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Assessing the progress towards the EU energy efficiency targets using index decomposition analysis in 2005-2016

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Contents

Abstract

Energy consumption trends are driven by several factors beyond energy efficiency, including economic activity, demography, lifestyle changes and weather. These can all have a profound effect in the aggregate energy use, irrespective of the impact of energy efficiency policies and measures. As more and more countries are relying on their energy efficiency targets as a means to address unprecedented challenges resulting from increased dependence on energy imports, scarce energy resources and climate change, robust methodologies that enable monitoring and measuring progress towards these targets are increasingly important. To identify the driving factors and their contributions behind the latest energy consumption trends in the EU, the Logarithmic-Mean Divisia Index method (LMDI) method, a widely-used IDA method, was applied to study both aggregated and sectoral energy consumption changes at EU and MS levels over the period 2005–2016 in this report.

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Executive summary

Policy context

Energy efficiency plays an integral role in the EU energy policy, with the 2020 and 2030 targets on energy efficiency expected to help pave the way towards a long-term vision for a climate neutral Europe. These targets —namely, a 20% energy consumption reduction against projections by 2020 and 32.5% reduction by 2030— aim to accelerate energy efficiency efforts across the EU, while contributing to the decoupling of economic growth from future energy demand. The EU has noted a considerable progress towards its 2020 targets since 2005, despite a recent hike in energy demand between 2014 and 2016. Monitoring progress towards these targets requires knowledge of the main influencing factors behind the latest energy consumption trends in order to capture real energy efficiency change. Decomposition analysis enables the isolation of factors such as economic activity and structural shifts from the general energy trends.

Main findings

In 2005-2016, consumption at EU level fell by −11% in primary and −7% in final energy. In terms of primary energy, the final energy demand was the most decisive explanatory factor behind the decrease in primary energy consumption, while the hike of just over +2% over the period 2014-2016 was exclusively attributed to the final energy demand increase of this latest 2-year period. Over the entire examined period, efficiency improvements in transformation, distribution and own energy sector systems generally drove down primary energy consumption to a lesser extent, highlighting the role of increased penetration of renewable energy sources in the energy system.

While the main driver of energy consumption was the higher economic activity at EU level in the 11-year period, examining the yearly results also confirmed the impact of the recent economic recession on consumption trends in most sectors of the economy. In particular, the decomposition results showed that the dip in energy consumption in 2009 was mainly driven by a negative activity effect, which was caused by lower economic output registered that year. The influence of the economic recession on the transport had the most lasting effect as the decline in passenger activity effect extended until 2012, while for freight transport this was still negative in 2016.

Labour productivity was a major driver in energy consumption in all productive sectors of the economy, with the highest impact in agriculture, followed by industry and then services. Economic growth was the main factor that led to the increase in total energy consumption of the service sector, with both positive labour and labour productivity effects contributing to this growth. Services were, indeed, the sector with the least evident impact from the economic recession. On the other hand, the labour effect in agricultural sector was negative throughout the entire period, suggesting that, in addition to the economic recession, a shift of labour force towards more labour productive sectors may also have played a role.

The analysis showed that energy intensity improvements —subsuming, inter-alia, the effect of technological change— played a dominant role in falling energy consumption during the study period, offsetting the activity effect. The intensity effect measured in monetary-based units was generally the main reason behind the final energy consumption decline in most end-use sectors of the economy, counteracting the +12% increase in final energy consumption compared to 2005 due to increased economic activity. A comparison between decomposition using production-based units and monetary-based units for industry showed that the use of gross value added generally overestimated efficiency improvements. While our analysis using the production-based units seems to indicate that the negative production-based intensity effect is of lower magnitude, more investigation is needed in the future as production units are currently available at a more aggregated industrial subsectoral level in official statistics.

In terms of other effects, the analysis showed that structural effects have had a secondary role in driving down energy consumption in industry over the examined period. In addition, a strong correlation between the weather and total effects is found in the residential sector, indicating the decisive impact the weather effect has had on the total energy consumption of this sector.

Results at Member State level are mixed for most sectors of the economy; these are discussed in the main body of the report.

