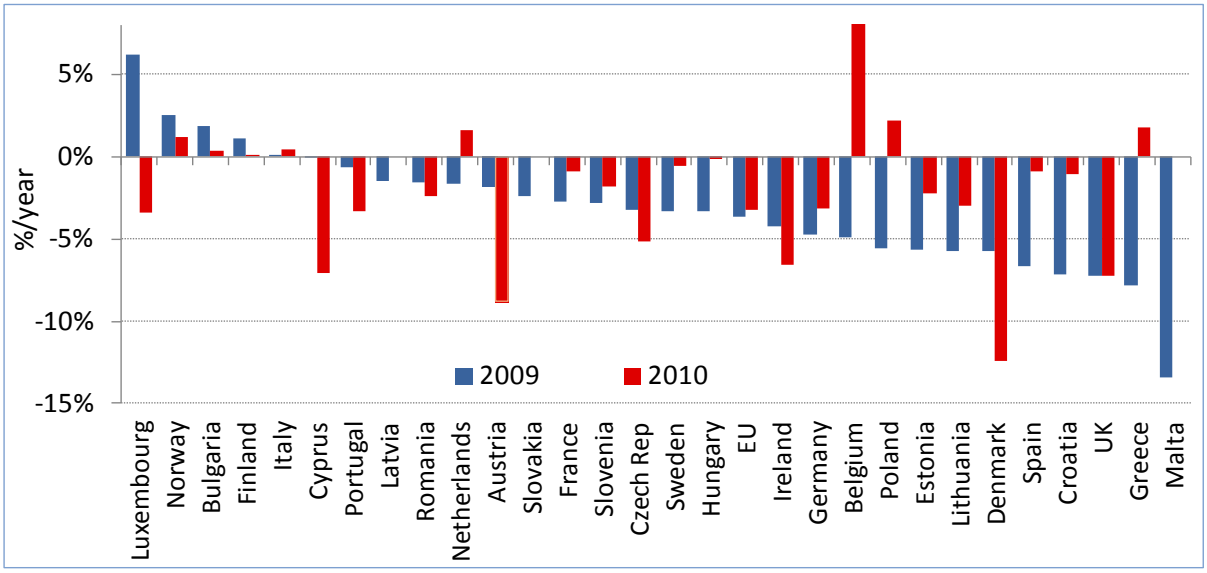


Source: Odyssee

[18]At normal climate; 2007 for Lithuania and 2008 for Malta. The number of dwelling corresponds to the number of permanently occupied dwellings and excludes vacant dwellings and summer houses.

In 2009, there was a strong reduction of the average energy consumption per dwelling compared to 2008 in most countries (Figure 12): it reached 3% at EU level compared to an average decrease of 1.1%/year over 2000-2008. There was a very large contraction (close to 5% or above 5%) in 12 countries (mainly Denmark, Malta, Greece, UK, Spain, Denmark). In 2010, ther was again a strong reduction in Denmark, Austria, UK, Ireland, Czech Rep and Cyprus (above 5%), that is not explained by economic trends, except for Ireland. In 2010, there was a progression in some countries, such as Netherlands, Belgium, Norway, Poland and Greece that are difficult to explain[19].

Figure 12: Variation of the average consumption per dwelling at normal climate



Source: Odyssee

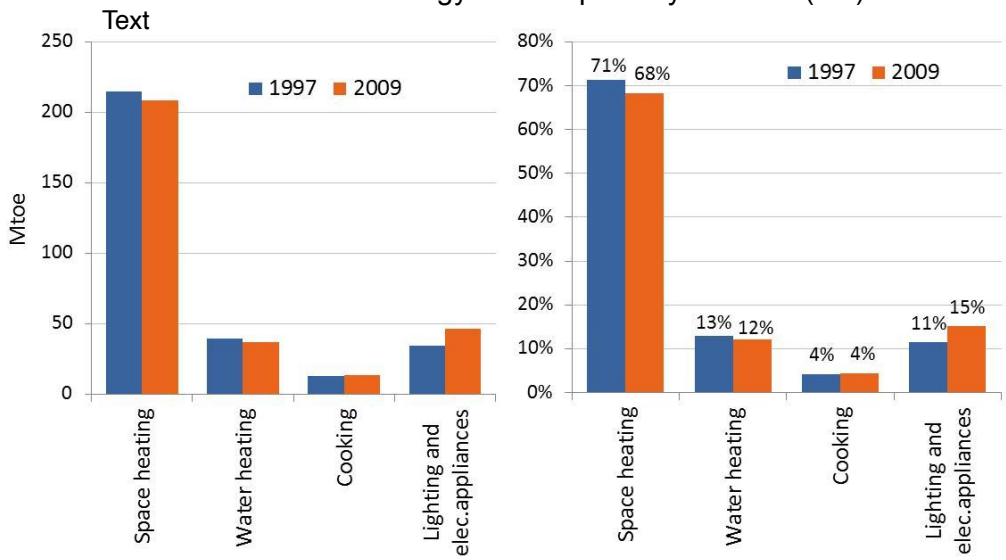
Decreasing share of space heating and greater use for appliances and lighting

At EU level, space heating is the predominant end-use (67%), but its share is slightly declining since 2000 (Figure 13). Water heating ranks second and has a stable share (13%). Electrical appliances and lighting absorb an increasing share of the consumption (+3 points). These trends can be explained by greater energy efficiency improvements for space heating than for other uses, because of building regulations and the diffusion of more efficient heating appliances; in addition, there is a multiplication of new electrical appliances, as analysed below.

The total consumption for heating is 3% lower in 2009 than in 1997 (- 7 Mtoe). This contrasts with the increasing trend observed before. For the other uses it is either stable (water heating and cooking) or in strong progression (+4% or 12 Mtoe for electrical appliances and lighting).

[19] It may be due to the large climate variation between 2009 and 2010.

Figure 13: Breakdown of household energy consumption by end-use (EU)

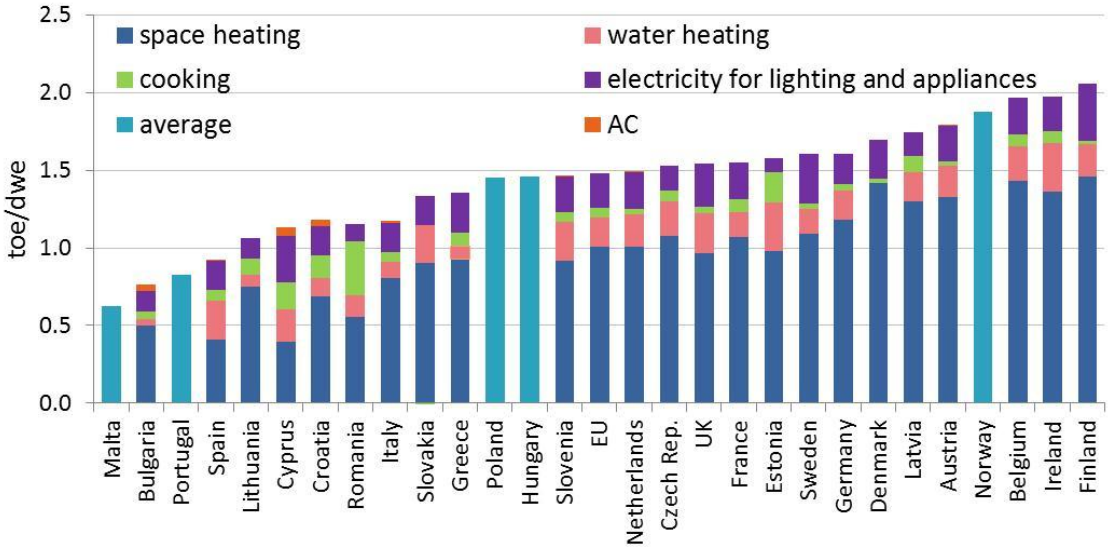


Source: Odyssee

Distribution by end-use differs significantly among countries

The breakdown of the household energy consumption by end-use differs substantially between member states (Figure 14). Space heating represents the largest share of household energy use: it corresponds on average to 60-80% of total energy consumption. A correlation with cold winters can be expected. Indeed, Cyprus, Portugal or Spain shows a small fraction for space heating. But Sweden does not show the highest fraction, probably due to substantial energy use for other purposes and to the large diffusion of heat pumps with an efficiency that is much higher than that of other heating equipment. Air conditioning still represents a marginal share of dwelling consumption, even if it reaches 5% of household consumption in Bulgaria and Cyprus[20].

Figure 14: Breakdown of household energy use by end-use for EU-countries (2009)[21]



Source: Odyssee

[20]Only eight countries publish data on air conditioning.
[21]Data not available for countries with only an average shown; in Denmark, space heating includes water heating.

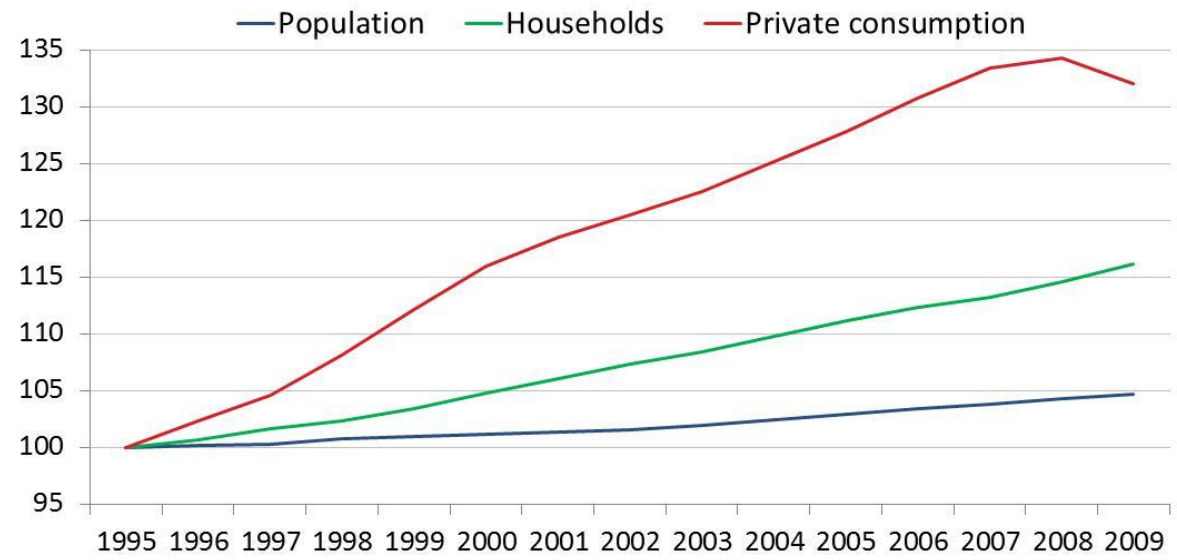
The highest share for electrical appliances and lighting is found in Cyprus (about 30%), then in Spain, Sweden and Greece with a share around 20%. In Baltic countries and Romania, the share of appliance is much lower than in the EU average (10% or below) due to lower per capita income and thus to a lower diffusion of appliances. In Germany and Belgium, the share of appliances (around 12%) is significantly lower than for the EU average: here it may come from more efficient appliances as this will be discussed in Chapter 5.

3.2. Socio economic drivers of energy consumption

The number of households increases much faster than population

Socio economic indicators shown above are related to the number of permanently occupied dwellings, which is by definition close to the number of households. This indicator is considered as the main driver of energy use for households as most of their consumption is taking place in occupied dwellings[22]. Variation in the number of households depends on population growth and on changes in the average number of persons per household. The number of households increased 3 times faster than the population, 1.0%/year versus 0.3 %/year over the period 1990 – 2009 (Figure 15). The difference is explained by the steady reduction in the number of persons per household (from 2.8 to 2.4 between 1990 and 2009) due to ageing of the population and the decohabitation[23]: this phenomenon is a major cause of extra energy use in the residential sector.

Figure 15: Trend for population, households and income (EU)



Source: Odyssee

Increase in household income was moderate and probably not a strong driver

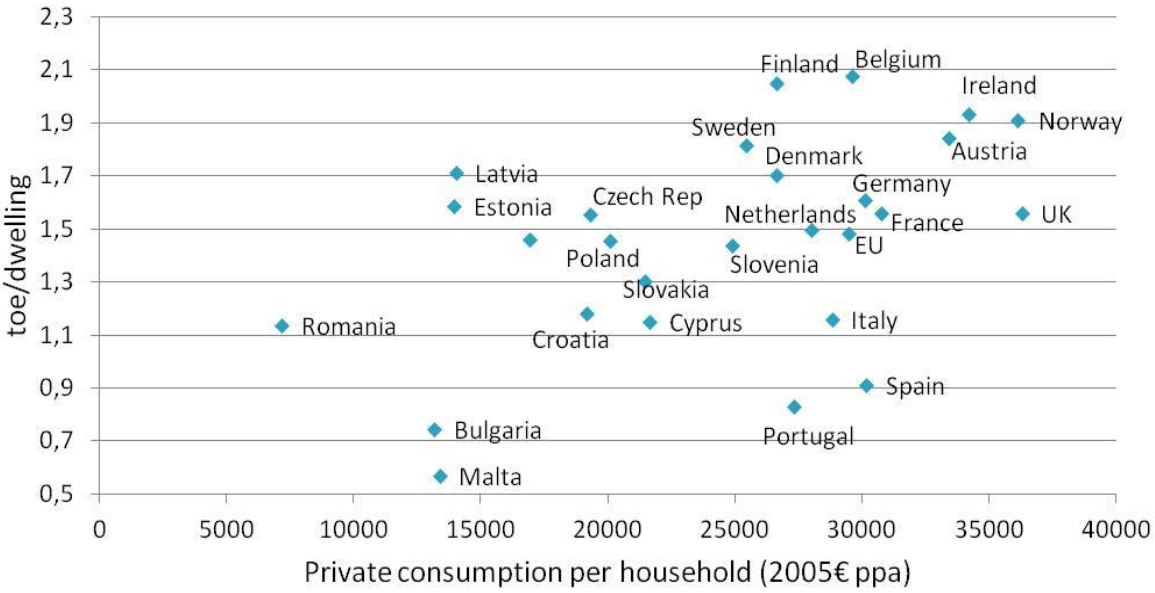
Another driver of increased energy consumption is higher incomes per household[24], which leads to better comfort and higher living standards, i.e. larger dwellings, more rooms being well heated in southern countries, more appliances and lighting points, etc. Average household income increased by 0.9%/year over the period 1995-2009, which is quite moderate compared to earlier trends (2%/year between 1995 and 2000).

[22] It can be estimated that less than 5% of total residential energy use is consumed in summer houses.
[23] Decohabitation refers to the fact that people who were living together split (e.g. young people living separately from their parents).
[24] Private consumption (household expenditure on goods and services) is used as a proxy for income.

Higher incomes determine increased energy use, but not good correlation

Although the average household income determines energy consumption, either directly (e.g. affordable comfort level for space heating) or indirectly (e.g. size of dwelling and number of appliances), there is no robust relationship between private consumption per household[25] and energy consumption per household (Figure 16). For instance, Belgium uses substantially more energy than Germany for the same income (and winter climate). On the other hand, The Czech Republic has a comparable energy consumption but a much lower income. These examples show that other factors, such as the quality of the housing stock, play a role.

Figure 16: Energy consumption versus income per household (at ppp, 2009)



Source: Odyssee

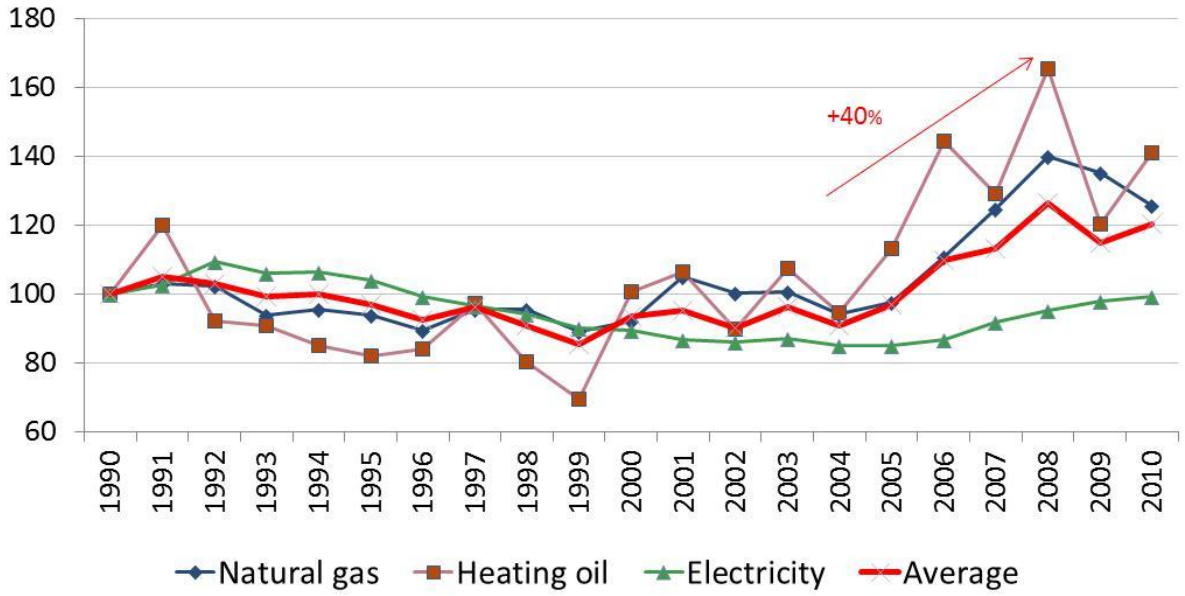
[25] To account for differences in the average price of goods and services, which are relatively low in most new member states, the private consumption is measured at power purchasing parities (PPP).

Energy prices are increasing since 2004

The average energy prices for households have increased by 40% between 2004 and 2008 (9%/year) (Figure 17)[26]. In 2009, they have dropped by 9% with the economic crisis (-27% for oil, and -3.5% for gas). In 2010, the trend is reversed (+5%).

Since 2005, the price of electricity is also increasing (+17% between 2005 and 2010), whereas there was a regular decline before 1999 (- 15%) and a relative stability between 1999 and 2004.

Figure 17: Trend in energy prices for households, weighted EU-27 average



Source: Odyssee

[26]Weighted average of the price of the different energy carriers (at constant 1990 prices).

4. Energy use for space and water heating

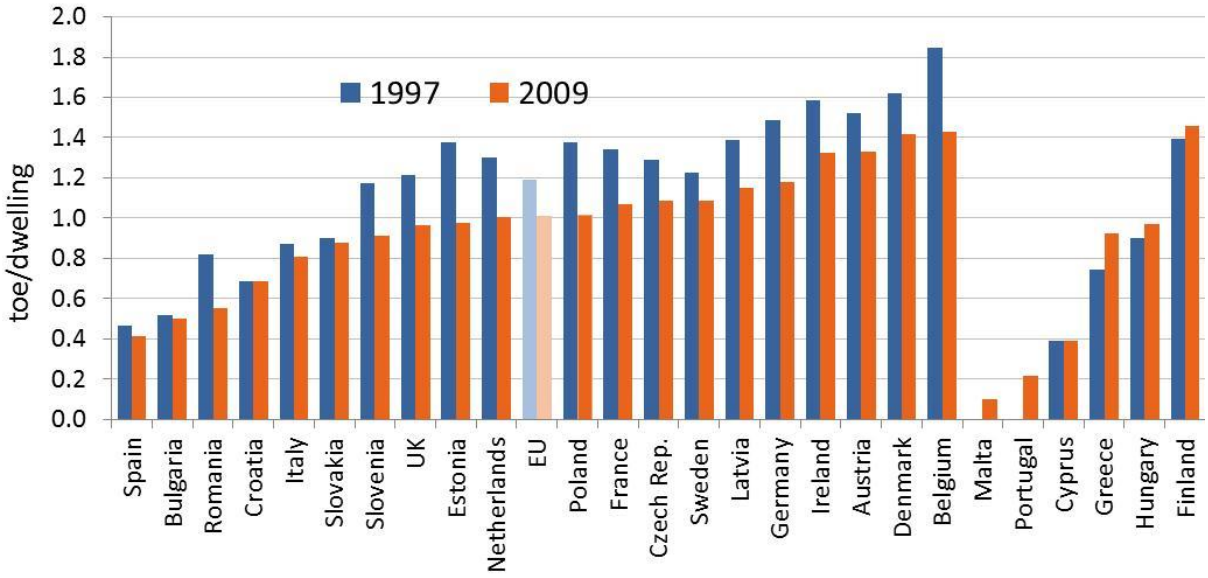
4.1. Space heating

High energy use for space heating in countries with moderate climate

The highest specific consumption of space heating per dwelling are not automatically found in countries with cold winters, like Sweden. Some countries with moderate winters, such as Ireland or Belgium, are among the highest values (Figure 18).

In most countries, energy use per dwelling for space heating decreased between 1997 and 2009 (-0.9%/year for the EU average), except for Finland, Greece and Hungary.