Related and future JRC work

Decomposition analysis is deployed by various international organisations, research institutes and national agencies as a tool to inform policy makers in the field of energy analysis. This report represents the second of the series of reports tracking economy-wide energy efficiency trends and the European Commission Joint Research Centre plans to continue and deepen its research in the future. The methodological approach has been revised and expanded (e.g. through the application of the activity revaluation approach) and the data are updated to cover the period 2005-2016[1]. The results of the decomposition analysis offer valuable insights into the factors behind recent consumption trends at both EU and MS levels, but also highlight the need for further investigation to provide a more comprehensive analysis. This will be feasible with the inclusion of more factors and availability of more statistical data in the future. For a more complete picture, decomposition analysis should be used alongside econometric and other tools focusing on the investigation of policy efforts on energy consumption trends.

To strengthen the analytical framework of tools such as the Logarithmic-Mean Divisia Index method, this research has shown that finer levels of disaggregation are necessary to conduct more detailed decomposition as disaggregated data are often accompanied with various data gaps and quality issues. Sectors with significant challenges include the transport sector as no full compatibility is currently offered between energy and activity data and services as the breakdown of energy consumption by services subsector and end use is currently not available in official statistics. To deepen the decomposition of the industrial energy changes using physical-based indicators, our analysis has also highlighted the need of collection of physical index data at compatible disaggregation level with energy consumption and monetary output data in national accounts. The JRC welcomes on-going efforts made by Eurostat and national statistical offices that can help enhance our ability for more detailed and precise energy efficiency monitoring.

Quick guide

Index decomposition analysis (IDA) is a widely adopted analytical tool used by researchers. This is done by breaking down changes in an aggregate indicator and assigning the effects to a number of predefined factors. To identify the driving factors and their contributions behind the latest energy consumption trends in the EU, the Logarithmic-Mean Divisia Index method (LMDI) method, a widely-used IDA method, was applied to study both aggregated and sectoral energy consumption changes at EU and MS levels over the period 2005–2016 in this report. All applications were run using Eurostat data, with a few exceptions where data from other sources were considered. Based on the analysis conducted, the primary energy consumption trends in 2005-2016 were decomposed into final energy demand, transformation and distribution/energy sector effects. Changes in final energy consumption of end use sectors (industry, transport, residential, services and agriculture) were decomposed separately to best reflect the particularities of each sector and their specific underlying driving forces.

[1] The first report covered the period up to 2015

1 Introduction

Energy consumption trends are driven by several factors beyond energy efficiency, including economic activity, demography, lifestyle changes and weather. These can all have a profound effect in the aggregate energy use, irrespective of the impact of energy efficiency policies and measures. As more and more countries are relying on their energy efficiency targets as a means to address unprecedented challenges associated with increased dependence on energy imports, scarce energy resources and climate change, robust methodologies that enable monitoring and measuring progress towards these targets are increasingly important.

The EU has noted a considerable progress towards its energy efficiency targets ‒translating into 1483 million tonnes of oil equivalent (Mtoe) of primary energy or 1086 Mtoe of final energy[2] consumption by 2020‒ over the few last years (Figure 1). The EU28 primary and final energy consumption was the lowest in 2014 (1508 Mtoe and 1063 Mtoe, respectively), only +1.7% above its 2020 primary energy target and −2.4% *below* the 2020 final energy target. These translated to a primary and final energy reduction of −18.6% and −22%, respectively. Despite these positive results, the EU28 primary energy consumption grew by +1.5% in 2015 and by +0.7% in 2016, leading to an increased gap to the primary energy target of +4%. In terms of final energy, a growth rate of +2.2% and +2.0% were registered in 2015 and 2016, respectively, which translates to a final energy target gap of +2.0%.

A complete analysis of the drivers behind the latest energy consumption trends requires the examination of wider range of factors beyond policy efforts. The separation of energy efficiency impacts from structural and activity changes of the economy as well as other factors has been examined extensively in the literature through the application of decomposition analysis techniques. Indeed, decomposition analysis has been used by several international bodies including the International Energy Agency to quantify the impact of such factors in historical energy- or emission- related trends (IEA, 2018). Index decomposition analysis has been used to single out the impact of energy efficiency in all sectors of the economy using data from national statistics and energy balances. Many of these studies commonly relate energy efficiency with energy intensity, although more recent attempts have been made focusing on the use of physical indicators (in addition to monetary indicators) to measure output, which, in turn, enable the consideration of more reliable energy efficiency indicators.

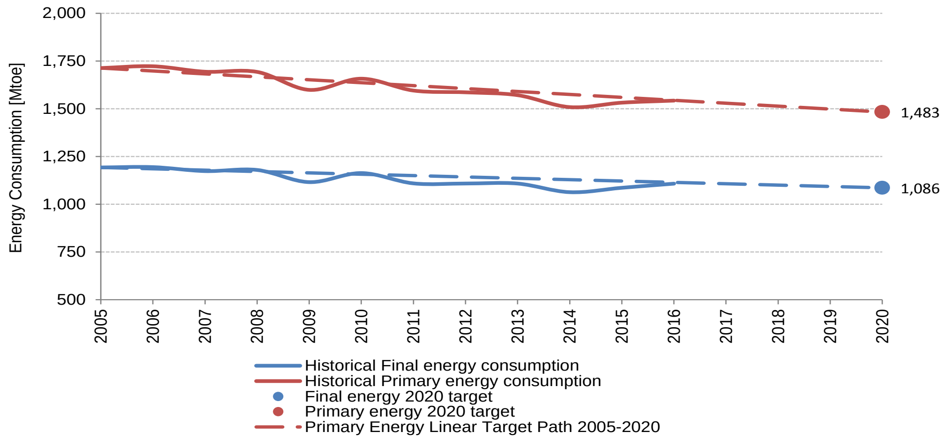

Figure 1. Final and Primary Energy Consumption trends of the EU28 (the dotted lines represent linear trajectory between the 2005 actual consumption and 2020 target consumption) Source: Tsemekidi-Tzeiranaki *et al.* (2019)

[2] Final energy is the total energy consumed by end users (e.g. households, industry, agriculture) while primary energy is the total energy demand including transformation and distribution losses.

To track and understand the progress towards the 2020 energy efficiency targets, this report examines the determinants of changes in primary and final energy consumption at EU and MS levels over the period 2005 to 2016. The year 2016 represents the latest available year covered by energy balance statistics. This report builds up from the first report published by the EC Joint Research Centre in 2017 (Economidou, 2017), informing policymakers on the latest progress towards the targets through the application of decomposition analysis.

Index decomposition analysis, and in particular the widely-used Logarithmic Mean Divisia Index methodology, is also applied in this second report to study the aggregated and sectoral energy consumption changes at EU and MS levels. The sectors considered include the productive sectors of the economy (that is, industry, services and agriculture) as well as residential and transport sectors. The application of the activity revaluation approach proposed by Ang and Xu (2013) is used to decompose energy consumption changes in industry based on physical units and the hybrid model outlined by Xu and Ang (2014) is applied for the residential sector.

The report is structured as follows. Section 2 describes the methodological approach and presents in detail the analytical framework of the decomposition options considered in the work. Section 3 discusses the results of the decomposition and conclusions are drawn in Section 4.

2 Methodology

The Logarithmic Mean Divisia Index (LMDI-I) is used to decompose changes in primary and final energy consumption in all EU28 Member States. In its simplest form, the following identity[3] is used to decompose energy consumption changes in activity, structure and intensity effects (Ang, 2005; Ang, 2015):

$$E = \sum_i E_i = \sum_i Y \frac{Y_i}{Y} \frac{E_i}{Y_i} = \sum_i Y S_i I_i \qquad (1)$$

where i denotes the sector, E is the total energy consumption, Y represents the economic activity such as Gross Domestic Product or Value added, S_i is the proportion of the economic activity of sector i in relation to the whole economy (Y_i/Y) and I_i is energy intensity (E_i/Y_i) of sector i.

The LMDI decomposition of additive change in energy consumption (ΔE) between time 0 and t is expressed as:

$$\Delta E = E_t - E_0 = D_{act} + D_{str} + D_{int} \qquad (2)$$

where D_{act}, D_{str} and D_{int} denote the overall activity, structure and intensity effects, respectively. When the effects are positive, they act as drivers and if they are negative, they will act as inhibitors of energy consumption changes. In its multiplicative form, the LMDI decomposition of the ratio of energy consumption between 0 and t is defined as:

$$R = \frac{E_t}{E_0} = R_{act} \,.\, R_{str} \,.\, R_{int} \qquad (3)$$

In the multiplicative decomposition, when the effects are above 100%, they act as drivers and if they are lower than 100%, they will act as inhibitors of energy consumption changes.