Figure 18: Energy use for space heating per dwelling[27]



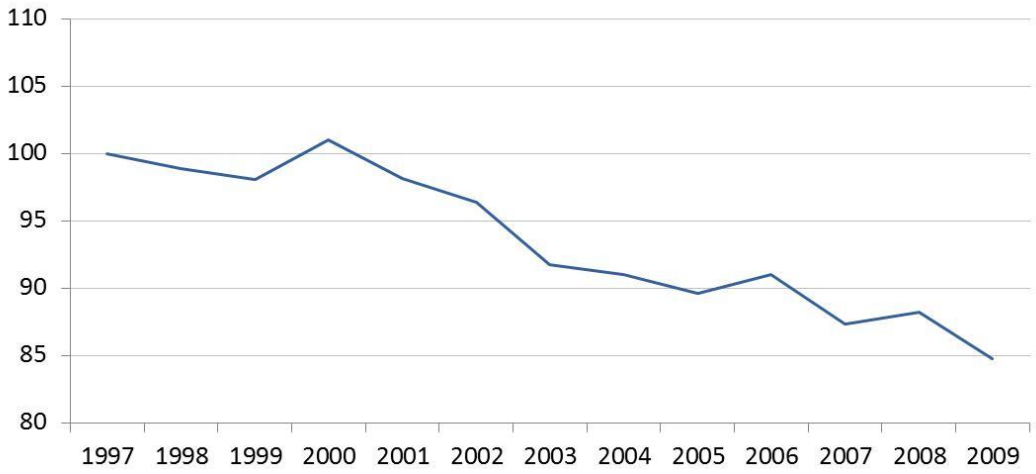
Source: Odyssee

Steady improvement in space heating efficiency at EU level, by 1.1%/year

Energy efficiency trends for space heating are measured on the basis of the decrease in annual energy use per m^2[28].Over the period 1997-2009, the energy used per m^2 for the EU as a whole decreased steadily by around 1.4%/year almost 15% (Figure 19). Part of this reduction is linked to the diffusion of new dwellings that consume in “theory” on average 40% less than dwellings before 1990[29]. This impact is however still limited as dwellings built since 1990 only represented 20% of the total stock in 2009. Other factors such as the diffusion of more efficient heating appliances, the retrofitting of existing dwellings or fuel substitution have also contributed to reduce this specific consumption.

[27] Climate corrected. 2008 data for Spain, Slovenia and Romania.
[28] Specific consumption per m² is more relevant to assess energy efficiency than specific consumption per dwelling, as it cleaned from the effect of change in the size of dwellings.
[29] This estimation is based on the relative performance by country of new buildings built with new regulations (see below) and account for the actual volume of construction by country.

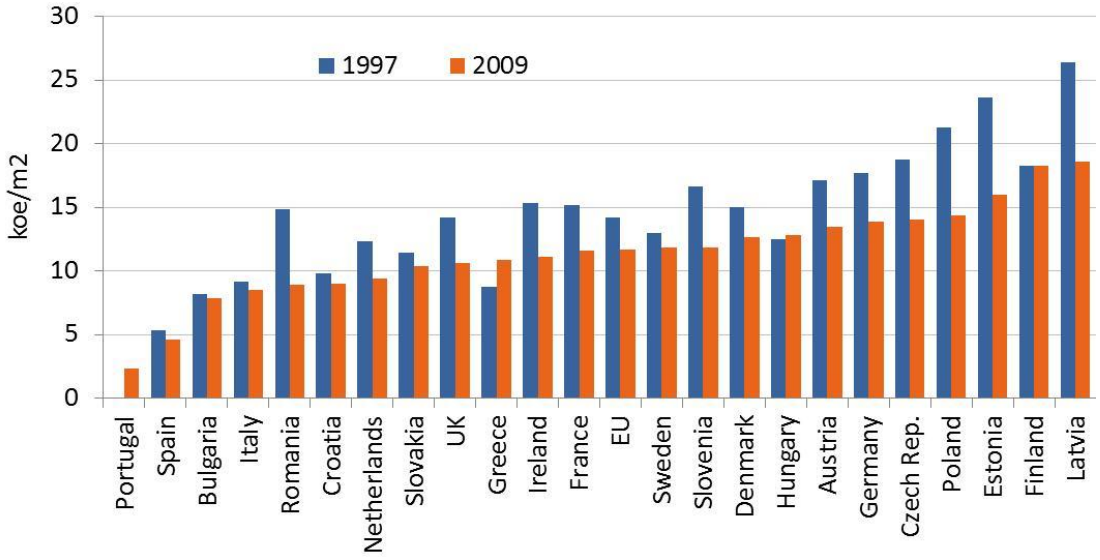
Figure 19: Energy efficiency trend for space heating in dwellings (EU)



Source: Odyssee

The specific annual energy consumption per m² for space heating decreased in all countries since 1997, except in Greece and Hungary (Figure 20)[30]. The reduction was quite significant in The Netherlands, Ireland and France, as well as in some new member countries (e.g. Romania, Latvia, Estonia and Poland)[31], thanks to a combined effect of higher energy prices and energy efficiency improvements. The Netherlands has one of the lowest levels of energy consumption per m^2 and is at the same time among the countries with the largest improvements[32].

Figure 20: Energy use for space heating per m^2 floor area[33]



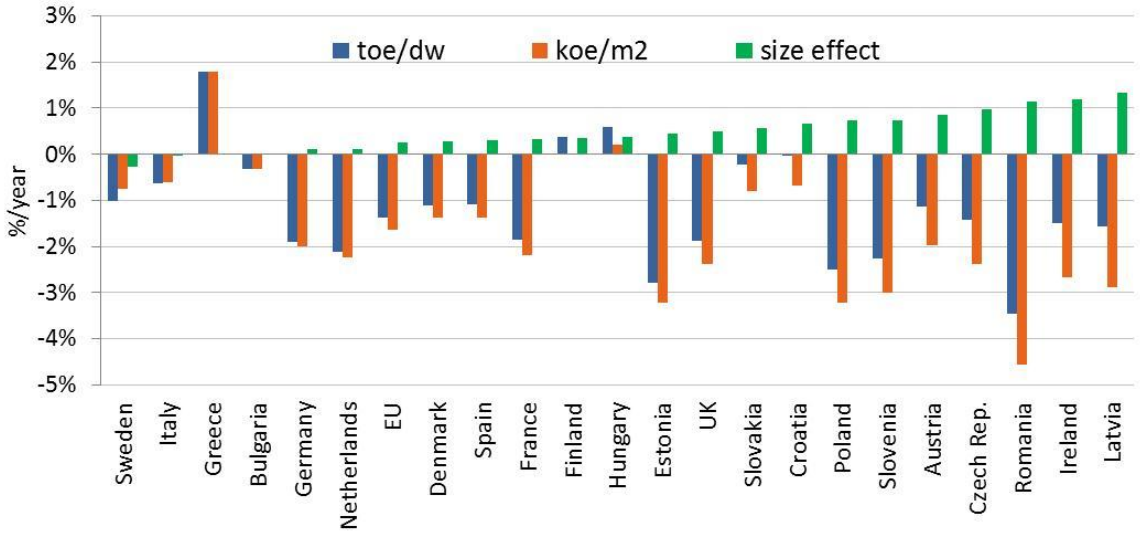
Source: Odyssee

[30] In Greece this trend may be due to progress in comfort.
[31] Latvia, Estonia and Poland realised the strongest decrease in absolute terms (around 7-8 koe/m² or 80-95 kWh/m²), while Romania registered the highest relative improvement (-40%).
[32] This could be due to extensive insulation measures in existing dwellings, to the large diffusion of gas condensing boilers and to the structure of the dwellings stock, with relatively few detached single family dwellings.
[33] 2008 data for Spain, Slovenia and Romania.

20% of efficiency gains in space heating are offset by larger dwellings

The energy consumption per dwelling decreased slightly less (1.4%/year) than the consumption per m^2 (1.6%/year) between 1997 and 2009 in the EU because of an increase in the average dwelling size (by around 3%) (Figure 21). In other words, 20% of energy efficiency progress for heating has been offset by larger dwellings. For new member states this size effect is larger as the dwelling size increased by 10%, but the effect is proportionally smaller given the large decrease in energy use per m^2.

Figure 21: Heating energy use per dwelling, per m^2 and size effect (1997-2009)[34]



Source: Odyssee

New dwellings are 30 to 60% more efficient in 2009 than in 1990

All EU countries have developed thermal regulations for new dwellings, some of them as far as the seventies. These standards, directly or indirectly, require a maximum heating consumption per m^2 for new buildings. Since 1990, these standards have been upgraded between 3 and 5 times in most countries: as a result, new dwellings built in 2009 consumed 30% to 60% less than dwellings built in 1990 (Table 1).

Table 1: Thermal regulations for new dwellings between 1990 and 2009

	Number of regulations	Total savings 1990[35]
Denmark	**3**	**-53%**
France	**3**	**-28%**
Ireland	**3**	**-48%**
Italy	**3**	**-27%**
Sweden	**3**	**-55%**
Norway	**3**	**-29%**

[34] 1997-2008 for Spain, Slovenia and Romania.
[35] Theoretical reduction in specific consumption per m^2 for dwellings built in 2009 compared to dwellings built in 1990 as implied by the standards.

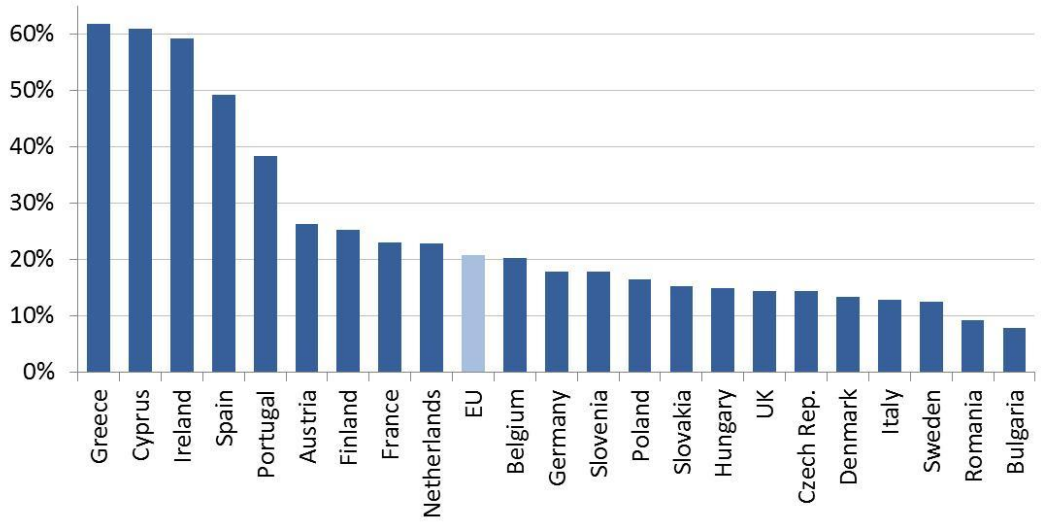
Germany	**4**	**-58%**
Slovakia	**4**	**-52%**
The Netherlands	**5**	**-50%**

Source: Odyssee

The low volume of construction limited the impact of standards on new dwellings

The effect of buildings standards on energy efficiency improvement for space heating is restricted by the often limited volume of construction. Most EU countries extend their dwelling stock by less than 1% per year (Figure 22). The main exceptions are Ireland, Greece, Cyprus, Spain and Portugal[36]. Eastern European countries have built very few new dwellings.

Figure 22: Share of dwellings built since 1990 in 2009 dwelling stock

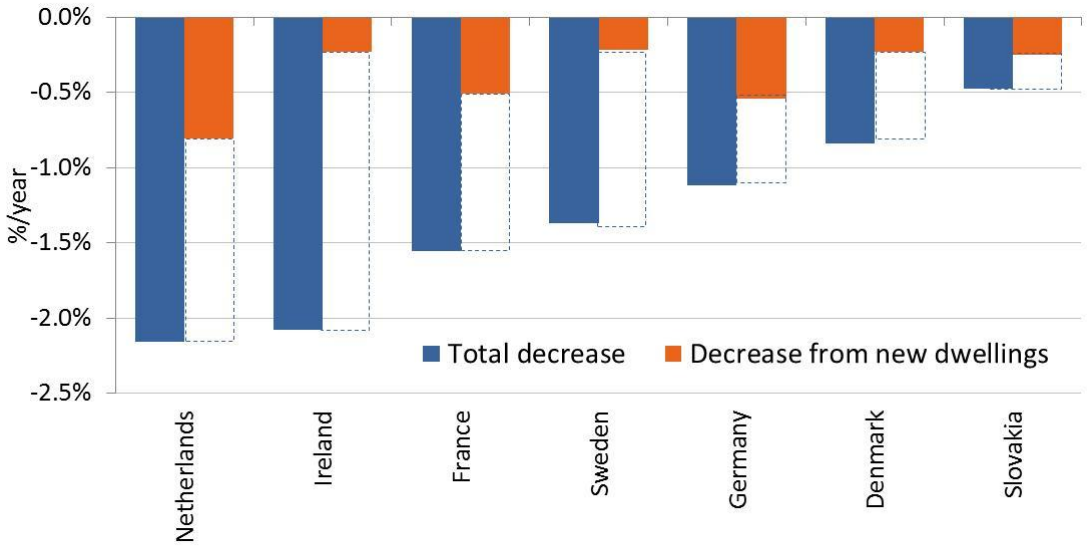


Source: Odyssee

The magnitude of the impact of the introduction of new dwellings with better insulation contributed to a decrease of the average energy consumption per dwelling depends on the number of standards upgrades, their severity and the volume of construction: 11% for Ireland, 16% for Sweden, 27% for Denmark, around 35% for France and Netherlands and around 50% for Germany and Slovakia (Figure 23)[37].

[36]For Greece, statistics could include secondary dwelling constructions and induce a bias.
[37] Result of a modeling assuming a unit consumption of new dwellings as implied by the standards.

Figure 23: Effects of building standards (1990-2009)



Source: Odyssee

This approach overestimates the impact of building regulations as it is well known, but not well quantified, that the actual specific consumption of new dwellings is higher than this theoretical consumption, because of non-compliance and rebound effects (i.e. the fact that, in well insulated dwellings, occupants tend to have a higher indoor temperature than in less insulated dwellings). The other factors responsible for the decrease of the average unit consumption per dwelling are the retrofitting of existing dwellings and the introduction of new more efficient heating appliances (namely, condensing boilers and heat pumps).

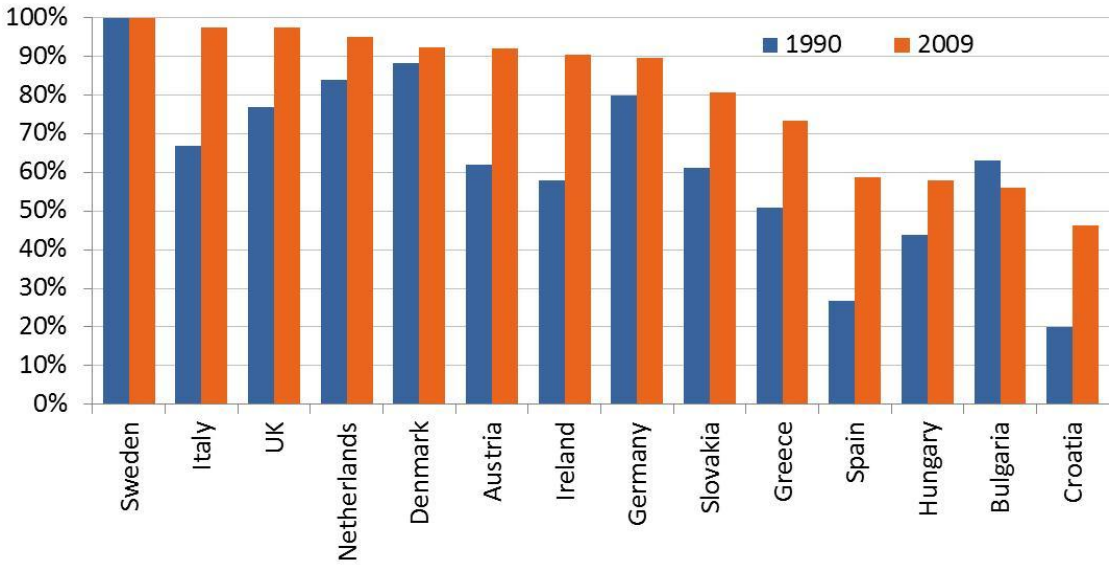
General trend for more central heating drives energy use up in some countries

In some countries the penetration of central heating[38] is also a driver of increased energy use for space heating. In past decades, room heating with one or more stoves per room has gradually been replaced by central heating either supplied from an individual boiler or by a collective heating in multifamily buildings, or by district heating (

Figure **24**). In most EU-15 countries the relatively high penetration has increased further. In most new member states and in Mediterranean countries the penetration has increased from a much lower level.

[38]Central heating 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. It is estimated that the replacement of single room heating by central heating increases the energy required for space heating by about 25 % on average.

Figure 24: Penetration of central heating in dwellings[39]



Source: Odyssee

[39] 1993 for Hungary, 1995 for The Netherlands and 2008 for Spain. The decrease in Bulgaria for both individual central heating and district heating is probably due to high prices. Indeed, after 1997 the price of heat increased 2 to 3 times faster than household's incomes.

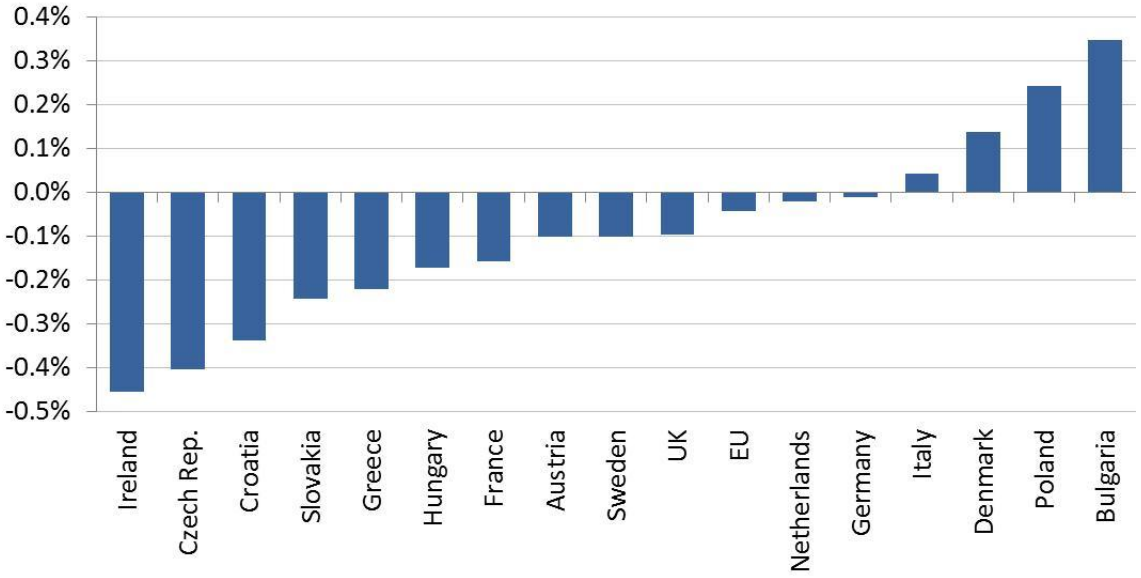
Fuel substitution generally contributed to energy savings

At EU level, coal and oil have been replaced for space heating by gas and to a lesser extent wood (-11 and 7 points in coal and oil market shares respectively compared to 1990; +16 and 4 points for gas and wood). As gas has a higher efficiency than coal and oil, substitution to gas led to an increase in heating efficiency that was however partly offset by the increasing share of wood. The effect of substitution was therefore marginal at EU level and only contributed to reduce the specific consumption for heating by 0.04% /year over 1990-2009 (Figure 25).

In some countries, "old fashioned" energy carriers, such as peat or coal (in Ireland and Czech Republic) have been replaced by oil and/or gas. As gas has a higher efficiency than coal or peat, thus fuel substitution contributed to efficiency improvements for both countries. In some new member states, such as Bulgaria and Poland, the share of wood has increased while the share of district heating has been reduced (Figure 25): in these cases, fuel substitution resulted in increased final energy consumption.

The effect of different types of substitutions can compensate each other, as in the case for the EU as a whole or for Germany with substitutions from coal to gas and from oil to wood. In The Netherlands, fuel substitutions were marginal due the dominant position of natural gas.

Figure 25: Contribution of fuel substitution to unit consumption per m^2 (1990-2009)[40]



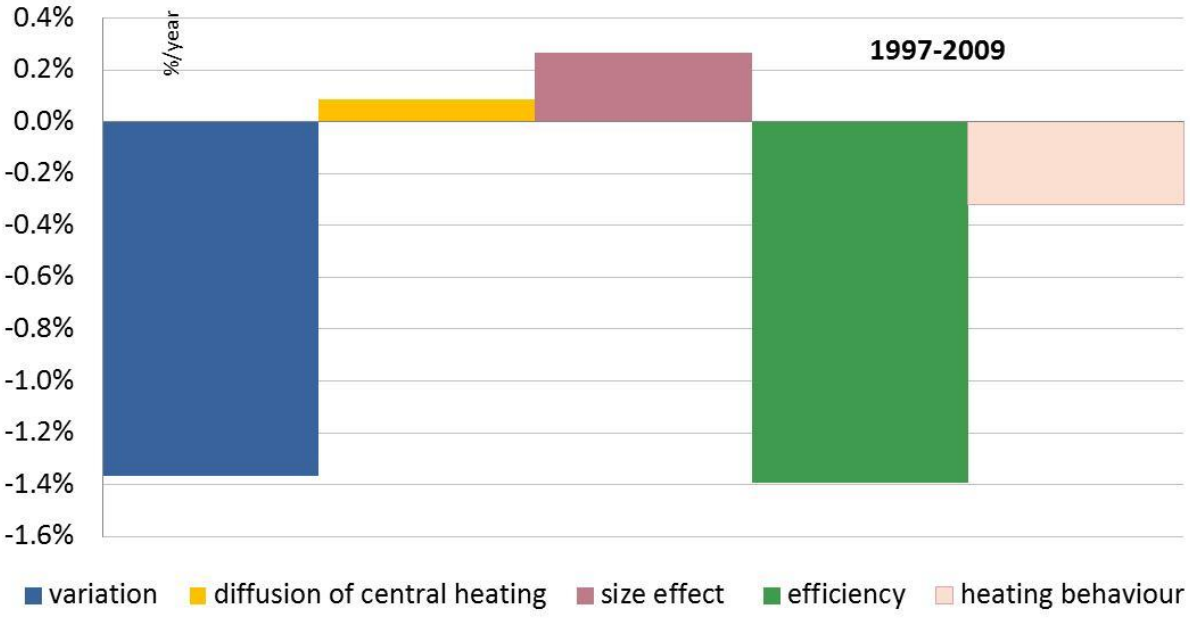
Source: Odyssee

[40]The impact of fuel substitution on the energy use per m^2 was calculated as the difference in the annual variation of the final and useful energy use per m^2. The useful energy consumption is calculated by multiplying the final energy consumption of each fuel by its average energy efficiency. In order to harmonize countries' comparison, the same values of heating efficiencies are used in Odyssee, based on data used by the Danish Energy Authority (DEA) in Denmark, the only European country to publish energy consumption statistics in useful energy (see Annex).