Concretely, the LMDI-I decomposition is carried out using the following formulae:

$$\left.\begin{array}{c}
D_{act} = \sum w_i ln\left(\frac{Y_t}{Y_0}\right),\; D_{str} = \sum_i w_i ln\left(\frac{S_{i,t}}{S_{i,0}}\right), D_{int} = \sum_i w_i ln\left(\frac{I_{i,t}}{I_{i,0}}\right) \\
R_{act} = e^{\sum_i \widetilde{w_i} ln\left(\frac{Y_t}{Y_0}\right)},\quad R_{str} = e^{\sum_i \widetilde{w_i} ln\left(\frac{S_{i,t}}{S_{i,0}}\right)}, R_{int} = e^{\sum_i \widetilde{w_i} ln\left(\frac{I_{i,t}}{I_{i,0}}\right)} \\
\text{where } w_i = \frac{E_{i,t} - E_{i.0}}{ln\left(\frac{E_{i,t}}{E_{i,0}}\right)} \text{ and } \widetilde{w_i} = \frac{\left(E_{i,t} - E_{i,0}\right)/ln\left(\frac{E_{i,t}}{E_{i,t}}\right)}{\left(E_t - E_0\right)/ln\left(\frac{E_t}{E_0}\right)}
\end{array}\right] \qquad (4)$$

While applications of decompositions may deviate from the above canonical setup by considering various other factors, the logic underpinning the analysis remains the same. Based on the data review focusing on the availability and comparability of possible input data at sectoral and subsectoral level in European countries carried out by Economidou (2017), the LMDI-I was applied to decompose:

(1) primary energy consumption into activity, transformation and distribution effects.

(2) final energy consumption of productive end use sectors[4] (namely, industry, services and agriculture) into activity, productivity, intensity and wherever possible structural effects.

[3] Identity refers to the governing decomposition equation that describes the relationship between the decomposed indicator (e.g. energy consumption or GHG emissions) and the various factors

[4] Freight transport was treated separately

(3) final energy consumption of passenger and freight transport into activity, modal shift and efficiency effects

(4) final energy consumption of residential sector into population, wealth, weather and intensity effects.

Various adaptations to the formulae (1)-(4) were made to best reflect the particularities of each sector and their specific underlying driving forces. Whenever possible, physical indicators were used to define activity and intensity effects. These are described in Sections 2.1-2.4. The principal source of data used in our analysis was the statistical database of the European Commission Eurostat (ESTAT), which inter-alia collects economic and energy use data for all European countries. These originate from national accounts data and are harmonised by Eurostat to ensure data quality, consistency and comparability across Member States. To complement current data shortcomings, the ODYSSEE database was used to cover specific data needs. These are discussed in more details below.

2.1 Primary energy consumption

Based on a simplified version of the methodology proposed by Reuter, Patel and Eichhammer (2017), we decompose primary energy consumption (PEC) by considering the following identity:

$$PEC = \sum \ FEC \frac{EAT}{FEC} \frac{PEC}{EAT} = \sum \ FEC \ \ EAFE \ \ PEAT \quad (5)$$

where FEC is final energy consumption and EAT is the energy after transformation. The latter was calculated as the sum of Energy Available for Final Consumption, Distribution Losses and Consumption in Energy Sector. The factors examined are: global efficiency of the transformation sector ($PEAT$), global efficiency of the final part of the process ($EAFE$), i.e. importance of the internal consumption of power plant and distribution losses and final demand of the energy consumption for end users (FEC).

These three factors enable the LMDI-I decomposition of PEC into three effects:

The **transformation effect** accounts for the *average* efficiency of the whole energy transformation system, providing an indication of the quantity of energy lost in the conversion/transformation processes. Negative transformation effect corresponds to cases where the overall efficiency of the conversion/transformation distribution system increases, i.e. the difference between the total energy which enters the system and the total energy available after transformation drops. Cases which cause a drop in the transformation effect include increased penetration of renewable energy sources, efficiency gains in conventional condensing power plants. Conversely, the transformation effect is positive in cases where the usage of transformed fuels (e.g. replacement of fuel use with electricity in the transport sector) increases. Thus, conversion/transformation system efficiency gains and energy mix changes both have an impact on the transformation effect.

Likewise, the **distribution and own conversion effect** captures efficiency gains in the distribution system and is negative if losses during distribution processes and/or reduction in energy sector consumption are realised.

Finally, the **final energy demand effect** measures changes in primary energy consumption due to changes in the final demand of the energy consumption for end users, and is negative in cases where the demand for final energy by end users drops.

2.2 Final energy consumption of productive sectors

2.2.1 Monetary-based activity measure approach

The final energy consumption (FEC) of each productive sector (industry, services and agriculture) is decomposed following the factorisation identity provided in equation 1 in three factors: activity, structural and intensity. The LMDI decomposition allows the analysis of the additive and multiplicative change of final energy consumption in the following effects. The **activity effect** shows the change in FEC due to a change in total GVA[5], the **structural effect** shows the change in FEC due to a change in the relative weight of subsectors in total GVA and **intensity effect** accounts for the change in FEC due to a change in energy intensity of sectors. Considering an additive LMDI decomposition such as the one provided in equation 2 the effects would be analysed as follows. The activity effect is positive if GVA grows due to additional energy demand of increased economic activity. The structure effect is positive if sectors of high energy intensity grow more relative to less intensive sectors. The intensity effect is negative if there is a drop in energy intensity. It should be stressed that the intensity effect accounts for changes in total energy consumption due to technology advancements, efficiency improvements, policy and all other effects not captured by the other two effects.

The comparison between energy balances and national account statistics carried out by Economidou (2017) has ensured the compatibility between energy and value added data for each sector. Industry covers the consumption in all industrial sectors with the exception of the energy sector. The agriculture sector comprises activities classified as agriculture (including engines used for agricultural transportation), hunting and forestry. The services sector consist of activities associated with business and offices in the public and private sectors, such as wholesale and retail trade, hotel and restaurants, transport and communications, real state and renting, financial intermediation, education, health and others.

As the breakdown of energy consumption of the services and agricultural sectors is not covered by official statistics, the structural effect within each of these sectors cannot be examined at this stage. Industry is the only sector of the economy for which a detailed decomposition examining the sector's structural effect is currently feasible. A detailed disaggregation of both energy and activity data of industry is available, allowing a fine level of decomposition for this sector. The division of industrial subsectors was done on the basis of the lowest available disaggregation level of energy consumption. This resulted in the consideration of the following 11 industrial subsectors[6]:

1. Food and Tobacco
2. Textile and Leather
3. Wood and Wood Products
4. Paper, Pulp and Print
5. Chemical and Petrochemical
6. Metals[7]
7. Machinery
8. Non-Metallic Minerals
9. Other manufacturing[8]
10. Transport equipment
11. Construction.

[5] To remove the impact of price changes, Gross Value Added expressed in chain-linked volume (2010) were used

[6] Mining and quarrying were excluded from our analysis as the match between activity and energy data for this subsector was not possible. This is a rather small energy consuming subsector, accounting for 1.1% of the total EU industrial energy consumption in 2005-2016.

[7] A further breakdown of the gross value added of metals in 1. iron and steel and 2. non-ferrous metals is currently not available

[8] This included rubber, plastics, furniture and other manufacturing

2.2.2 Activity revaluation approach

To identify differences in decomposition results between the use of monetary versus physical units, the refined activity revaluation (AR) approach, proposed by Ang and Xu (2013) is considered (see Box 1 for more methodology details).

This comparison has only been carried out for industrial sector because industry is the only sector where physical production data are available. Concretely, the industrial production index has been used as a proxy of industrial physical production. However, as the industrial production index data are not provided separately for all 11 subsectors, the industry has been broken down in 2 industrial subsectors: (1) manufacturing and (2) construction.

Following the methodology provided in Box 1, the final energy consumption of the industrial sector (FEC) has been decomposed as shown in equations (7) and (8), where E_i is the final energy consumption, Q_i is the industrial production index IPI_i and Y_i is the gross value added GVA_i of subsector i, respectively.