One fourth of the efficiency increase offset by comfort

Energy efficiency progress contributed to decrease the space heating consumption per dwelling by 1.4%/year on average for the EU since 1997 (and 1.2%/year since 1990). Larger dwellings and the diffusion of central heating in the south of Europe have offset the equivalent of 25% of these energy efficiency gains (they contributed to increase the consumption respectively by 0.3% and 0.1%/year on average) (Figure 26). Heating behaviour had a significant impact at EU level on space heating consumption (-0.3%/year) since 1997.

Figure 26: EU decomposition of change in heating energy use per dwelling



Source: Odyssee

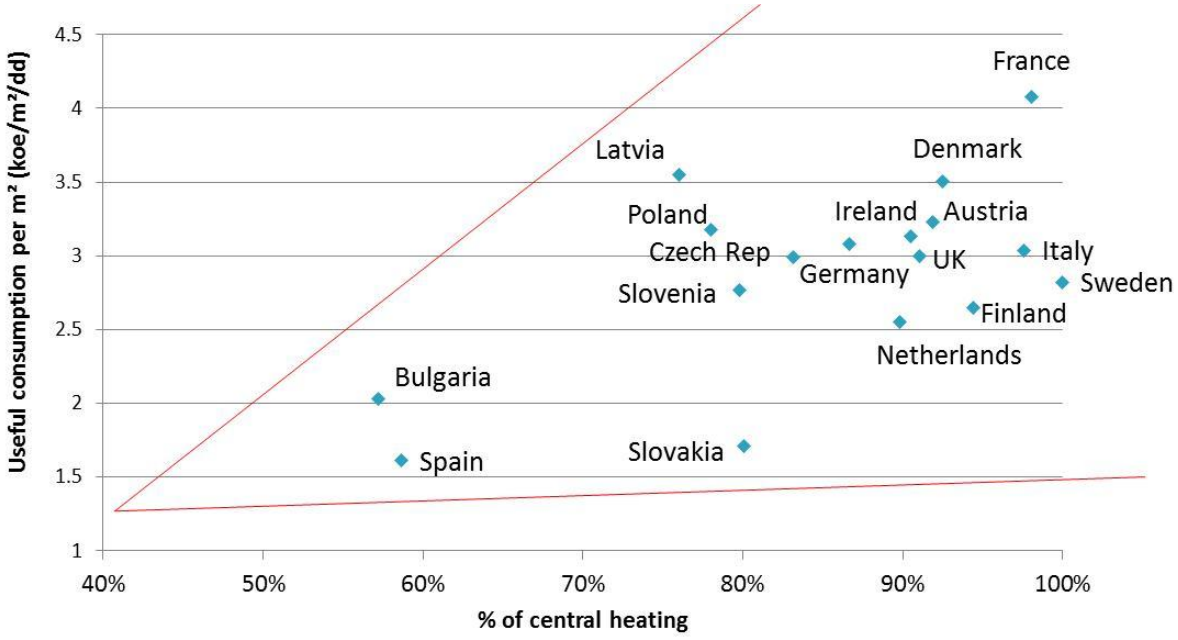
Benchmarking of heating consumption

Comparison of heating energy use per dwelling should take into account countries specificities in terms of climate, dwelling size and fuel mix. Thus, in Odyssee, the comparison is based on an indicator of useful energy consumption (to adjust for differences in the energy mix and thus in efficiency), per m² (to adjust for differences in dwelling size) and degree-days (to correct for differences in climate). The comparison should also take into account the level of heating comfort, captured, as explained above by the penetration of central heating: countries, like Spain or Bulgaria, with a much lower diffusion of central heating will have, all other things being equal, a level of consumption lower than countries with most dwellings equipped with central heating, as the level of comfort is not the same.

The specific useful space heating consumption per m² and degree-day of The Netherlands, the country with the best performance among countries with a large diffusion of central heating, is 40% lower than for France, the least efficient country (Figure 27). Finland, Denmark and Sweden are 30% more efficient than France.

A recent study published by ADEME[41] tries to understand why France has lower space heating energy performances than the best practices in The Netherlands (Box 3).

Figure 27: Energy use for space heating per m2 and degree days[42].



Source: Odyssee

Box 3: Comparison of space heating performance of France and The Netherlands

The dwelling stock structure between individual and collective dwellings influence countries energy performance, since an individual dwelling consumes on average more energy per m² than a collective dwelling, and the share of individual and collective dwellings is substantially different from one country to another. However, the lower share of collective dwellings in The Netherlands is offset by the fact that single family dwellings are mainly composed of semi-detached houses (60% against 20% in France of the housing total).The structure of occupation (owner versus renter), the average age of building stock are not significantly different and do not explain the performance difference.

The large diffusion of condensing boilers in the Netherlands (68 % of dwellings) significantly impacts the heating efficiency, and therefore the specific consumption in useful energy.

Without data on the thermal retrofitting of existing dwellings, the report assessed by modelling the relative impacts of new dwelling penetration and of substitution of energy and space heating equipment, and by difference with the overall trend observed, the impact of the existing dwelling stock retrofitting since 1980. In the Netherlands, efforts to improve energy efficiency in existing dwellings occurred during the 80's thanks to very active policies, in particular the national program for the insulation of existing dwellings that concerned 2.5 million dwellings from 1978 to 1987. While the energy performance of the Netherlands was 9% lower than France in 1980, it became rapidly more efficient as early as 1986. In addition, The Netherlands implemented more thermal regulations than France, and enforced more rigorous specific consumption norms for new dwellings than in France.

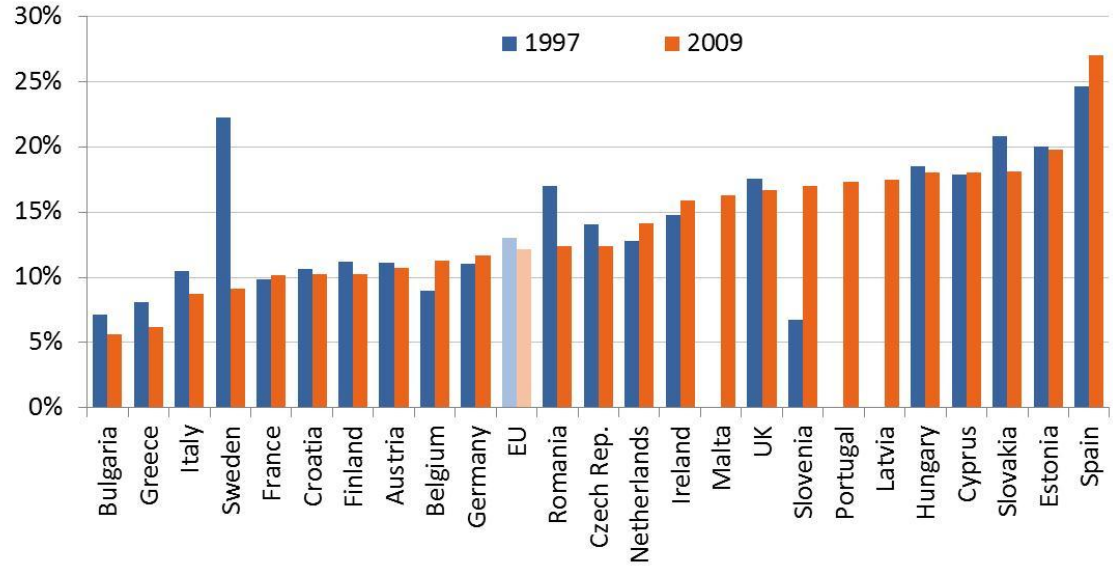
[41] "Quantitative evaluation of explanatory factors of the lower energy efficiency performance of France for space heating compared to European benchmarks", ADEME, 2011 http://www.odyssee-indicators.org/publications/PDF/English-final-report-french-dwelling-efficiency.pdf

[42] The comparison only makes sense for countries with similar level of central heating penetration, i.e. with similar level of comfort.

4.2. Water heating

Water heating represents around 13% of the household consumption in 2009 at EU level and its share had slightly decreased since 1997 (-1 point) (Figure 28).

Figure 28: Share of water heating in household energy consumption[43]

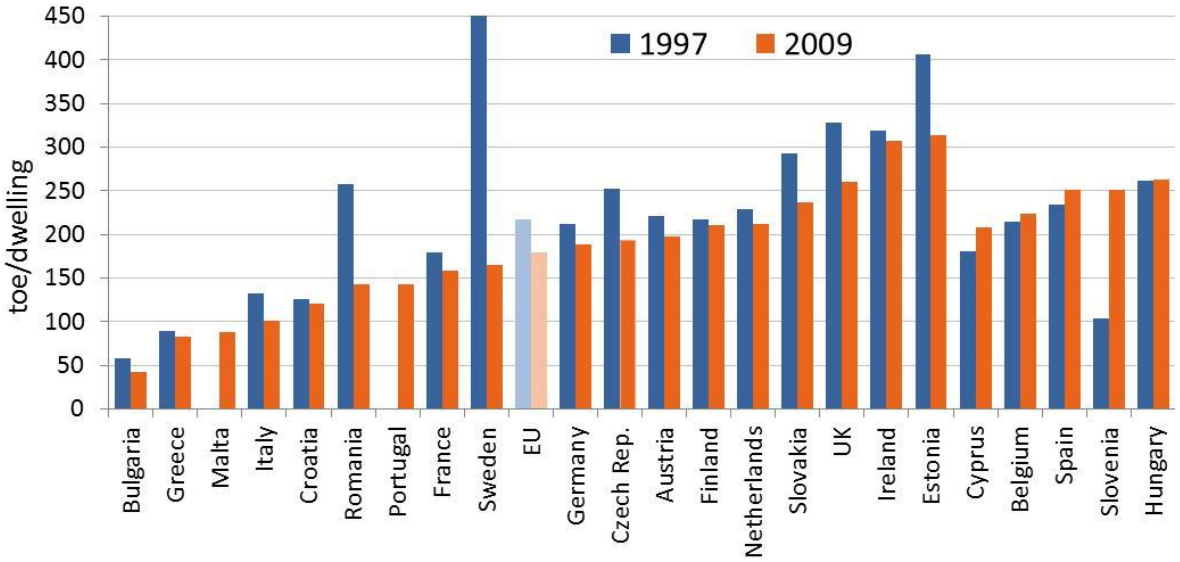


Source: Odyssee

Energy consumption for water heating per dwelling tends to decrease in most countries since 1997 (-1.6%/year since 1997) except in 5 countries, Cyprus, Belgium, Spain, Slovenia and Hungary.

[43] 2008 for Spain, Romania and Slovenia.

Figure 29: Water heating consumption per dwelling[44]



Source: Odyssee

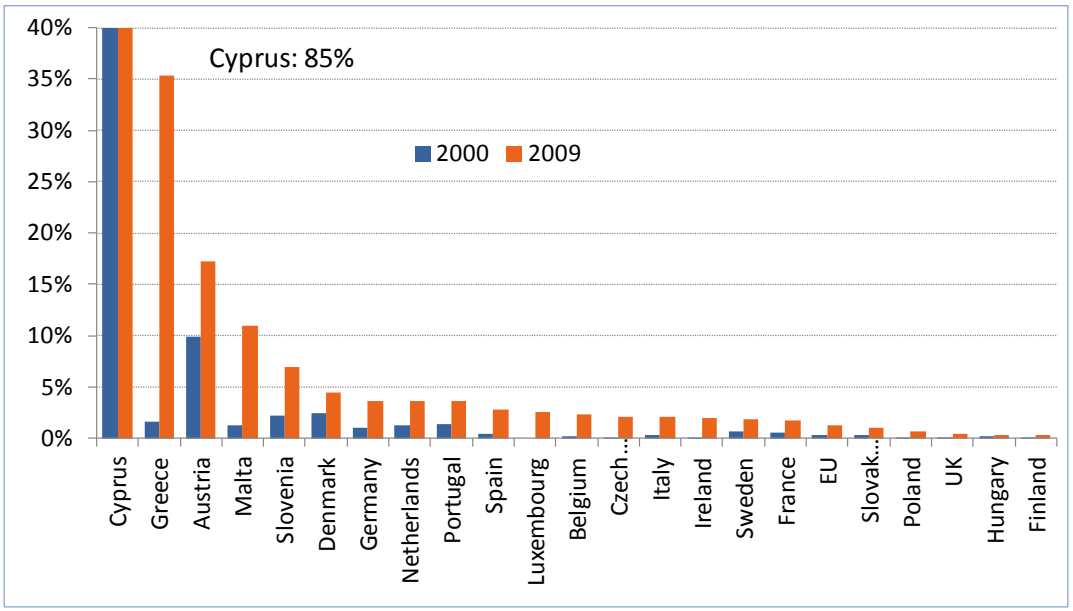
Solar energy is promoted in many countries as a substitute for conventional energy currently used to produce hot water. Solar water heaters represent a good economical and environmental solution to save commercial energies, especially in southern countries with a good solar radiation. The question is how much energy savings the diffusion of solar energy will generate. The answer is not simple and will depend on the conventions used. If we consider the impact on the household energy consumption statistics, as given by Eurostat, the diffusion of solar does not really result in significant energy savings as it appears as a substitution of conventional fuel with solar energy: the only savings come from the fact that one kWh of solar replaces more than one kWh of conventional energy, the difference depending on the efficiency of the replaced water heaters[45]. These savings are measured from the reduction in the average amount of final energy used for water heating[46]. In national evaluations or in the Energy Services Directive, solar water heaters are considered as an energy saving technology and all the contribution of solar is accounted for as energy saving and thus the saving is much larger[47].

Large diffusion in southern countries and Austria

About 85% of dwellings have solar heaters in Cyprus, 35% in Greece, 17% in Austria, and 11% in Malta (Figure 30). The larger progression is observed in Greece (+ 15 points), followed by Malta and Austria (+9).

[44] 2008 for Spain, Romania and Slovenia.
[45] The exact value depends on the fuel that is substituted and the technology previously used to produce hot water; the value is lower if solar replaced hot water produced from an old boiler: the range can be 60-90% and much above if heat pump is considered.
[46] Given the small magnitude of the savings so far and the uncertainty of existing data on the energy used for water heating, this evaluation may not be meaningful.
[47] This is the case for the measurement of savings linked to solar water heaters in national white certificate schemes. Savings are in a range of 500-1000 kWh/m2 depending on the country.

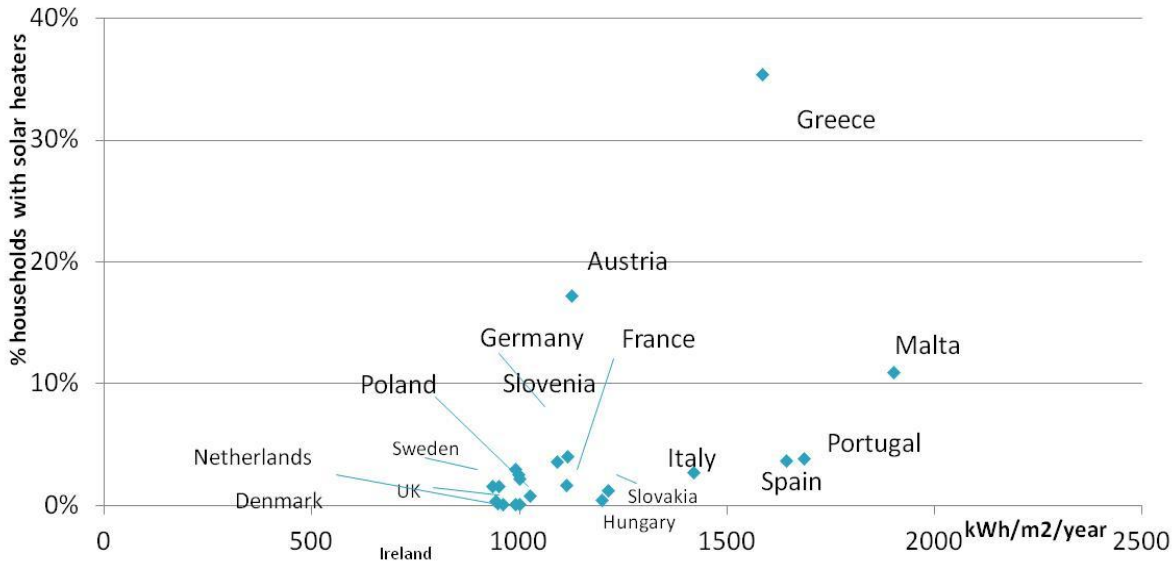
Figure 30: Diffusion of solar water heaters: % of dwellings of solar water heaters



Source: Odyssee

Austria is the benchmark for most countries with medium solar radiation (24% of dwellings equipped in 2009) (Figure 31).. In most EU countries there exist financial incentives (subsidies or soft loans) and fiscal incentives (tax credit) to encourage households to install solar water heaters in their dwellings and even more recently regulations making mandatory the installation of solar heaters in new construction (e.g. Spain and Portugal).

Figure 31: Diffusion of solar water heaters and solar radiation



Source: Odyssee

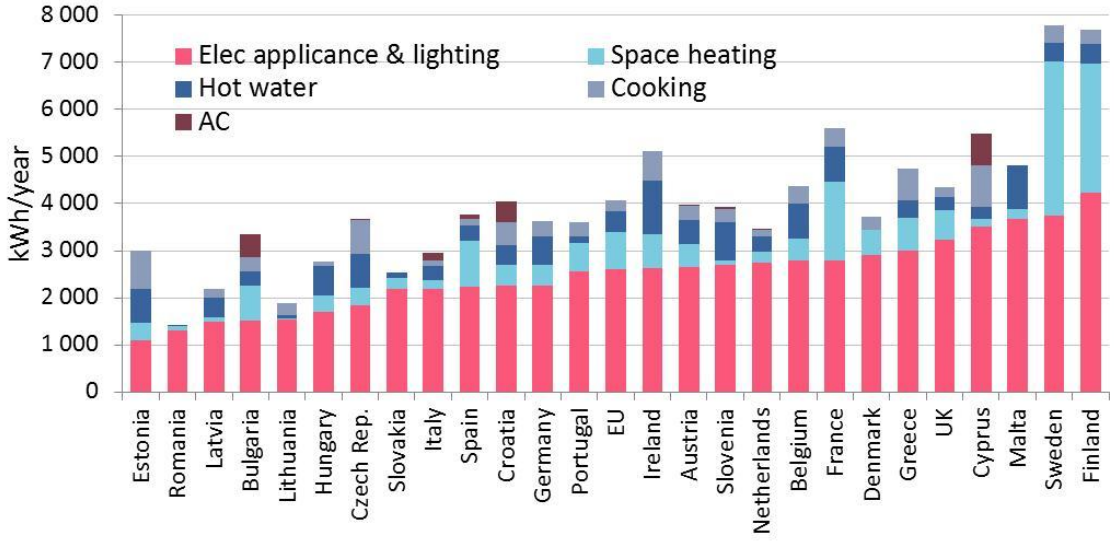
5. Electricity uses for appliances and lighting

5.1. Overall electricity uses

Large electricity consumption for some countries is due to space heating

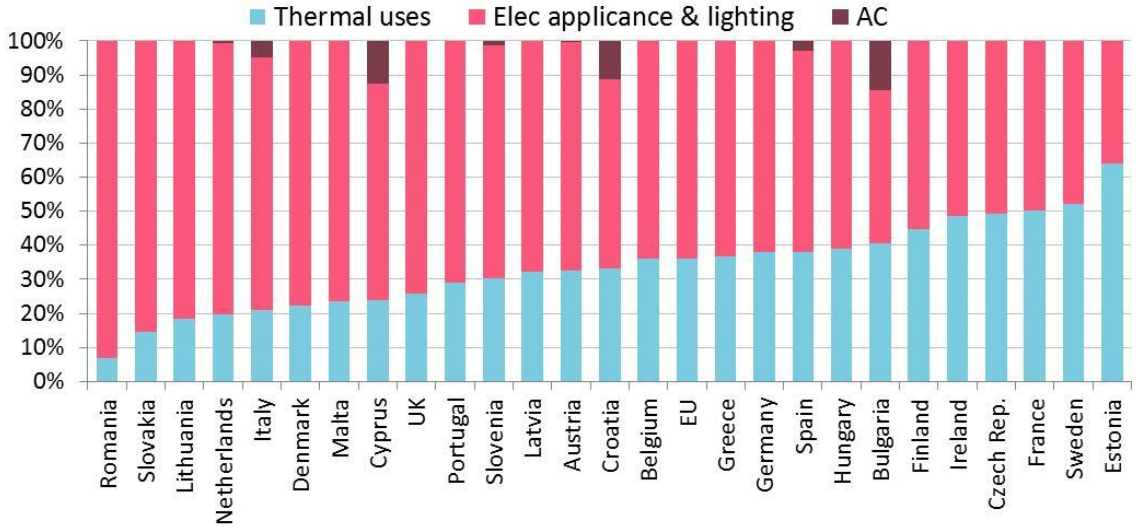
Average electricity use per household in EU is about 4000 kWh per year (Figure 32). For most countries the largest part of electricity use concerns electrical appliances and lighting; it is above 60% at EU level and in most countries (Figure 33). Electrical appliances include the large appliances (cold and washing appliances), IT equipment (TV, PC, etc.) and all other small appliances. Thermal uses are substantial (around or above 50%) in Norway, Estonia, Sweden, France, The Czech Rep. and Ireland The share of AC is still low in southern countries (10-15% in Cyprus, Croatia and Bulgaria).