2.2.3 Monetary-based activity measure approach (gross value added) combined with labour force

Based on Román-Collado and Colinet (2018), the final energy consumption (FEC) of each productive sector of the economy (services, industry and agriculture) is decomposed using the factorisation identity:

$$FEC = \sum_i L \frac{GVA}{L} \frac{GVA_i}{GVA} \frac{FEC_i}{GVA_i} \qquad (6)$$

where i denotes the subsector, L is the employment in terms of hours worked and GVA represents the Gross Value Added expressed in chain-linked volumes (2010).

This factorisation allows us to decompose the additive and multiplicative change of FEC of productive sectors (industry, services and agriculture) into four effects. The **labour effect** accounts for changes in energy consumption due to a change in the overall employment measured in total number of hours worked. The labour effect is positive if the increase in global hours worked L grows the final energy demand. The **labour productivity** effect, measured by the gross value added (GVA) produced per hour worked, reflects changes in the productivity of each sector due to e.g. of advancements in equipment used in production processes or penetration of technologies that enhance the output per unit hour worked. The labour productivity effect is positive when an increase in labour productivity drives up final energy demand. The **structural effect**, represented by the relative share of activity of individual sectors (GVA_i/GVA), accounts for changes in energy consumption due to change in the relative importance of sectors with different energy intensities. The structure effect is negative if lower energy intensive sectors grow more relative to more intensive sectors. Finally, the **intensity effect**, represented by final energy consumption per value added in monetary terms, accounts for changes in total energy consumption due to technology improvements, policy effects and other factors. The intensity effect is negative if there is a drop in energy intensity.

Box 1. Decomposition of industrial energy changes using physical units

The activity indicator can be either given by a monetary measure such as value added or physical measure such as physical units of production. Liu and Ang (2007) showed that monetary-based activity is adopted in over 90% of the empirical studies on industrial energy use in the index decomposition analysis literature. The popularity of the monetary measure can be associated with the facts that the aggregate activity level and activity structure can be easily computed and data are readily available through national accounts (Ang and Xu, 2013). However, the choice of activity in monetary terms typically implies the use of monetary-based intensity effect, which may not provide a reliable proxy to measure energy efficiency changes as there are a number of limitations due to both price fluctuations and productivity changes (Norman, 2017). The challenges of using a physical measure is associated with the facts that actual production units cannot be added up and data requirements for obtaining aggregate physical output measures are high, limiting their use in practice (Nanduri, Nyboer and Jaccard, 2002; Farla and Blok, 2001).

There are a number of techniques available to overcome some of the issues associated with the use of physical units. One of these techniques is the refined activity revaluation (AR) approach, proposed by Ang and Xu (2013). This technique is appropriate in cases when monetary output data is available for all subsectors and physical output data is available for some or all subsectors. The activity refactorisation (AR) approach utilising the Montgomery-Vartia (M-V) index is preferred to the alternative Laspeyres index as the former offers perfect decomposition (with no residual) and maintains consistency in the index procedures used throughout the method (Ang and Xu, 2013).

When physical output data are available for subsectors i (Q_i), the following revaluation procedure is used to adjust the activity indicator:

$$A^t = \frac{Q_i^T}{Q_i^0} \cdot Y_i^0 \qquad (7)$$

After adjusting the activity indicators of the relevant subsectors, the aggregate energy consumption is decomposed as follows:

$$E = \sum_{i=1}^{n} E_i = A \cdot \sum_{i=1}^{n} \cdot \frac{A_i}{A} \cdot \frac{E_i}{A_i} = A \cdot \sum_{i=1}^{n} \cdot S_i \cdot I_i \qquad (8)$$

This factorisation allows us to decompose the additive and multiplicative change of final energy consumption in three effects: activity, structural and intensity. The additive decomposition formulae proposed by Ang and Xu (2013) are expressed as:

$$D_{act} = \sum_{i=1}^{n} L(E_i^t, E_i^0) \cdot \ln Q^{M-V}, \quad D_{str} = \sum_{i=1}^{n} L(E_i^t, E_i^0) \cdot \ln \frac{Q_i^t / Q_i^0}{Q^{M-V}}, \quad D_{\text{int}} = \sum_{i=1}^{n} L(E_i^t, E_i^0) \cdot \frac{UC_i^t}{UC_i^0}$$

where UC_i is the energy consumption per physical output unit of subsector i ($UC_i = E_i / Q_i$) and Q^{M-V} is the Montgomery–Vartia (M–V) index:

$$Q^{M-V} = \exp\left(\sum_{i=1}^{n} \frac{L(Y_i^t, Y_i^0)}{L(Y^t, Y^0)} \cdot \ln \frac{Q_i^t}{Q_i^0} \right) \qquad (9)$$