Figure 32: Average electricity consumption per dwelling (2009[48])



Source: Odyssee

Figure 33: Electricity consumption per dwelling: share of thermal uses



Source: Odyssee

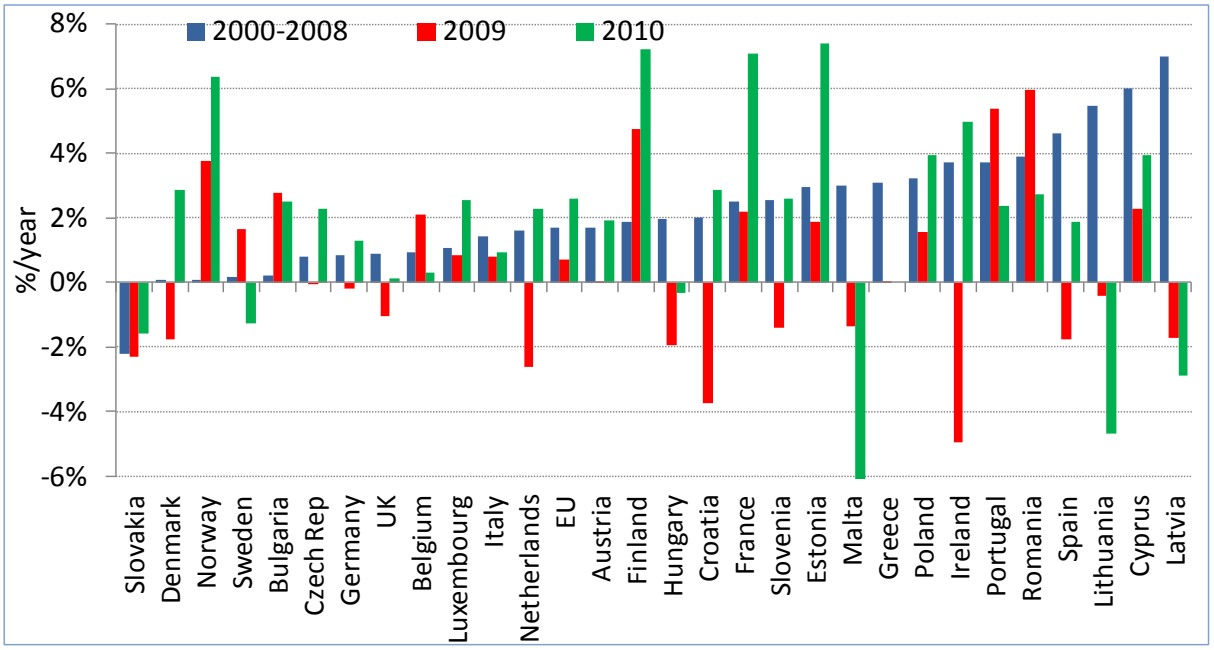
[48]Total for Norway: 16000 kWh. 2008 for Spain, Romania and Slovenia; 2007 for Lithuania.

Largest growth in electricity use in southern and new member countries

Electricity consumption increased at a rate above 2%/year in half of the countries between 2000 and 2008 (1.7%/year for the EU average) (Figure 34). The progression was particularly rapid in 5 countries, above 4%/year, of which 3 southern countries (Greece, Spain and Cyprus), because of the diffusion of AC, and 2 Baltic countries (Estonia and Latvia), because of a high economic growth and a catch up in household appliances ownership. On the contrary, this consumption decreased in Slovakia or had a very low progression in Norway, Denmark, Sweden and Bulgaria, which is partly due to substitution of electricity with fuels for thermal uses.

There is a strong impact of the 2009 crisis in 20 countries and at EU level, with a sharp decrease of the electricity consumption in 12 countries. In 2010 electricity consumption continues decreasing in 5 countries only.

Figure 34: Trends in household electricity consumption

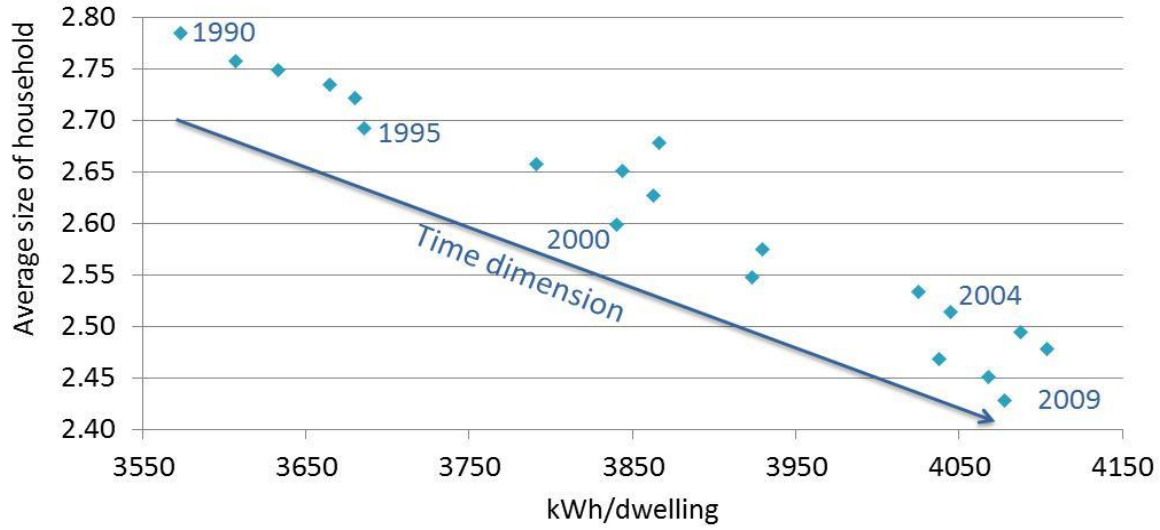


Source: Odyssee

Growth of electricity use per household is mitigated by smaller households

There is a negative correlation between the size of household and the electricity consumption per dwelling (Figure 35). With a constant size of households (2.8 persons per dwelling in 1990), the growth in electricity use per household between 1990 and 2009 would have been around 0.1%/year instead of an observed increase of 0.7%/year.

Figure 35: Average size of household and electric consumption/dwelling (EU level)



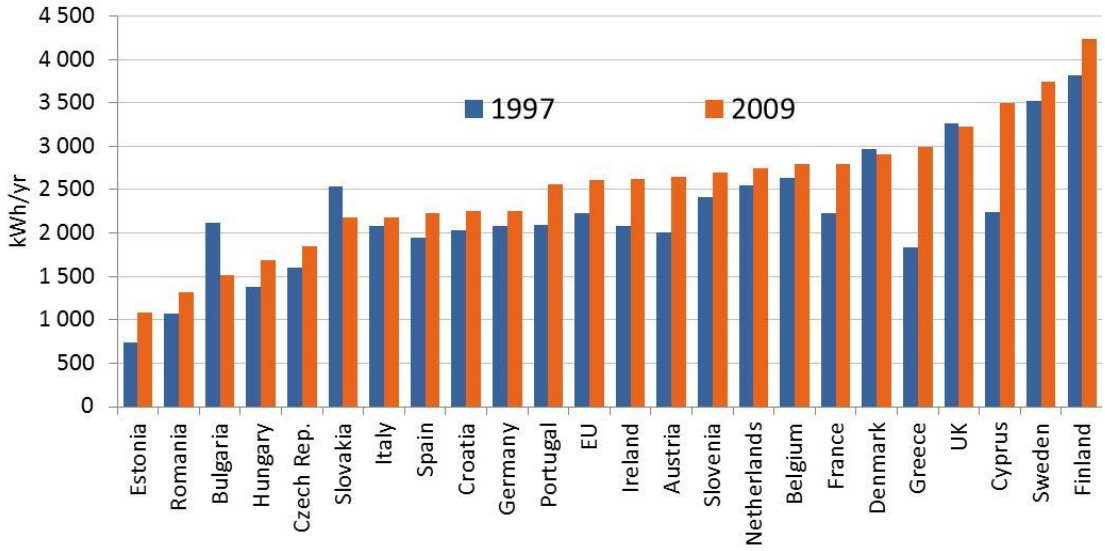
Source: Odyssee

5.2. Electrical appliances and lighting

Large differences in the unit consumption for electrical appliances and lighting

Among EU countries there are significant discrepancies in the electricity consumption for electrical appliances[49] and lighting: in a range from 1000 kWh (Estonia, Romania) to 4000 kWh (Finland, Sweden) (Figure 36).

Figure 36: Electricity consumption per dwelling for electrical appliances & lighting



Source: Odyssee

[49]Electrical appliances include large cold and washing appliances, IT equipment and other appliances.

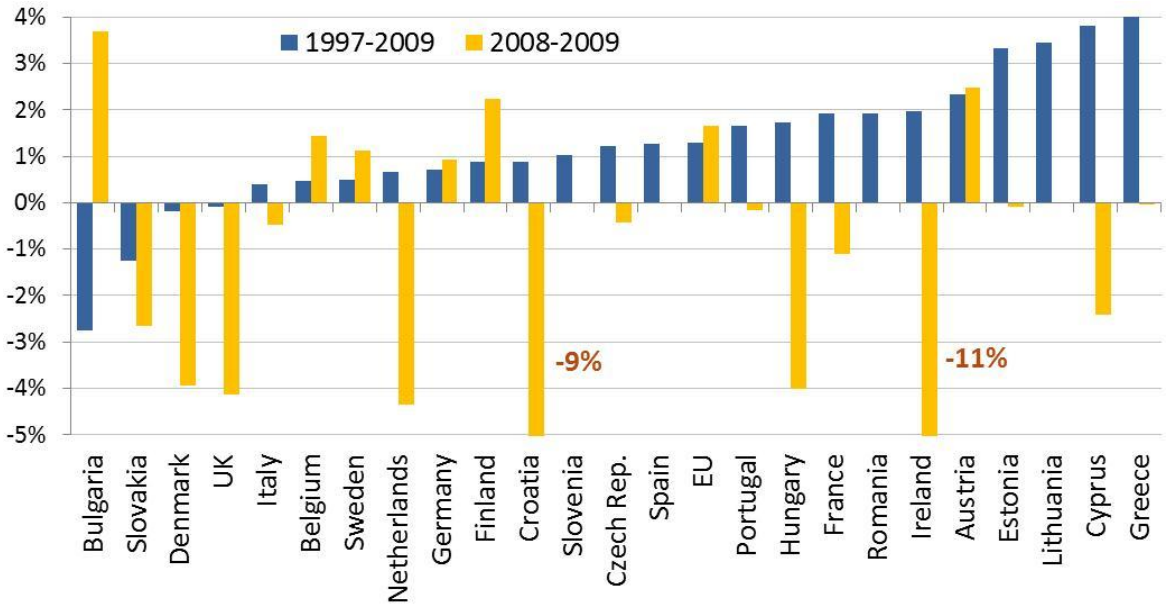
Different trends for the consumption per household for electrical appliances and lighting, and strong impact of the crisis

At EU level, the unit consumption for electrical appliances and lighting increased by 1.7%/year since 1997 (Figure 37) with a very unequal progression across countries:

- decreasing trends for Bulgaria and Slovakia, countries with a rather low consumption level (about 2000 kWh) as well as for Denmark and UK, countries with higher consumption level (about 3000 kWh);
- moderate progression in Sweden and Germany, countries with an already high electricity use;
- rapid growth in southern countries, such as Cyprus and Greece.

During the 2009 crisis, the consumption for electrical appliances and lighting has substantially decreased in some countries, by around 10% in Ireland and Croatia and around 4% in Denmark, UK, The Netherlands and Hungary.

Figure 37: Trends in electricity use per household for appliances & lighting[50]



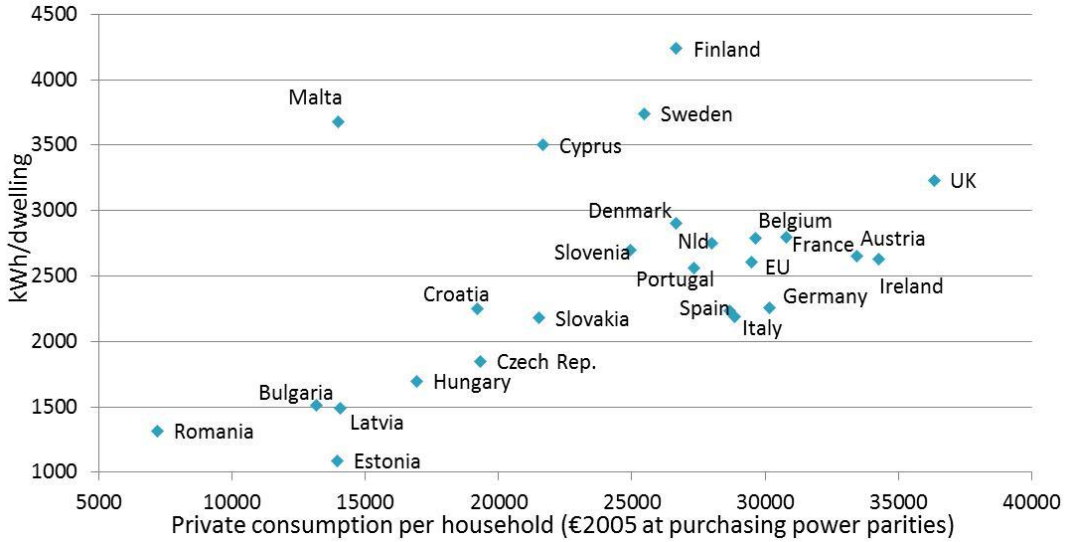
Source: Odyssee

[50] 1997-2008 for Spain, Slovenia, and Romania; 1997-2007 for Lithuania

Electricity consumption is not well correlated with income

Electricity use for electrical appliances and lighting is correlated with the average income (Figure 38). However for a given level of income, there exist huge disparities reflecting differences in lifestyles and in equipment efficiency.

Figure 38: Appliance electricity use versus income, per household (PPP, 2009)

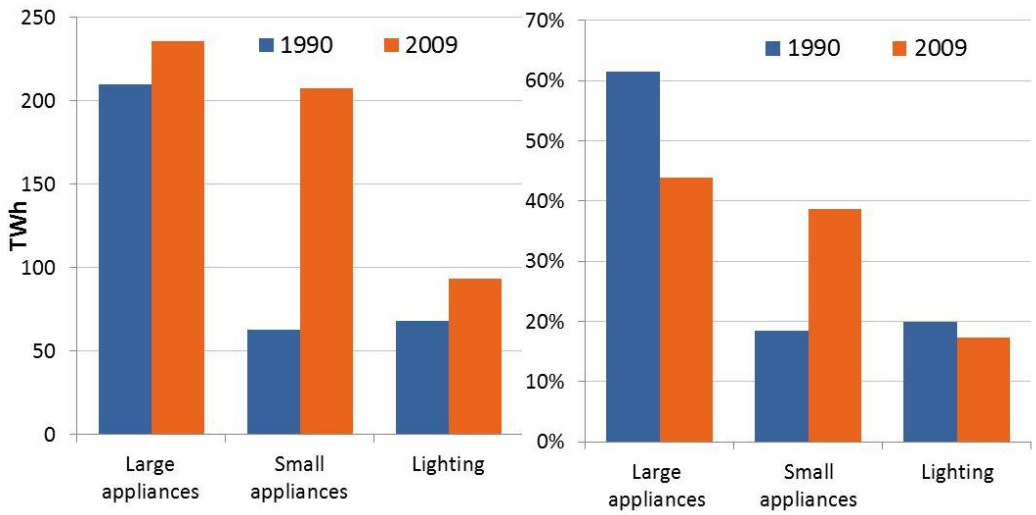


Source: Odyssee

Growth of electricity consumption concentrated on small appliances

The breakdown of appliances consumption shows that the strongest growth is recorded for small appliances (6.5%/year on average) (Figure 39). These small appliances more than doubled their share of the total consumption for appliances and lighting, from 18% in 1990 to 39% in 2009. The consumption of large appliances recorded a moderate growth and their share declined from 62% to 44 %. Lighting has a rather stable share (about 20%).

Figure 39: Change in total electricity use for large/small appliances and lighting



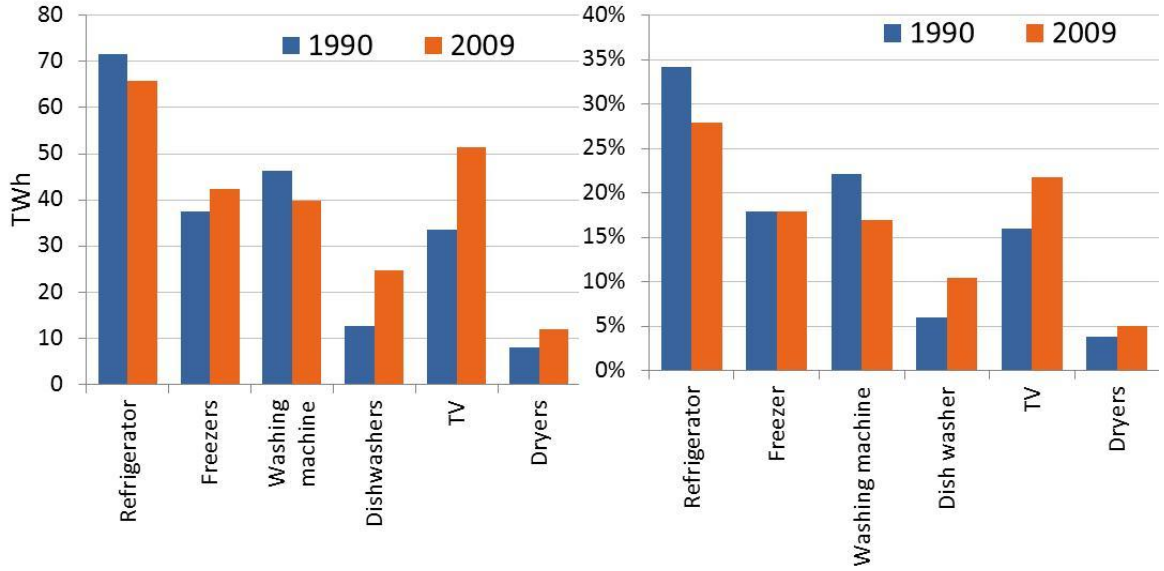
Source: Odyssee

5.3. Large appliances

Clothes dryers and dishwashers drive electricity consumption upwards

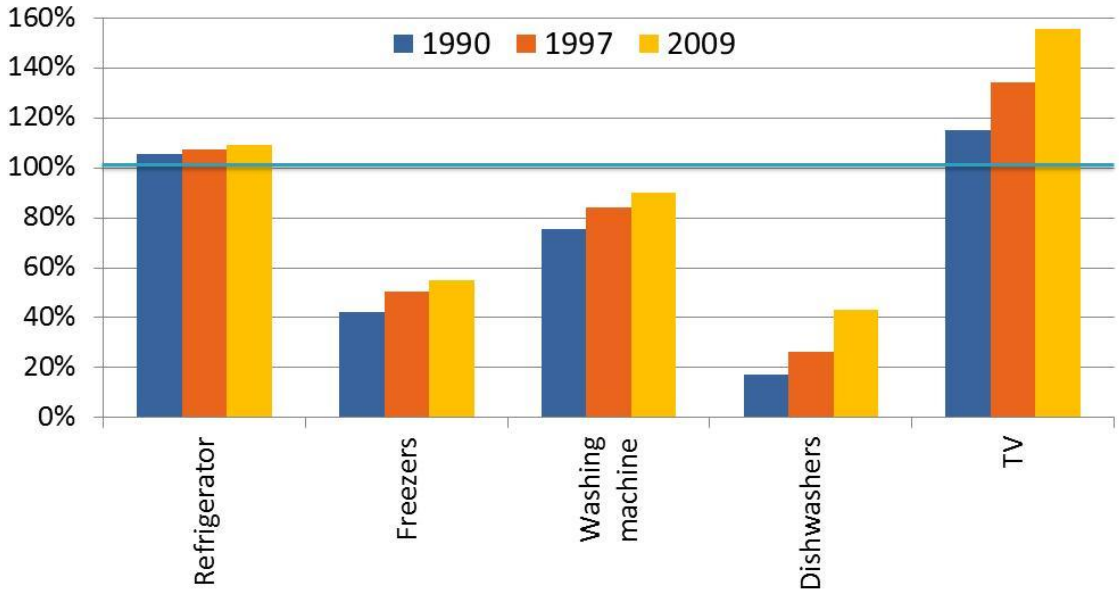
Figure 40 shows the development of electricity consumption by type of large appliances. Televisions, clothe dryers and dish washers increased their share over the period 1990-2009, due to higher penetration rates (Figure 41). Refrigerators and washing machines registered a decline, mainly due to substantial electricity savings and ownership saturation.