The multiplicative formulae are given by: $R_{act} = \exp\left(\sum_{i=1}^{n} \frac{L\left(E_i^t, E_i^0\right)}{L\left(E^t, E^0\right)} \cdot \ln Q^{M-V} \right)$,

$$R_{str} = \exp\left(\sum_{i=1}^{n} \frac{L\left(E_i^t, E_i^0\right)}{L\left(E^t, E^0\right)} \cdot \ln \frac{Q_i^t / Q_i^0}{Q^{M-V}} \right), \quad R_{\text{int}} = \exp\left(\sum_{i=1}^{n} \frac{L\left(E_i^t, E_i^0\right)}{L\left(E^t, E^0\right)} \cdot \ln \frac{UC_i^t}{UC_i^0} \right) \qquad (10)$$

The **activity effect** accounts for the change in final energy demand due to the change in physical units produced. The **structure effect** shows the change in final energy demand due to a change in the relative importance of physical production of sectors on total production. The **intensity effect** accounts for the change in final energy demand to a change in energy intensity measured in terms of physical units.

2.3 Final energy consumption of transport

The passenger and freight transport are decomposed as separate sectors. While various studies use turnover to define activity in the transport sector (Zhang *et al.*, (2011), Liang *et al.* (2017), Achour and Belloumi (2016)), we opt for a physical unit based activity measure expressed in terms of transport volume (that is, passenger kilometres and freight kilometres). This raises the need to deal with each transport subsector —passenger and freight transport— separately. According to the Eurostat glossary, passenger-kilometre, abbreviated as pkm, is the unit of measurement representing the transport of one passenger by a defined mode of transport (road, rail, air, sea, inland waterways etc.) over one kilometre. A tonne-kilometre, abbreviated as tkm, is a unit of measure of freight transport which represents the transport of one tonne of goods (including packaging and tare weights of intermodal transport units) by a given transport mode (road, rail, air, sea, inland waterways, pipeline etc.) over a distance of one kilometre.

The factorisation identities used for the transport sector are given by:

$$FEC = \sum_i PKM \frac{PKM_i}{PKM} \frac{FEC_i}{PKM_i} \quad \text{for passenger transport}$$

$$FEC = \sum_i TKM \frac{TKM_i}{TKM} \frac{FEC_i}{TKM_i} \quad \text{for freight transport} \qquad (11)$$

where PKM is the total passenger-kilometres; PKM_i is the passenger-kilometres by mode of passenger transport and FEC_i is the final energy consumption by mode of passenger transport; TKM is the tonne-kilometre of freight transport, TKM_i is the tonne-kilometre by mode of freight transport; FEC_i is the final energy consumption by mode of freight transport. The transport modes considered for passenger transport are car, bus and rail. For freight transport, the modes of road and rail are considered; the inland waterways transport is excluded from our analysis as no sufficient match between the energy consumption and activity data could be obtained. Air transport is decomposed separately, as explained below.

The above factorisation allows us to decompose the additive and multiplicative final energy consumption change of passengers and freight transport in the following effects. The **activity effect** is measured in physical units either in passenger-kilometres or tonne-kilometres. This effect shows the change in final energy consumption due to a change in the physical units. The **modal shift effect** shows the change in final energy consumption due to the modal shift change. The **intensity effect** shows the change in final energy consumption due to the change in final energy consumption by mode of transport per physical activity unit.

Given that statistical data on transport energy consumption are scarce, various additional sources were considered in this analysis. Eurostat does not currently distinguish transport energy consumption between passenger and freight, so Odyssee data were used to calculate the share of passenger versus freight transport for road and rail modes. These were then multiplied with the appropriate Eurostat energy data to deduce the equivalent passenger and freight transport energy consumption for each transport mode.