Figure 40: Shares of large appliances in total appliance electricity use



Source: Odyssee

Figure 41: Penetration rate of appliances per household (EU)

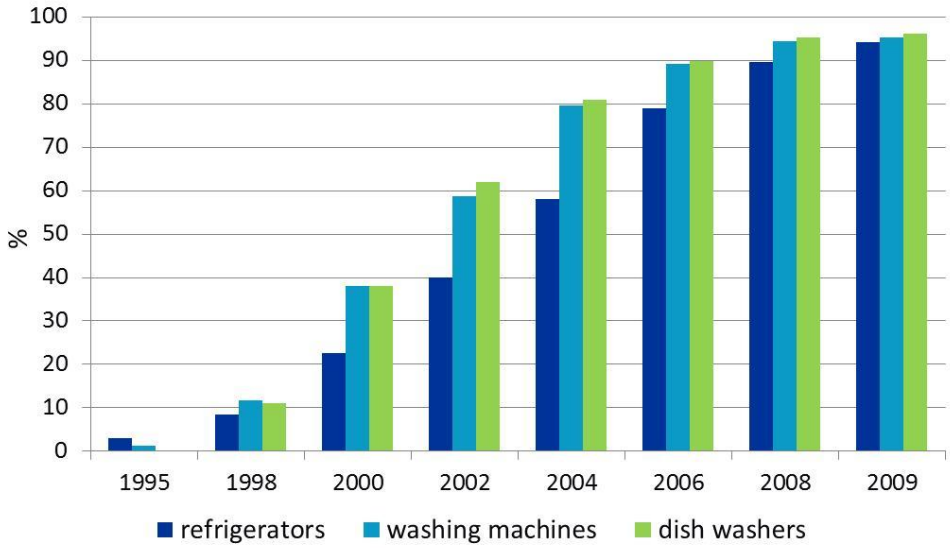


Source: Odyssee

Increased penetration of efficient new appliances

The diffusion of new efficient large appliances had a direct impact on their average efficiency: in 2009, almost 90% of refrigerators, washing machines and dishwasher's sales corresponded to an efficiency class equal or above A class (Figure 42).

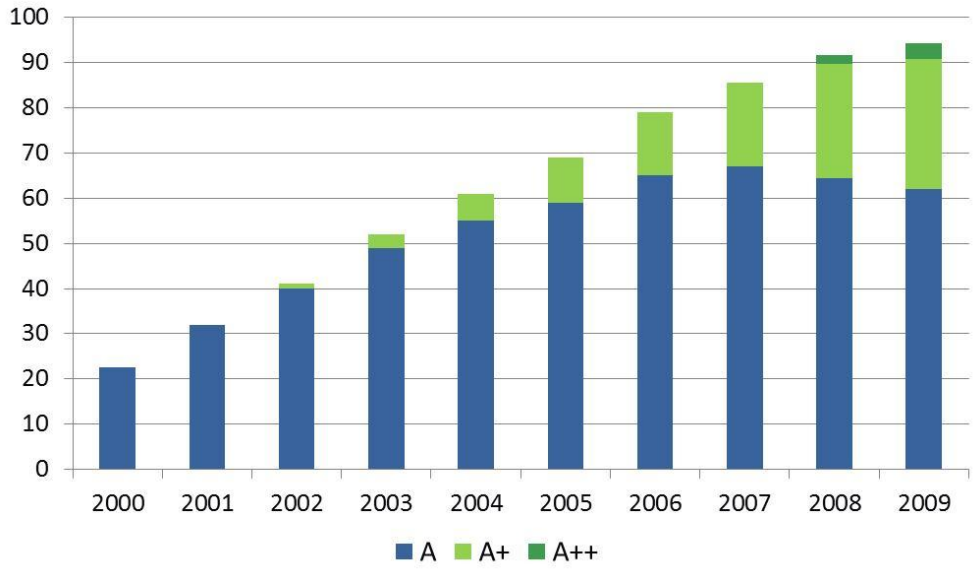
Figure 42: EU Market share of label A, A+, A++ for cold and washing appliances



Source: GfK, EEDAL

On average, about 30% of new refrigerators sold in 2009 were in the highest efficiency class (labels A+ or A++) compared to less than 10% in 2005 (Figure 43). This share reached around 40% in The Netherlands and 45% in Germany in 2009.

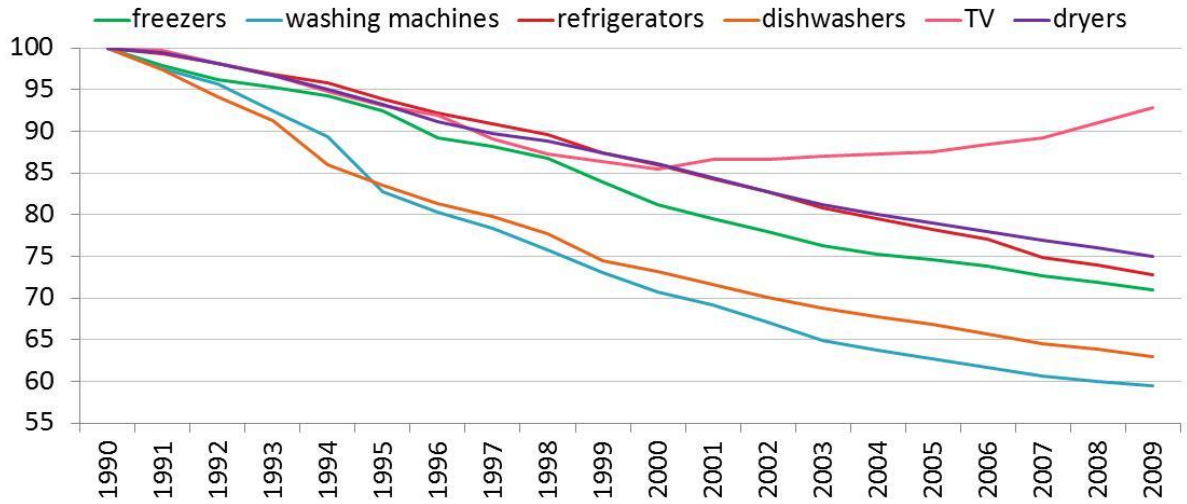
Figure 43: Market share of label A, A+ and A++ for refrigerators (EU-15)



Source: GfK, EEDAL

The specific consumption of all large appliances except TV has been decreasing steadily since 1990 (Figure 44): efficiency improvements have reached almost 40% for washing machines and dishwashers, and around 30% for freezers, refrigerators and dryers. These improvements are linked to the diffusion of new appliances (Figure 42 and Figure 43). Concerning TV, the specific consumption decreased steadily until 2000, and then it increased until today (due to the diffusion of larger TVs).

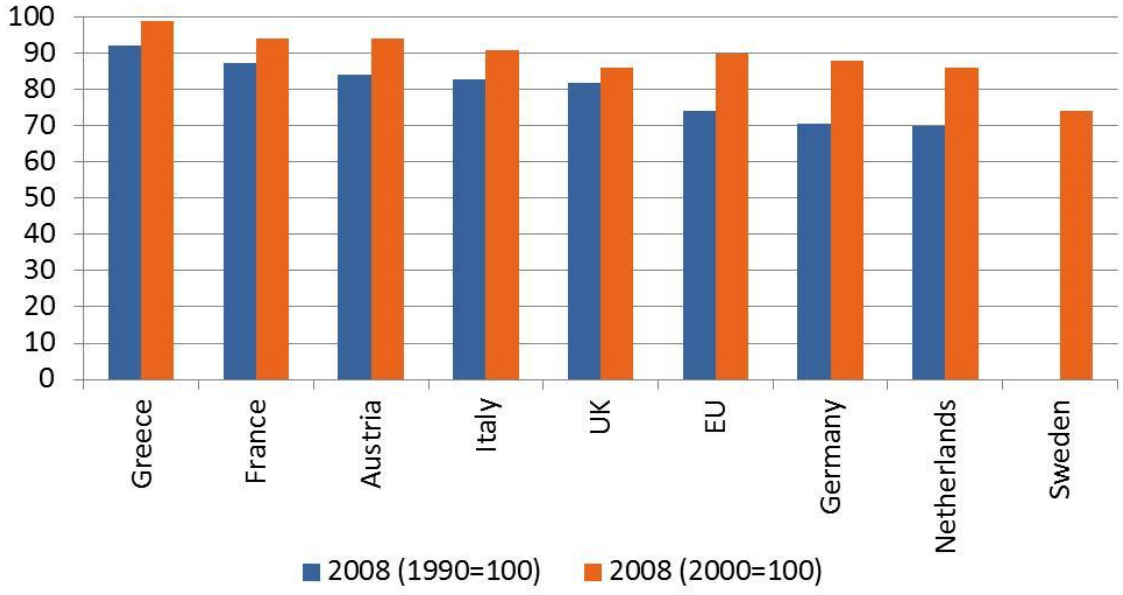
Figure 44: Evolution of specific consumption of large appliances (base 100=1990)



Source: Odyssee

Large appliances are on average 25% more efficient than in 1990, with some countries registering very strong progress (Germany, Sweden, the Netherlands): ~2%/year. There is a slight reduction in the progress achieved since 2000 (1.6%/year over 1990-2008 and 1.3%/year since 2000 at EU level).

Figure 45: Energy efficiency trends for large appliances (ODEX)

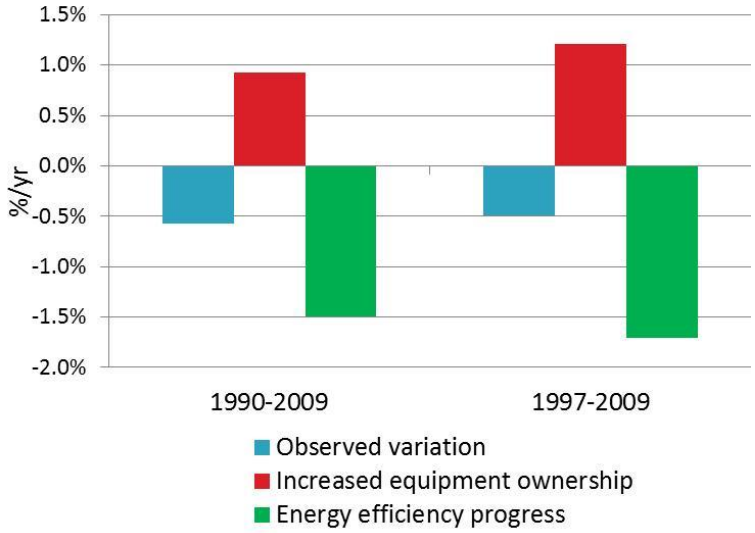


Source: Odyssee

Energy efficiency of large appliances is offset by more appliances

The decomposition of the observed change in electricity use by large appliances shows that almost all energy efficiency gains over the last years have been offset by an increase in equipment ownership (Figure 46). As a result, electricity consumption per household for large appliances is only slightly lower in 2009 than in 1997.

Figure 46: Decomposition of change in electricity use of large appliances

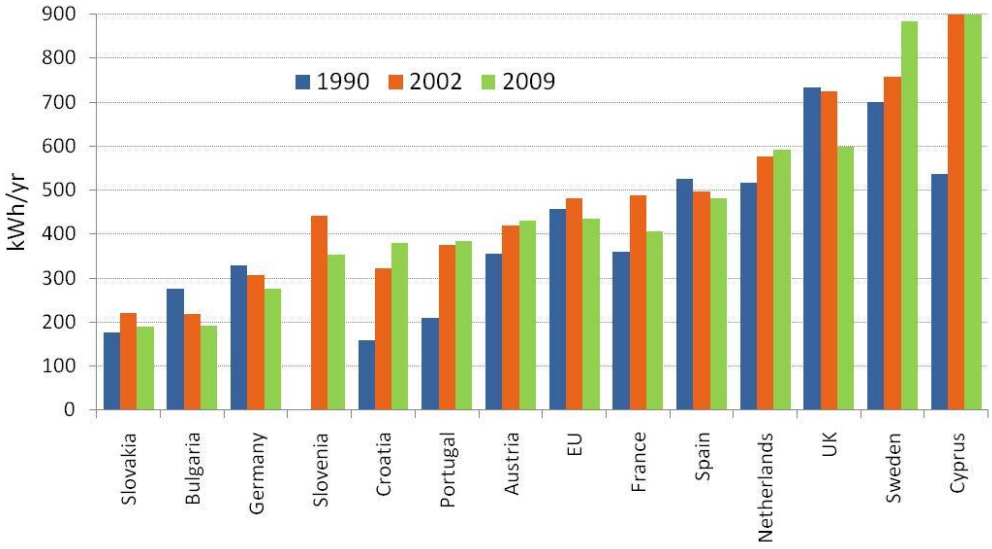


Source: Odyssee

5.4. Lighting

Electricity consumption for lighting represented 11% of total household electricity in 2009 at EU level, with a stable share over time. The lighting consumption per dwelling has slightly increased at EU level until 2002 (1.4%/year between 1990 and 2002). From 2002, it started to decrease by 0.2%/year. It is now around 450 kWh/year (Figure 47). The unit consumption for lighting is quite diverse among EU countries: from 200 kWh/year for Slovakia and Bulgaria up to 900 kWh/year for Sweden. In more than half of the sample of countries, it is decreasing thanks to the diffusion of CFL.

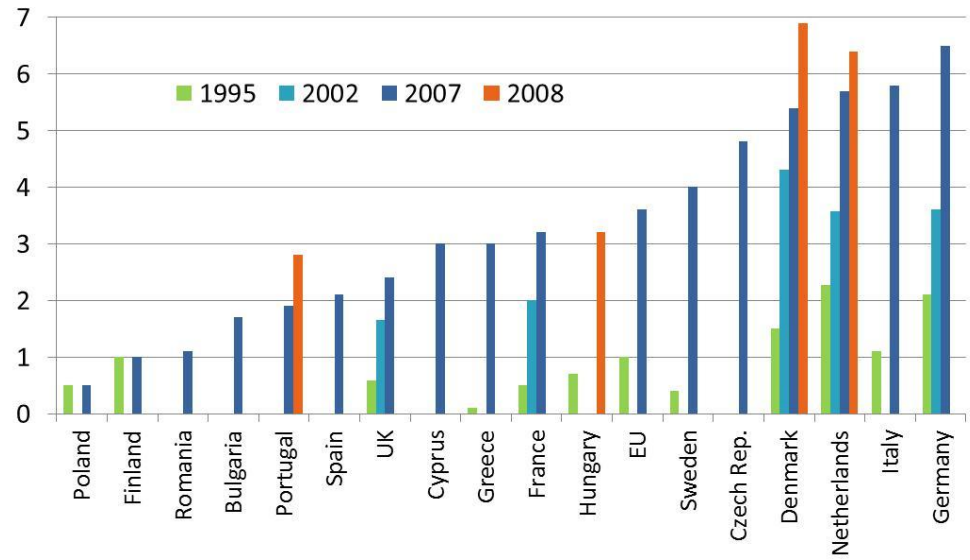
Figure 47: Electricity consumption per dwelling for lighting



Source: Odyssee

In countries with the largest diffusion of CFL (i.e. Denmark, Netherland and Germany), households have around seven CFL per dwelling on average.

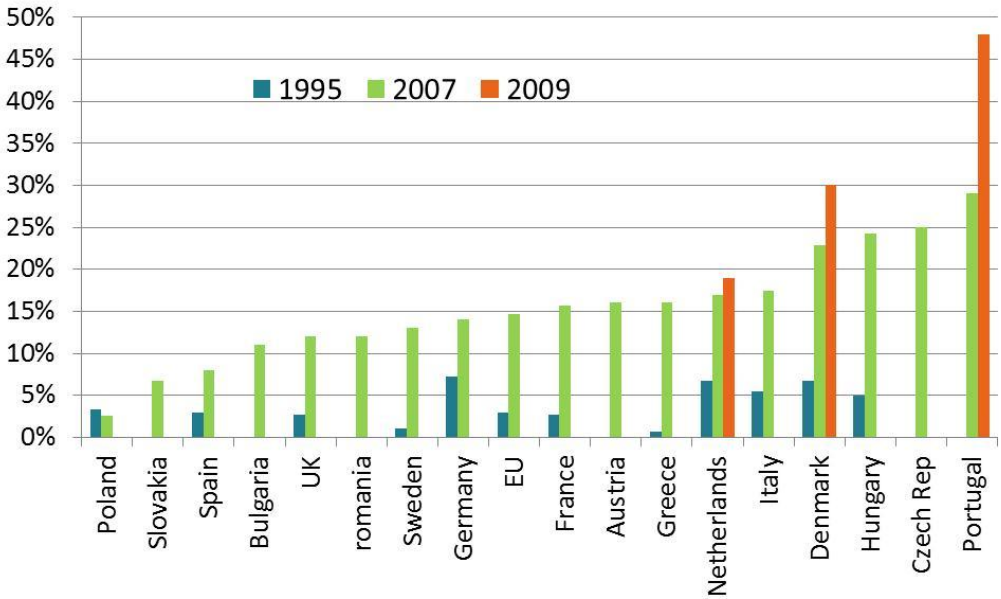
Figure 48: Diffusion of CFL lamps- number of lamps per household



Source: Compiled by Enerdata from various sources, of which Odyssee, Remodece, JRC-Ispra

The share of CFL in the total number of lamps depends on the number of CFL per household and the total number of lighting points (Figure 49). There is a high penetration of CFL lamps in Portugal, Czech Republic and Hungary (above 20% of CFL in total number of lamps).

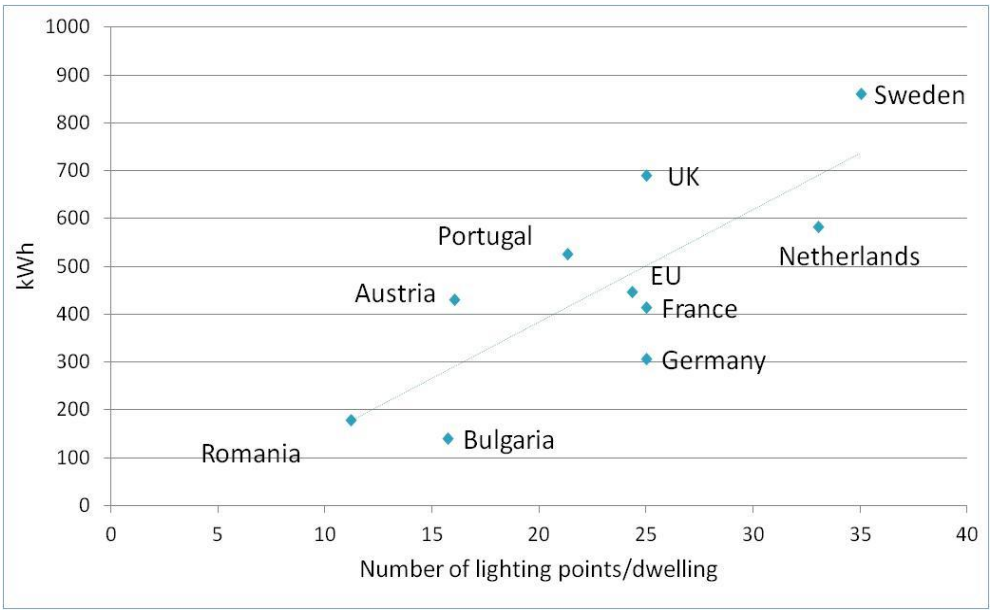
Figure 49: Diffusion of CFL lamps –share of CFL in total number of lamps



Source: Compiled by Enerdata from various sources, of which Odyssee, Remodece, JRC-Ispra

The level of consumption depends not only on the lamps efficiency (i.e. the penetration of CFL), but also on the number of lighting points per dwelling (Figure 50).

Figure 50: Electricity consumption per dwelling for lighting

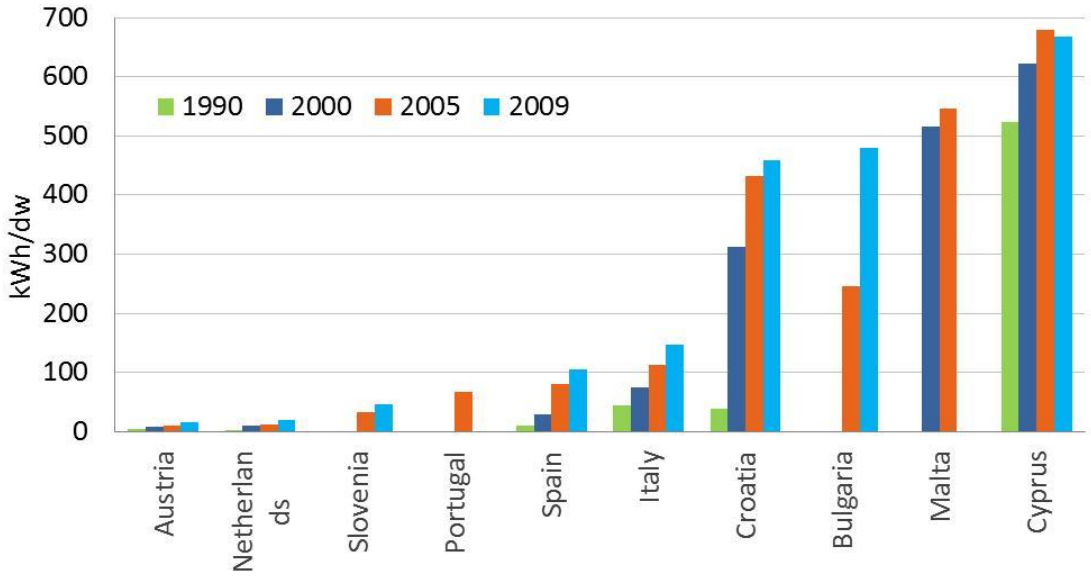


Source: compiled by Enerdata from various sources, of which Remodece, JRC-Ispra

5.5. Air conditioning

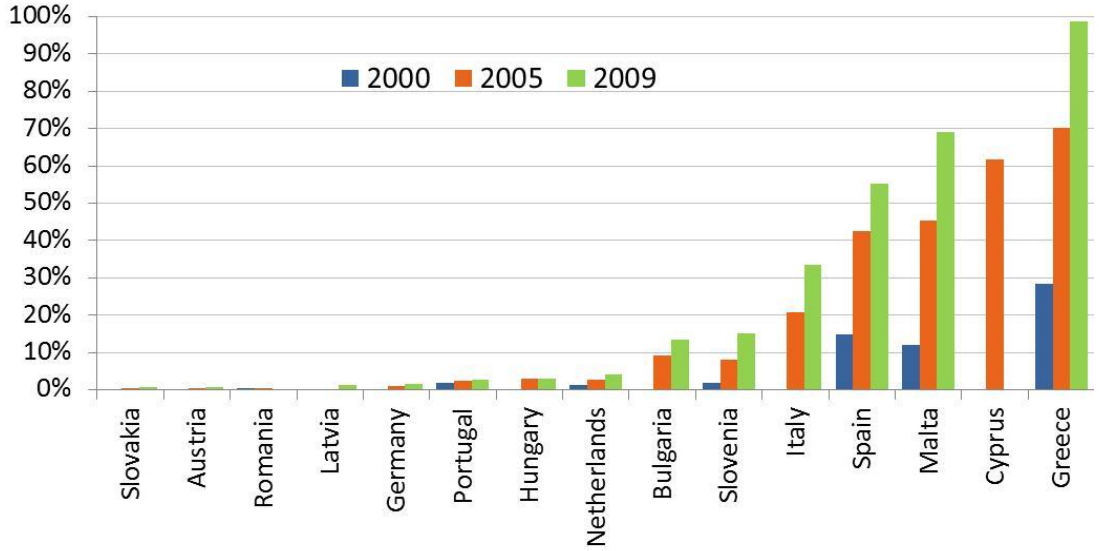
Air conditioning only represents 10% of total electricity consumption in countries with the largest penetration of air conditioning (Cyprus, Malta and Bulgaria) (Figure 33). The average consumption per dwelling for this end-use is increasing as air conditioning is spreading in Southern countries (Italy, Spain, Malta, Cyprus and Greece) (Figure 51, Figure 52).

Figure 51: Consumption per dwelling for air conditioning



Source: Odyssee

Figure 52: Ownership rate of air conditioning

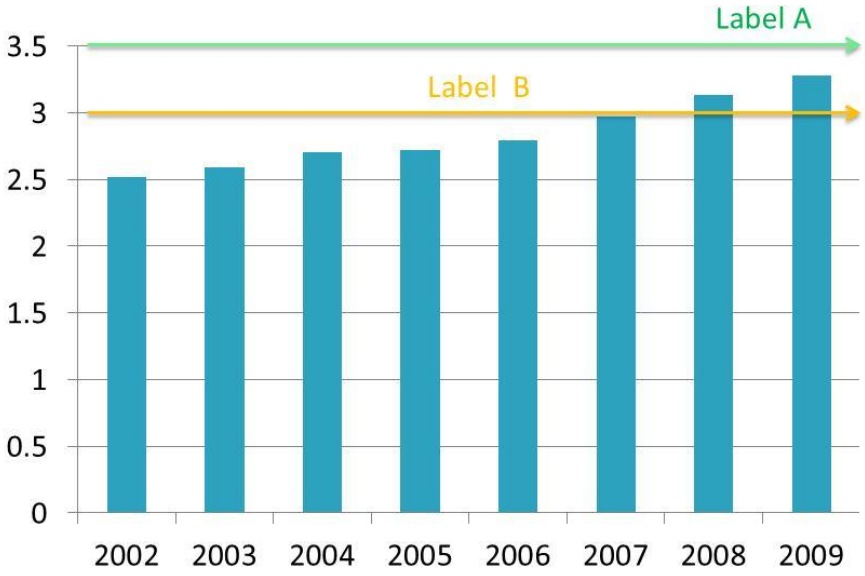


Source: Odyssee

The efficiency of new air conditioners is improving rapidly

Labelling exists since 2002 (Figure 53). New air conditioners are 30% more efficient in 2009 than in 2002 in the EU; this is mainly due to the increasing share of units with variable speed drive (from 4% in 2002 to 50% in 2009)[51]. Thanks to these efficiency improvements, the electricity consumption growth was lower than the progression in air conditioning ownership.

Figure 53: Efficiency of new air conditioners in the EU (EER[52])



Source: IEA, Mapping and Benchmarking, 2010[53]

[51] Almost 90% of new air conditioners are reverse cycles models (up from about 50% in 2002)
[52] EER: kW per kW
[53] Data from GFK; sales weighted; include split and multi-split (split about 95% of the market) ; products < 14kW

6. Energy efficiency and CO_2 emission trends for households

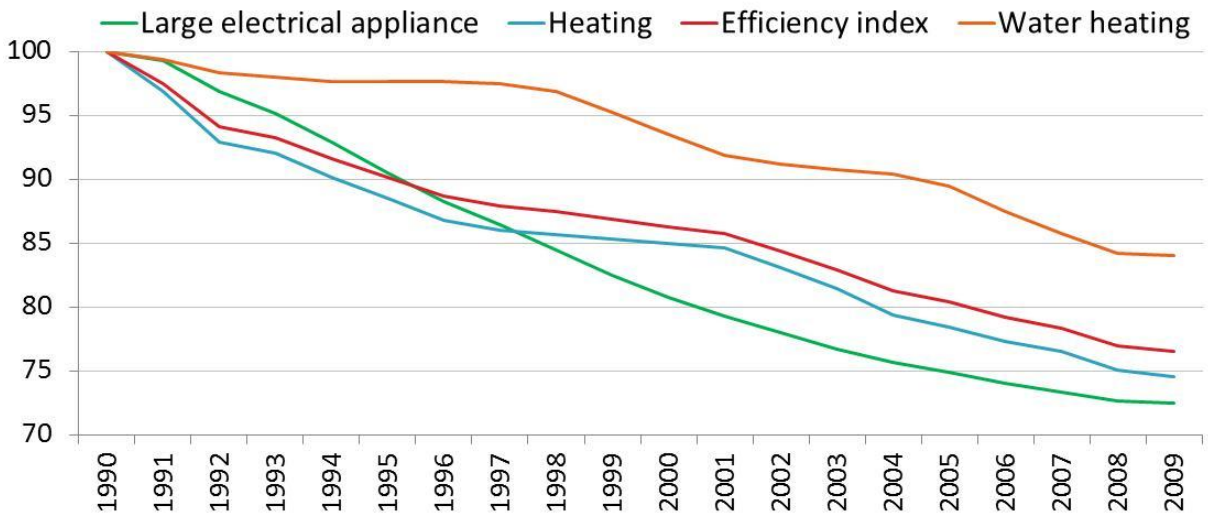
6.1. Energy efficiency and savings

The overall efficiency improvement is given by the so-called ODEX[54] which is calculated from the efficiency increase for a set of 8 end-uses and appliances.

Household energy efficiency has improved by 10% at EU level since 2000

The ODEX[55]for European households shows an improvement of almost 10% for the period 2000-2009 (or about 1.3%/year) and 24% since 1990 (or about 1.4%/year, Figure 54). The efficiency improvement for heating, hot water and large appliances reaches about 10% since 2000. Since 1990 heating and large appliances efficiency improvement reached 25% whereas it was only 15% for hot water. These energy savings are largely due to the deployment of technologies that reduce energy demand (e.g. double glazing, insulation), convert fuels more efficiently (e.g. high efficiency boilers) or use electricity more efficiently (e.g. labels A, A+ and A++).

Figure 54: Overall efficiency index ODEX of households for EU



Source: Odyssee

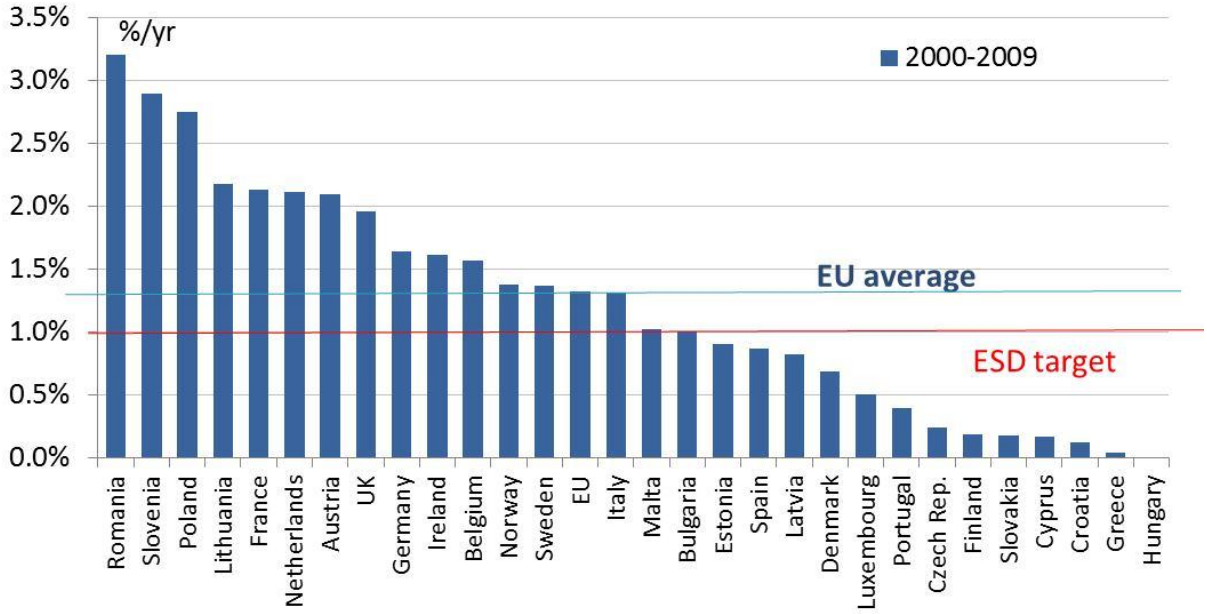
[54] ODEX is an index weighting the energy efficiency progress gains by end-uses/appliances measured from changes in specific consumption measure in different units: heating (toe/m2), water heating, cooking (toe/dwelling), refrigerators, freezers, washing machine, dishwashers and TV (kWh/year).
[55]The yearly figures for ODEX have been converted into three-year moving average values.

Some new member states show very high energy efficiency improvement

Yearly energy efficiency improvements are not homogeneous among European countries: the three EU countries with by far the highest efficiency improvement are Romania, Slovenia and Poland with above 2.5%/year, while Croatia, Greece and Hungary did not improve really their energy efficiency during the same period, i.e. less than 0.1%/year (Figure 55)[56]. Most other new Member States also do better than the EU-27 average improvement of 0.8%/year.

The historical improvement of energy efficiency for EU is now higher than the 1%/year requested in the Energy Services Directive (ESD) by the European Commission, and more than half of countries are above the ESD energy efficiency requirements.

Figure 55: Yearly energy efficiency improvement by country (2000-2009[57])



Source: Odyssee

6.2. Trends in CO2 emissions

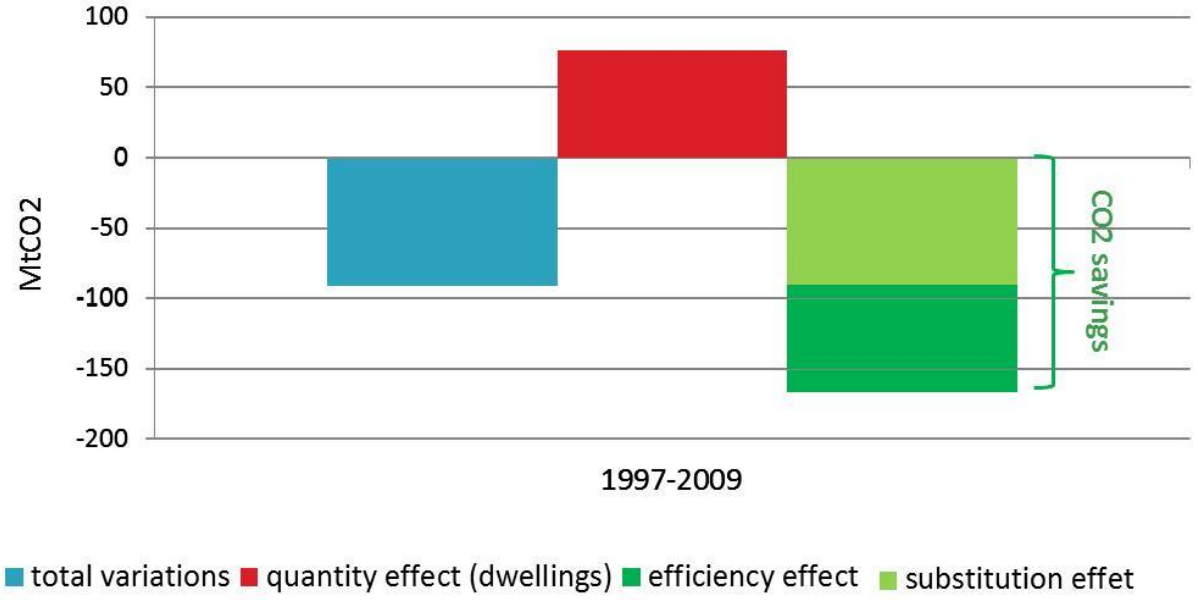
Energy savings and fuel switching reduced direct CO_2 emissions in the EU

In the period 1997-2009 emissions of EU households decreased by 91 Mt, from 503 to 413 Mt (- 18%)[58] (Figure 56). This result was achieved despite an increase in the stock of dwellings and in the number of appliances. These two developments would have implied, all other things being equal, an emission increase of about 76 Mt. The reduction in the level of emissions was made possible by efficiency improvements and substitution between energy

[56] Low performances may be due to the fact that it is difficult to separate out for the indicators available changes in lifestyle that contribute to increase consumption from energy efficiency gains.
[57] 2000-2008 for Spain, Luxembourg, Czech Rep, Romania, Slovakia, Slovenia and 2000-2007 for Lithuania.
[58] All the figures given here are not corrected for climate variations.

carriers, which contributed to reduce CO_2emissions by 167 Mt, equally split between energy efficiency and fuel substitutions. This large contribution of substitution (90 Mt) is due to switches to fuels with a lower CO_2 content (e.g. gas, heat and biomass) or to electricity, the emissions of which are not included in the household sector.

Figure 56: Decomposition of 1997-2009 variation in CO_2 emissions for EU



Source: Odyssee

7. Energy use in the tertiary sector

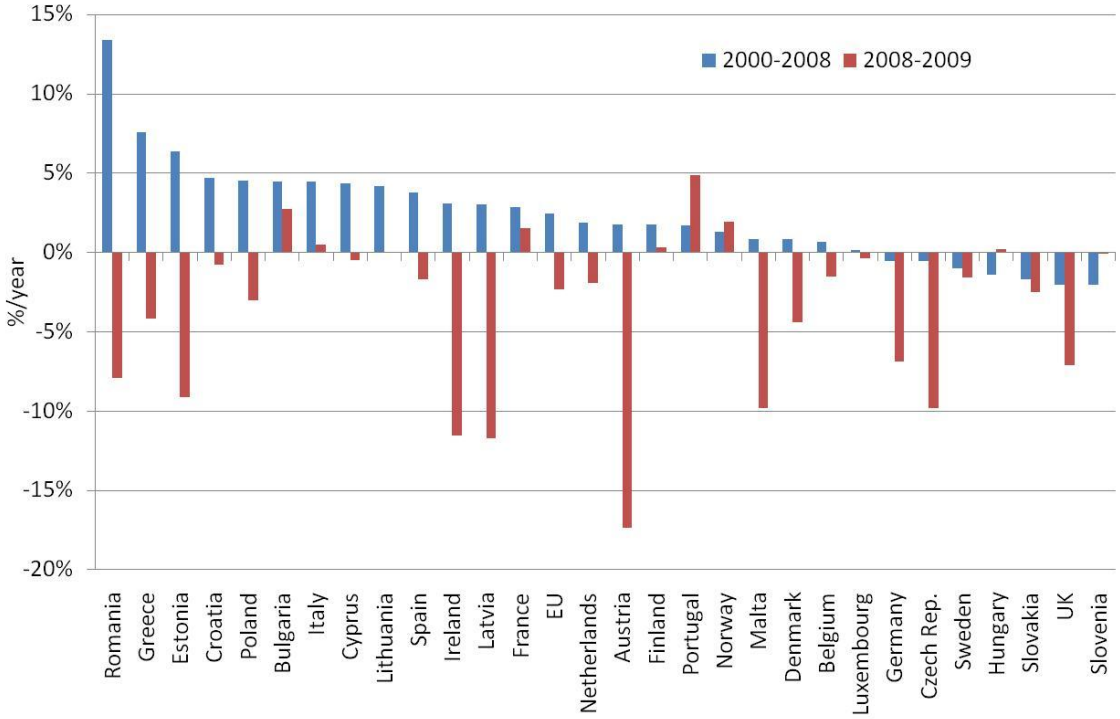
7.1. Energy consumption trends

The tertiary sector comprises energy users outside industry, agriculture, construction, households and transport, e.g. offices, shops and hospitals. A large part of energy consumption in the service sectors comprises energy used in public and private buildings. It also includes the energy used for public services, such as public lighting and water distribution.

No clear pattern for direction of energy consumption trend in countries

Energy consumption in the tertiary sector increased rather rapidly by 4%/year between 2000 and 2005 at EU level, and was rather stable until 2008. It then decreased by 2.3% in 2009 because of the economic downturn. However, no clear pattern emerges when looking at country level. Energy consumption increased in almost all countries in the period 2000-2008, at a rate in a range of 2 to 5%/year for most countries (Figure 57). A decrease can be observed for some EU-15 countries (e.g. UK, Germany and Sweden) but also for some new member states (e.g. Slovakia and Slovenia). Other new member states (e.g. Romania, Croatia and Bulgaria) show very high growth rates, but the same is true for some EU-15 countries (e.g. Greece). In 2009, because of the economic downturn, energy consumption decreased in almost all countries. Exceptions are Bulgaria, Italy, France, Finland, Portugal, Norway, Hungary and Slovenia.

Figure 57: Energy consumption trends in the tertiary sector

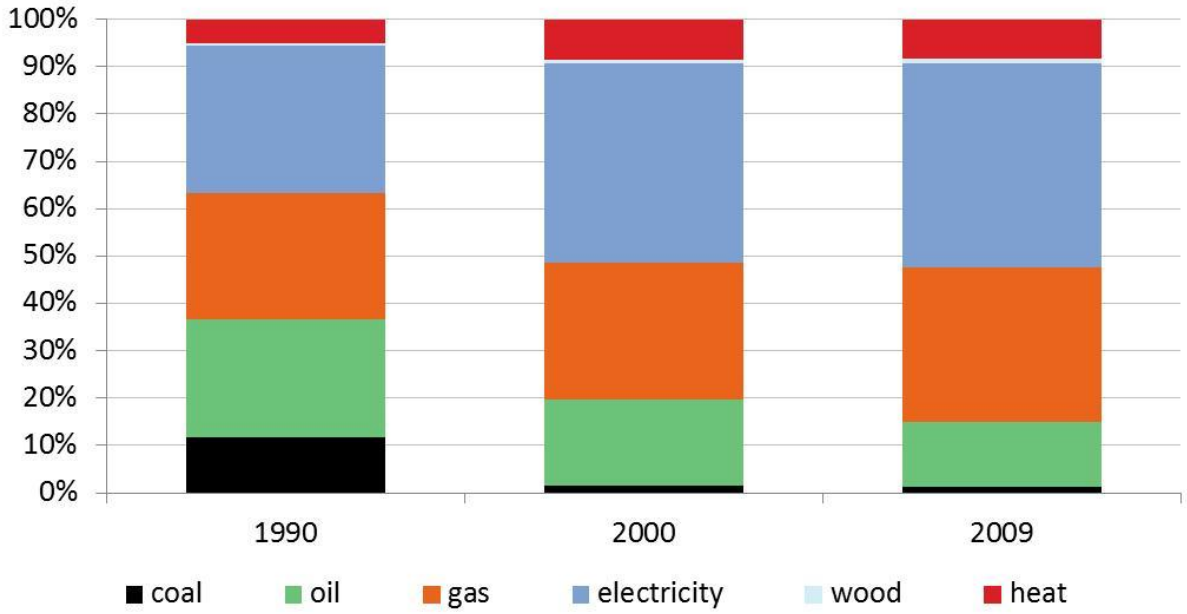


Source: Odyssee

Gas and electricity account for nearly 80% of energy consumption in services

The share of electricity has increased a lot due to the greater use of electricity, especially for information/communication technologies and air conditioning, from 31% in 1990 to 43% in 2009 at EU level (Figure 58).Gas met 33% of the energy consumption in 2009, up from 27% in 1990. On the other hand, the contribution of oil has decreased from 25% to 14% and coal has disappeared in most countries (Box 4).

Figure 58: Energy consumption by energy carrier for tertiary (EU)



Source: Odyssee (without climate correction)

Box 4: Countries with an extreme fuel mix and large changes for tertiary

Solid fuels: most countries hardly use solid fuels but their share remained significant in Poland (11%) and Slovakia (25%) in 2009.

Liquid fuels: in 2009, oil still accounted for about 20% of energy consumption in 7 countries; it even reached 49% in Slovenia and 29% in Ireland, because of limited gas grid. The oil share generally drops (by nearly 20% points for Luxembourg and Portugal), but a reversed change has occurred for Bulgaria.

Natural gas: the increase in gas market share stands out for Romania, from 24% in 2000 to 48% in 2009. Luxembourg and Latvia follow with about +10% points. The countries with gas resources show a large share (The Netherlands 54% and the UK 40% in 2009), but the largest share is found in Italy (58%), followed by Hungary and Luxembourg (50%).

Heat from district heating: large fractions are typically found around the Baltic Sea (25-35% in 2009). In Eastern European countries, the share has fallen most in Latvia (20% point) although it remained high (23% in 2009). The largest increase was observed in Austria (+15% points, up to 33% in 2009).

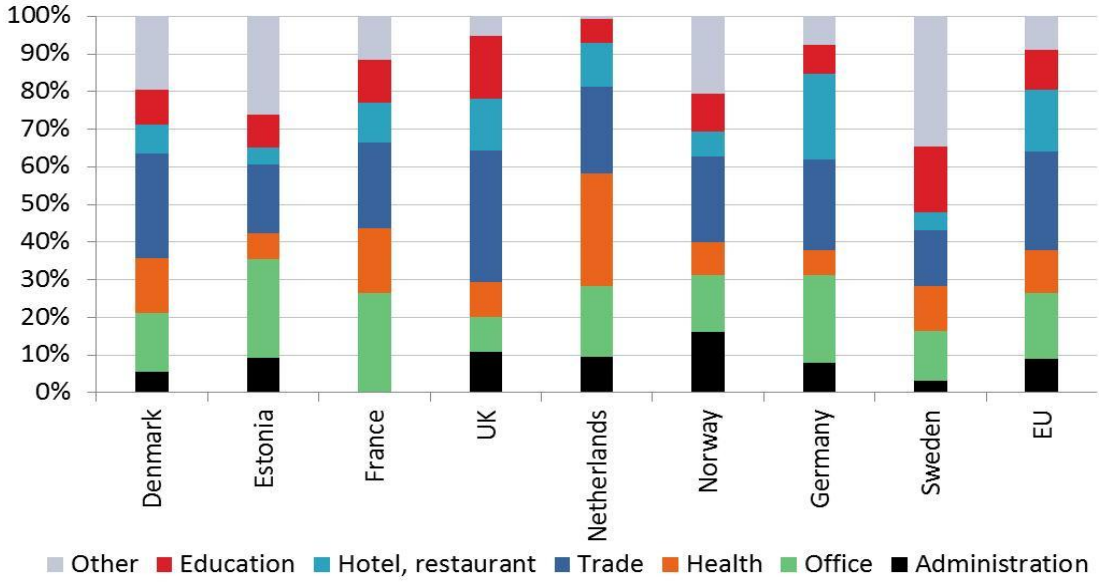
Wood/biomass: the largest share is found in Latvia (13% in 2009) followed by Hungary, Romania and France (6-7%).

Electricity: high shares are found in countries with air-conditioning uses (Greece, Cyprus, Malta, Spain and Portugal) or with a large share of hydro or nuclear electricity (Norway for hydro, Sweden and Bulgaria). Shares above 80% are found in Greece and Norway.

More than half of the energy is consumed in the trade sector and offices

The distribution of energy consumption by service sub-sector is quite homogeneous (Figure 59). The most important sectors are the trade sector and private and public offices, both with 26% of the total.

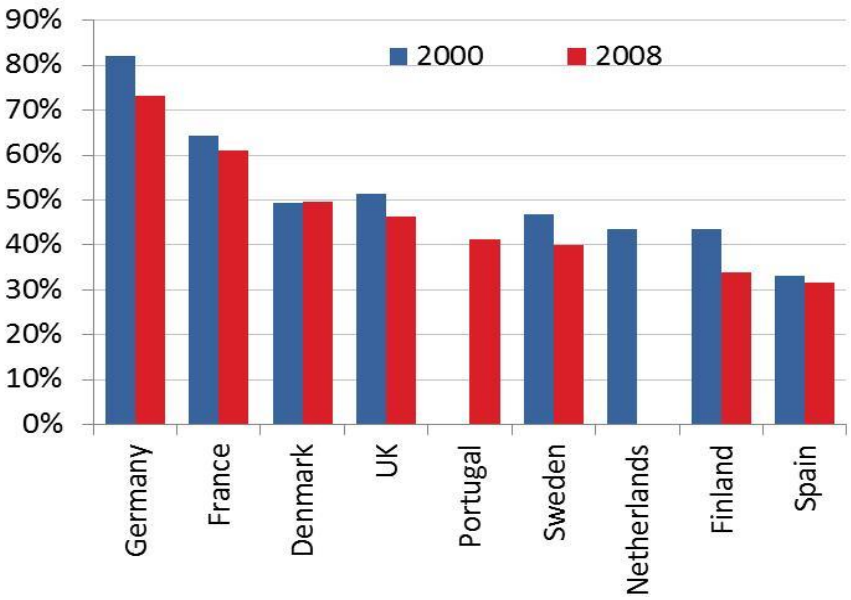
Figure 59: Energy consumption by subsector in services (2008)



Source: Odyssee

As in the household sector, space heating represents a high share in the total energy consumption of services (Figure 60). It accounts for more than 70% in Germany and for 60% in France. However, the share of space heating is decreasing over time (-10 points for Germany and Finland, -7 points for Sweden) thanks to energy efficiency improvements (insulation of buildings, efficiency of boilers, etc.) and because of high growth of specific electricity end-uses.

Figure 60: Share of space heating in services sector consumption

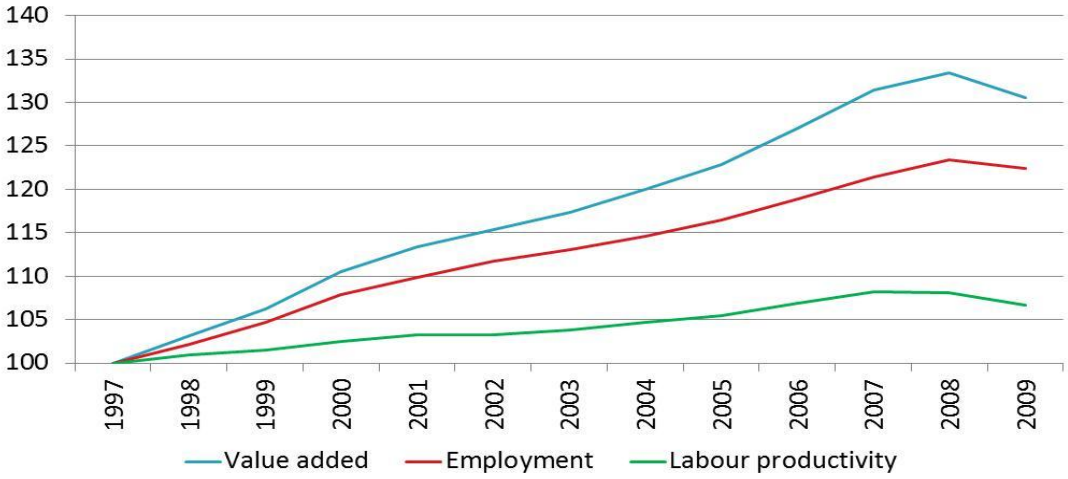


Source: Odyssee

7.2. Energy intensity and unit consumption

Two main drivers can be used to analyse trends in energy use: the value added[59] and employment[60]. Value added increased by almost 2.7%/year from 1997 to 2008 and employment by 1.9%/year (see Figure 61). The value added created per employee (labour productivity) thus increased by 0.7 %/year on average. For new member states labour productivity increased much faster (2.8%/year).

Figure 61: Value added, employment and labour productivity for tertiary (EU)



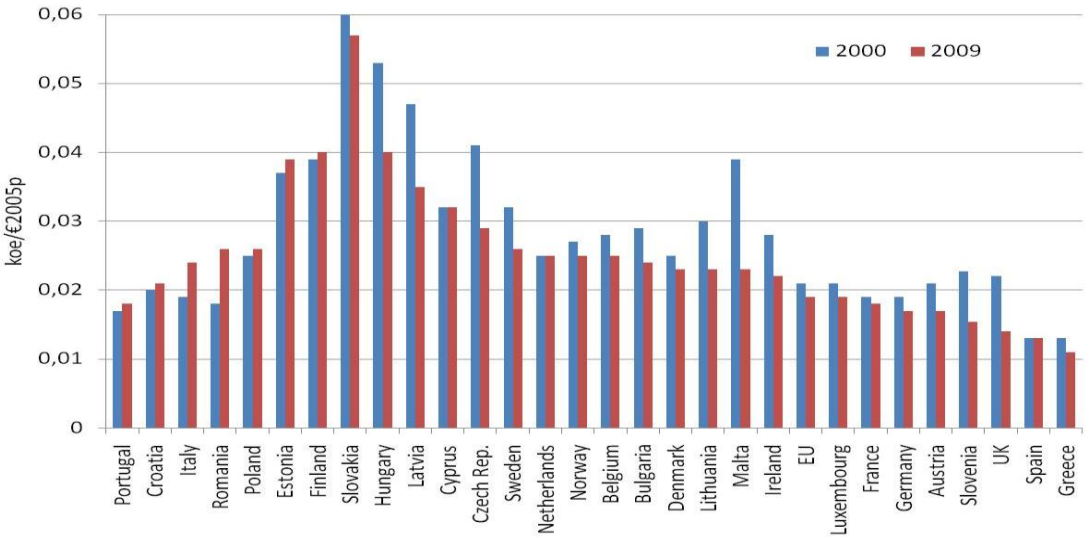
Source: Odyssee

[59] Value added in €2000
[60] Floor space is not used as driver, because few data are available, especially for new member states.

Eastern European countries usually show a large decrease in energy intensity

The energy intensities are generally decreasing with a few exceptions (Portugal, Croatia, Italy, Finland, Poland, Estonia and Romania) (Figure 62).Countries with high energy intensity in 2000 usually show a larger decrease in energy intensity, which tends to homogenise energy intensity levels.

Figure 62: Energy intensity of tertiary sector

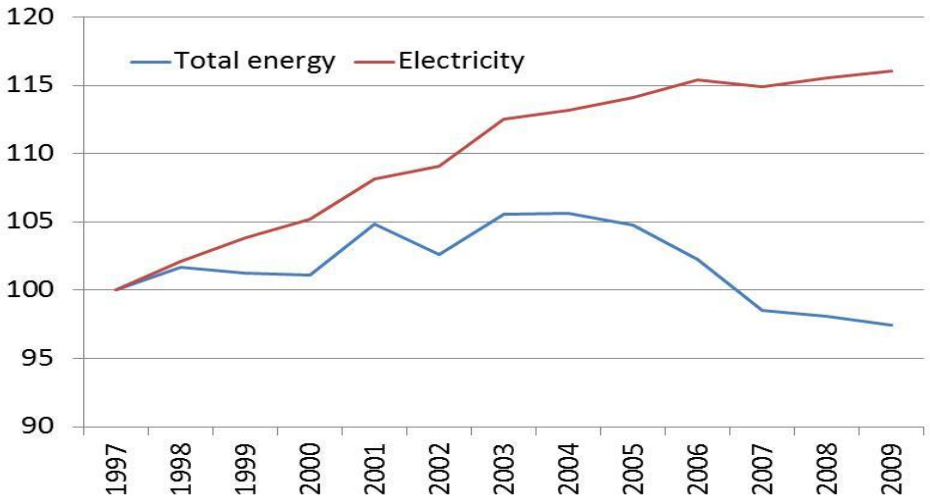


Source: Odyssee

At EU level less energy is used per employee but substantially more electricity

Total energy consumption per employee increased until 2003 and decreased since then (Figure 63). The overall decrease (-0.2%/year) is in contrast with the substantial increase in electricity consumption per employee (+0.6%/year). At EU level, almost 800 extra kWh per employee were used in 2009 compared to 1997 (from 3960 to 4730 kWh/employee). These developments suggest that increased productivity of labour is accompanied by more electricity using appliances and systems.

Figure 63: Total energy and electricity use per employee for tertiary (EU)



Source: Odyssee

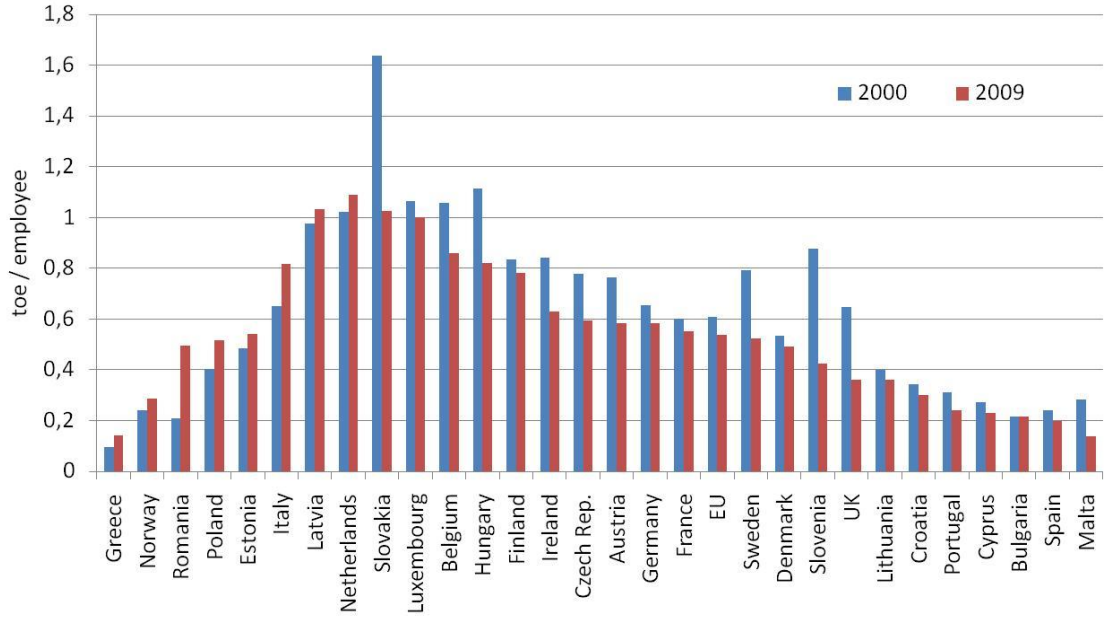
Non electric consumption per employee is mainly related to climate

The non electric consumption (fuels and heat) per employee shows large differences between countries (Figure 64). The values are not correlated to the level of economic development. There seems to be a closer relationship between climate and fuel consumption per employee, as fuels and heat are mainly used for heating: the lowest values are found in southern countries with lower needs for space heating.

Decreasing fuel use per employee in two-thirds of countries

Between 2000 and 2009, fuel use per employee (climate corrected) for EU decreases slightly (Figure 64). A decrease is visible for about two-thirds of the countries. For new member states very large differences occur with regard to changes, e.g. twice as low (Slovenia) versus twice as high (Romania).

Figure 64: Non electric consumption per employee in services

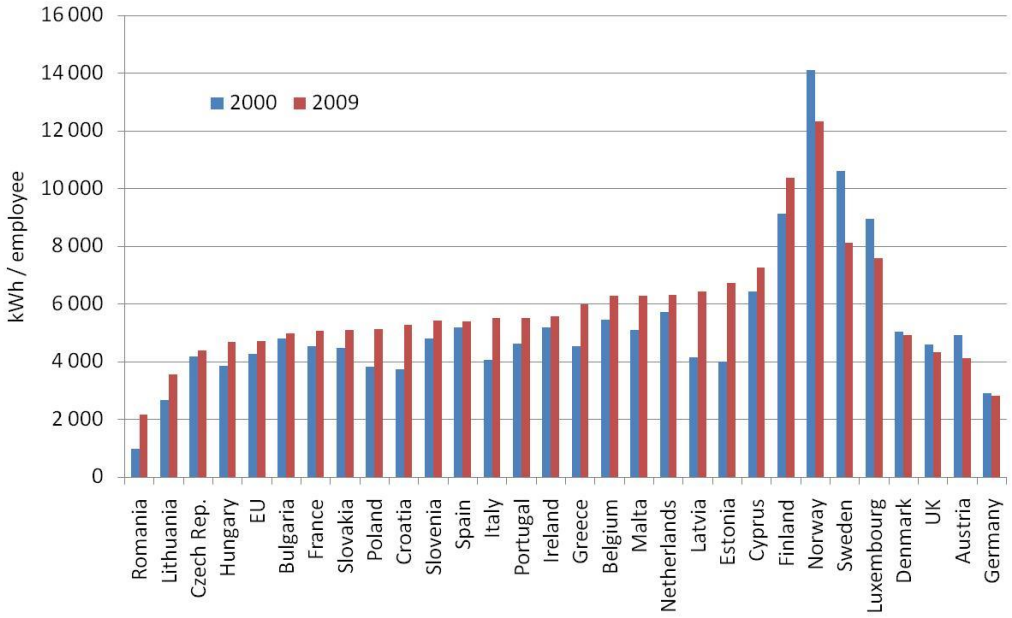


Source: Odyssee

Large use of electricity for space heating in Scandinavian countries

Norway, Sweden and Finland use by far the largest amount of electricity per employee (more than twice the EU average), which probably has to do with electric heating (Figure 65). For the other countries, electricity consumption per employee is much more homogeneous than fuel consumption per employee: most countries use between 4,000 and 7,000 kWh per employee. Electricity consumption per employee is increasing in most countries. Large increases can be observed for all southern countries, because of the penetration of air conditioning. The high growth for eastern European countries is linked to their fast economic growth.

Figure 65: Electricity use per employee, per country for tertiary

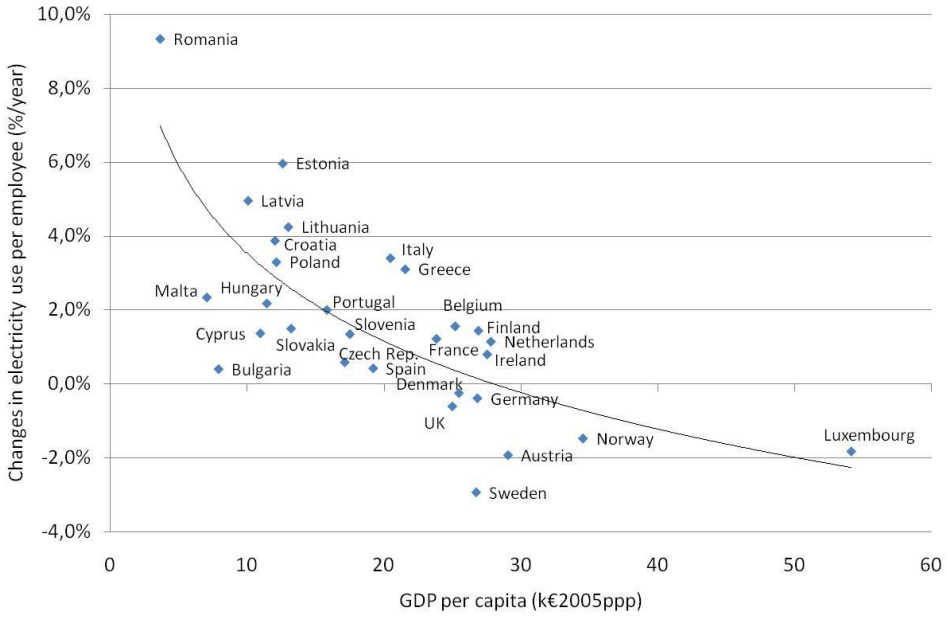


Source: Odyssee

Rich countries show saturation for electricity use per employee

For the most developed EU countries, electricity use per employee is stable or sometimes decreasing (Figure 66). This could signal that electricity use reaches a saturation level after the "computerisation" of offices, shops, schools, etc. since the eighties. However, saturation will not be reached if air-conditioning develops at a large scale in these countries. Also the strong growth in ICT networks could lead to the continuation of the trends for increased electricity use[61].

Figure 66: Changes in electricity use per employee according to economic welfare



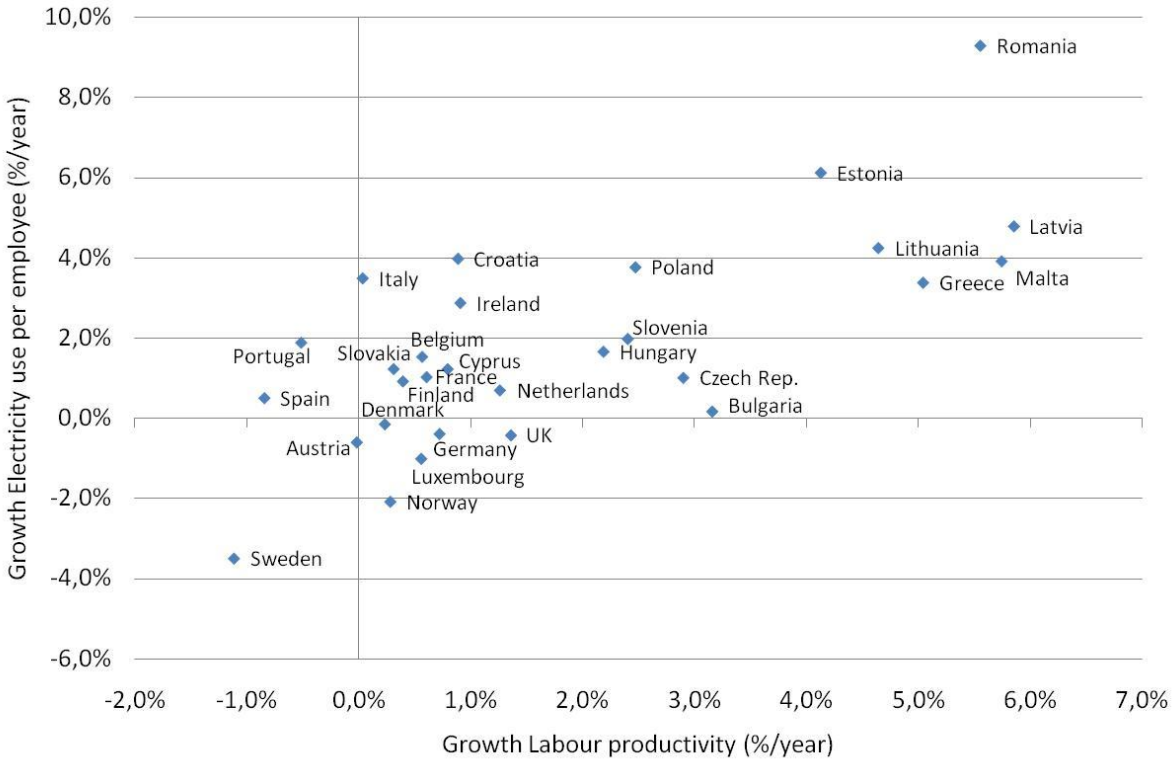
Source: Odyssee

[61]More information can be found in "Energy Efficiency Trends of IT Appliances in Households", Fraunhofer ISI], Karlsruhe, September 2009.

Growth in electricity use per employee is linked to labour productivity

An increase in labour productivity, i.e. value added per employee, will often be accomplished by using more office equipment and other electrical appliances (e.g. computers and communication devices, and air-conditioning and lighting systems that provide a better working environment) (Figure 67). No such relationship exists for fuel/heat use per employee and value added per employee.

Figure 67: Value added versus electricity use, per employee, for services



Source: Odyssee

7.3. Drivers behind changes in energy consumption

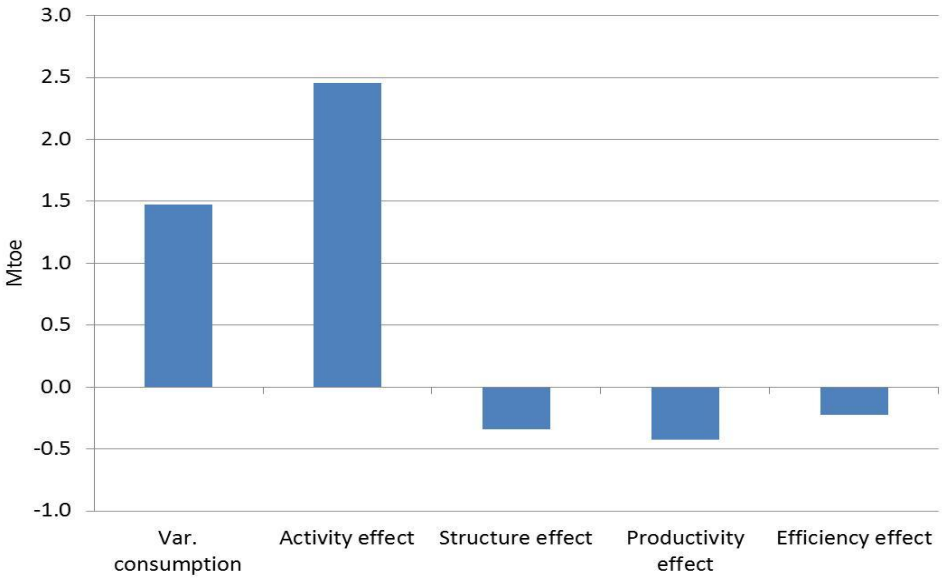
Structural changes also contribute to change in energy use

Changes in energy consumption in the service sector can be decomposed into various explanatory factors: growth in value added ("activity effect"), labour productivity improvements, energy efficiency gains, and shift between subsectors with different intensities ("structural changes"). In the service sector, as in industry, some subsectors are more energy intensive than others, e.g. retail-food (with much product related lighting and cooling) versus schools (only used for a limited part of the year). If activities in these subsectors grow faster than the average it will further increase total energy consumption of services.

This decomposition analysis has been carried out for two countries with detailed energy consumption data by sub-sector: France and Denmark

In France, the overall change in energy consumption (+1.5 Mtoe) is the combined result of growth of value added ("activity" +2.5 Mtoe), the shift between subsectors leading to decreased energy consumption ("structural changes" -0.3 Mtoe), labour productivity improvements (-0.4 Mtoe) and energy efficiency gains (-0.2 Mtoe) (Figure 68).

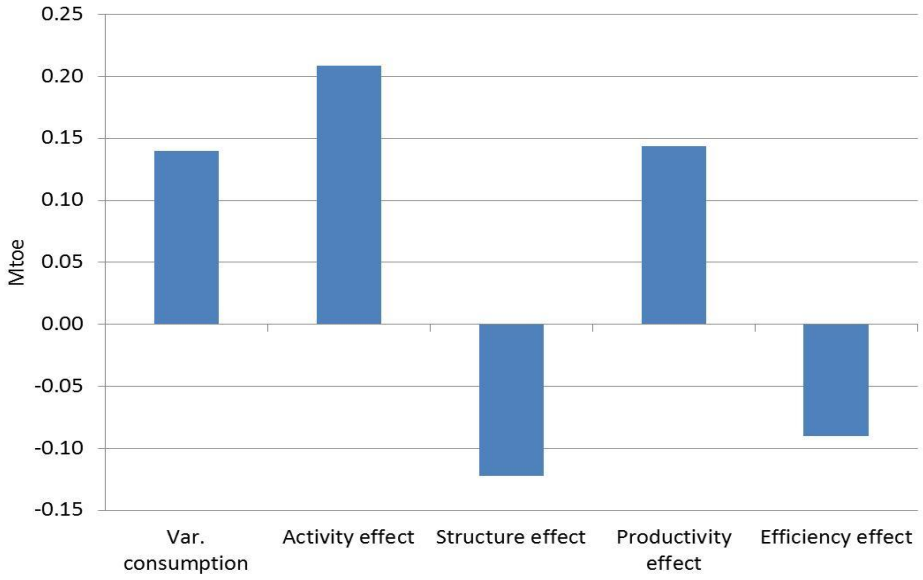
Figure 68: Decomposition of energy use for services in France (2000-2009)



Source: Odyssee

In Denmark, energy consumption of the services sector grew by +0.14 Mtoe between 2000 and 2009 (Figure 69). The activity and productivity effects (+0.21 Mtoe and +0.14 Mtoe, respectively) were partly offset by structural changes (-0.12 Mtoe) and energy efficiency improvements (-0.09 Mtoe). Although the overall labour productivity of the tertiary sector increased between 2000 and 2009, a large decrease in the labour productivity of energy intensive subsectors (e.g. trade and hotels & restaurants subsectors) led to a positive productivity effect.

Figure 69: Decomposition of energy use for services in Denmark (2000-2009)

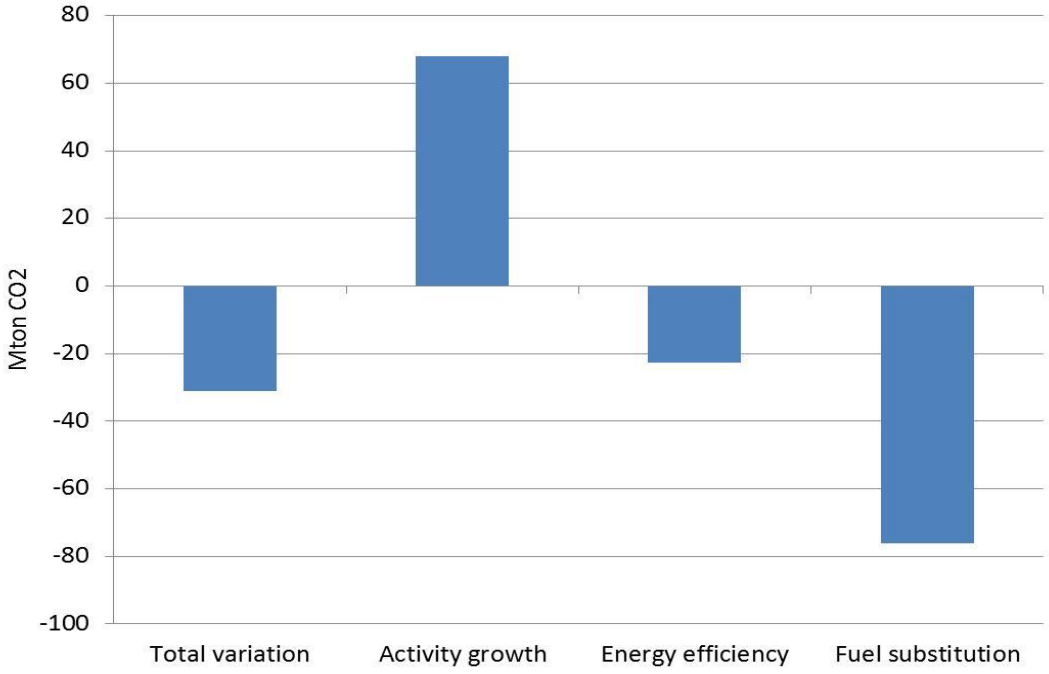


Source: Odyssee

Fuel substitution also important for lower CO_2 emissions

Tertiary represents 8% of CO_2 emissions in the EU in 2009. From 1996 to 2009, the direct CO_2 emissions have decreased by 16% (see "variation" in Figure 70). The value added has increased by 34%, which would have implied an increase of 68 Mt CO_2 (see activity effect). The reduction of CO_2 emissions by energy efficiency and fuel substitution has more than offset the effect of economic growth. About ¾ of these reductions are linked to a switch to natural gas and the increased use of electricity. However, if the indirect CO_2 emissions from electricity production are also taken into account the emissions increase substantially.

Figure 70: Decomposition of change in CO_2 emissions[62] for tertiary (EU, 1996-2009)



[62] It refers to direct CO_2 emissions

Definitions and glossary

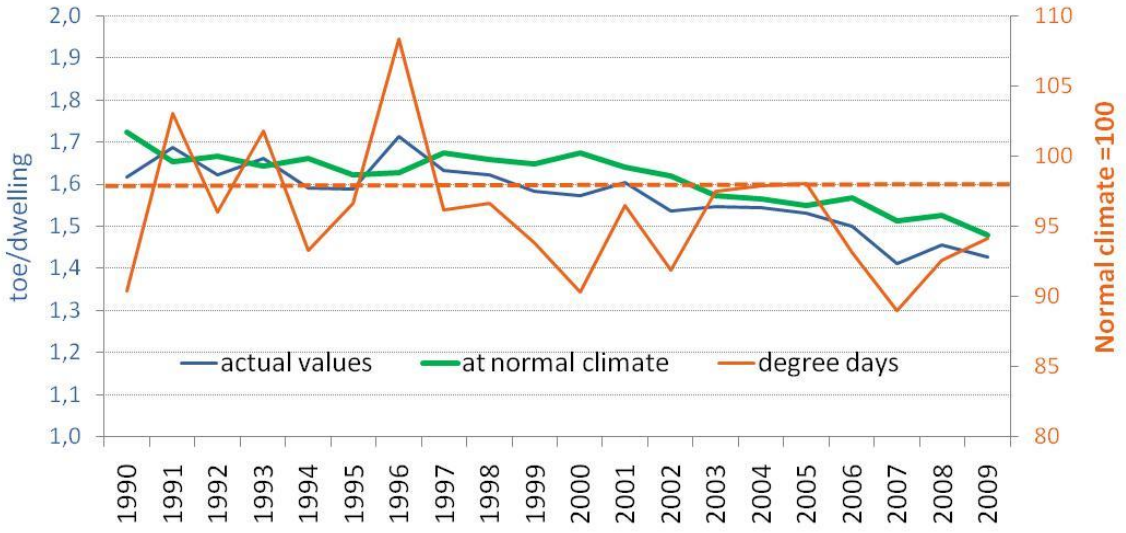
- **Yearly climatic corrections**

Years with cold winters will have a higher consumption level than years with mild winters, all things being equal. In order to assess correctly energy consumption trends, these fluctuations due to climate should be removed by calculating an energy consumption for a normal winter. These climatic corrections are necessary before any interpretation can be made. Climatic corrections only regard energy use for space heating, as other energy uses are not influenced by temperature variations.

In ODYSSEE, climatic corrections are carried out for all countries using the same methodology, even if climate corrected national data exist (e.g. France, Denmark).The heating consumption at normal climate is equal to the actual consumption divided by a climate index; this climate index for year t is the ratio between the actual number of degree days of year t and the number of degree days for a normal year. It is over 1 for year with a cold winter.

Figure 71 shows how the method works for the EU-27. The red line denotes the actual number of heating degree days (HDD) against the long term average (i.e. the “normal climate”). It appears that since 1990 there were only three years with relative cold winters. For these years corrected energy consumption is lower than the actual value. For the other years the corrected value is higher than the observed figure. The green line, corresponding to the climate corrected consumption, is smoother and shows that yearly fluctuations in energy consumption are smaller after correction.

Figure 71: Yearly HDD and climate corrected energy consumption per dwelling (EU)



Source: ODYSSEE

- **Definition of degree days**

The actual number of heating degree days is an indicator of the winter severity, and thus of the heating requirement. It is calculated as the sum over each day of the heating period (e.g. October to April) of the difference between a reference indoor temperature (usually 18°C) and the average daily temperature[63]. The daily outside temperature is measured from the various meteorological stations existing in the country and averaged to get a national value. The national average should be calculated as a population weighted average[64]. The number of degree-days in EU countries is in a range from 700-800 degree-days for Cyprus and Malta to 4000-5000 degree-days in Nordic and Baltic countries.

The **mean heating degree days** represents the number of degree-days for a normal winter or an average winter; it is based on a long-term average of degree-days value. Eurostat uses a 25 years average (1980-2004); some national data are based on a 30 years average[65].

- **Climatic adjustments**

Countries with cold winters will often show higher energy use than countries with mild winters. In order to make a "fair" comparison of energy consumption per country these differences should be removed. Therefore, climatic adjustments are necessary before that any interpretation can be made. Climatic adjustments only regard energy use for space heating.

- **Energy consumption by end-uses for EU as a whole**

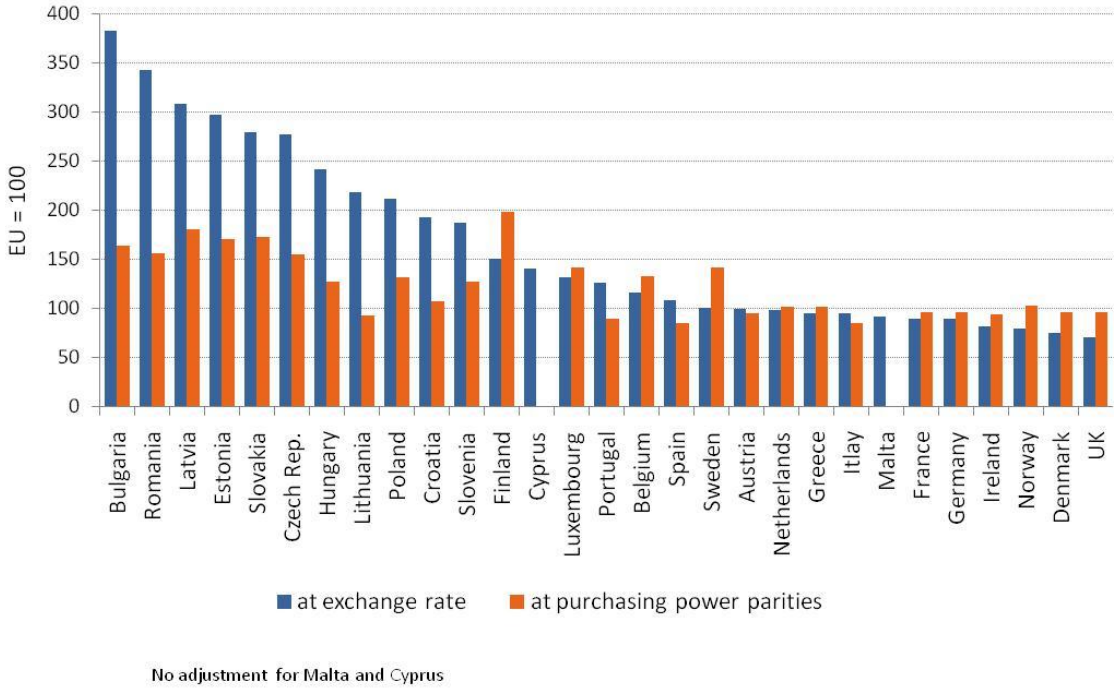
At EU level, energy consumption of households is split by 4 main end-uses / equipment, which are: space heating, water heating, cooking, electrical appliances and lighting. These energy consumption figures are extrapolated from 16 EU countries (11 main EU-15 countries and 5 new Member countries) representing more than 90% of the households energy consumption. Electricity consumption from electrical appliances is broken down into 5 main electrical appliances: refrigerators, freezers, washing machines, dishwashers and dryers. Data for the average specific consumption by appliance for the EU are calculated as a weighted average for countries with national data.

[63] If the average temperature of a day in winter is 5°C, the number of degree day of that day is 13 degree days (18-5).
[64] The national average can be just calculated as an arithmetic average or as a population weighted average. The second approach should be used as it is more representative of the heating requirement in the country. Eurostat calculates these two values for all EU countries, but only the arithmetic national average is available on its web site.
[65] Some countries have however shortened the reference period and are calculating the average since 1990 to account for the fact that winters have been warmer since 1990. Some countries are in addition changing the period (moving reference period), which means that the number of normal degree-days is not fixed.

- **Adjustment in purchasing power parities**

The economic performance of EU countries, e.g. GDP/capita or income per household, differs substantially between EU countries. Given comparable energy consumption this leads to large differences in energy intensity values. However, in practical life the differences in production and income are not always experienced as such, because prices of goods and services are relatively low in new member states. Therefore, economic quantities are adjusted for purchasing power parities (PPP) for reasons of comparability. If the PPP correction is applied to the new member states the energy intensities decrease and the difference with EU-15 countries is much smaller (Figure 72).

Figure 72: Energy intensity of EU countries with/without PPP correction (2009)



No adjustment for Malta and Cyprus

- **Overall energy efficiency index ODEX**

For households, energy efficiency improvement is calculated through an index so-called ODEX ("ODyssee indEX") which is calculated from the efficiency increase for 8 end-uses and large appliances: heating, water heating, cooking, refrigerators, freezers, washing machine, dish washers, TV. This index is calculated from the change in unit consumption by end-use or appliance (measured in indices), weighting for each year by the fraction of each end-use or appliance in total household energy use.

As indices are used, it is possible to combine different units for unit consumption to provide the best proxy of energy efficiency; for each end-use, the following indicators are considered to measure efficiency:

- Heating: unit consumption per m2, at normal climate (koe/m2)
- Water heating: unit consumption per dwelling (toe/dwelling)
- Cooking: unit consumption per dwelling (toe/dwelling)

- Large electrical appliance: electricity consumption per appliance (kWh/appliance/year)

A decrease in the index means an energy efficiency improvement: a value of 85 in 2009, for instance, means a 15 % efficiency improvement compared to a base year (2000[66]).

Energy efficiency gains are measured in relation to the previous year to avoid having results influenced by the situation in the base year. In addition, they are calculated as a 3 years moving average to avoid short-term variations of the indices.

- **Decomposition of the energy consumption in tertiary**

The variation of the final energy consumption in the tertiary sector is decomposed into 4 effects:

- An activity effect, measuring the effect of change in the value added of tertiary;
- Structural changes, measuring the impact of changes in the structure of the value added by branch;
- A productivity effect, measured by the change in the ratio value added per employee;
- 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 : $EQT_{t/t0} = \sum_{i=0}^{n} \Delta VA_{i,t/t_0} * I_{i,t_0}$

With
EQT: activity effect
VA: value added by branch i
I : Energy intensity by branch i
i: branches (hotel-restaurant, health, education, public, private offices, wholesale and retail trade)
t=final year
t_0=reference year

The structural effect is measured by changes in the structure of the tertiary value added by branch. It corresponds to the fact that branches with different energy intensities are not growing at the same rate. It 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 for a reference year, so as to leave out the influence of structural changes.

[66] Reference chosen in ODYSSEE due to non relevant data for some new Member countries by end-use before 2000

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

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 (energy intensity with the same structure in value added than in the reference year $t_{0)}$
VA : Value added in constant prices
t=year t
t_0=reference year t_0

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

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

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

The productivity effect is calculated as a 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; in this case we consider the evolution of the unit consumption of the tertiary sector, by separating energy consumption into “non electric” and electric[67]

[67] This calculation corresponds to the use of the so called “minimum indicators” according to ESD.