Moreover, the detailed data on passenger and freight kilometres by transport mode published in the Statistical Pocket book on EU Transport in Figures prepared by DG MOVE were used (EC, 2017).

The air transport was singled out from the other transport modes, as a distinction between passenger and freight in terms of energy consumption is not covered by any statistical source. The recently published Eurostat datasets on the air passenger and air freight kilometres were not considered in this analysis as the time-series of these new datasets start from 2008 instead of 2005. For this reason, the total number of passengers, tonnes of goods transported (GT) and number of flights (NF) were used instead. Air transport was decomposed separately using the following factorisation identity:

$$FEC_{air} = \sum NF \frac{GT}{NF} \frac{FEC_{air}}{GT} \qquad (12)$$

The number of passengers is converted into tonnes by following the methodology used by (Wang, Zhang and Zhou, 2011). This conversion allows us to have a unique activity indicator (tonnes) that cover both passengers and goods. As the conversion ratio corresponds to the average human body weight, this assumption was considered a sensible conversion ratio.

This factorisation allows us to decompose the additive and multiplicative change in air transport final energy consumption into three effects. The **activity effect** accounts for the changes in final energy consumption of air transport due to the number of flights, the **productivity effect** reflects the change in final energy consumption due to a change in the weight of tonnes of goods and passengers transported per flight. And the **intensity effect** shows the change in final energy consumption due to a change in the energy consumption by tonnes transported.

2.4 Final energy consumption of residential sector

In line with the decomposition analysis applied to the transport sector in which passenger and freight transport are treated separately, decomposition of the residential energy consumption can also be carried out at the subsector level. Xu and Ang (2014) proposed a hybrid model, which decomposes the energy consumption of various energy services in the residential sector according to their specific underlying driving forces. The approach used by these authors informs the methodology used in this study. Due to data restrictions, two subsectors were considered in this study are: (1) space heating, and (2) all other end-uses. The subsector decomposition results are then combined to obtain the final effects for the whole sector.

Therefore, the final energy consumption of the residential sector is decomposed into two subsectors: space heating (FEC_{heat}) and other end-uses (FEC_{other}). The factorisation was carried out using the following identity:

$$FEC = FEC_{heat} + FEC_{other} = POP.\frac{TFA}{POP}\frac{FEC'_{heat}}{TFA}\frac{HDD}{HDD_{ref}} + POP\frac{GDI}{POP}\frac{FEC_{other}}{GDI} \qquad (13)$$

where POP denotes population, TFA is the total floor area of dwellings and GDI is the gross disposable income in purchasing power standard. FEC'_{heat} stands for the weather adjusted final energy consumption for heating. This was calculated by dividing the final energy consumption with the weather factor, which has been defined as ratio HDD/HDD_{ref}.

This factorisation allows us to decompose the additive and multiplicative change in residential final energy consumption into four effects. The **population effect** accounts for changes in energy consumption due to a change in the population size and the **wealth effect** changes in energy consumption due to changes in the wealth represented by the total floor area of dwellings (TFA) per capita for the heating end use and gross disposable income in purchasing power standard (GDI) per capita for all other end uses. The **weather effect,** represented by the ratio of the heating degree days of a given year (HDD) over the average heating degree days in a reference period (HDD_{ref}), accounts for changes to energy consumption due to weather changes. If weather effect is negative, energy consumption has dropped due to warmer climate. The weather adjustment was considered only for the final energy consumption attributed to the heating use (FEC_{heat}), while the share of the consumption associated with all other uses (FEC_{other}) remained unchanged. The **intensity effect** was defined as the final energy consumption per unit of physical activity; that is, TFA and GDI respectively for the space heating and other end-uses.

The period 1990-2016 was considered as a reference period for the weather adjustment.

3 Decomposition results

3.1 Primary energy consumption

In 2005-2016, the EU28 primary energy consumption decreased by −10% from 1713 to 1543 Mtoe. Over three quarters of this decrease of 170 Mtoe was achieved by the UK (−41 Mtoe), Italy (−33 Mtoe), France (−25 Mtoe), Germany (−21 Mtoe) and Spain (−19 Mtoe). Poland (+6.7 Mtoe) and Estonia (+0.7 Mtoe) were the only countries which experienced an increase over the study period. While the gap between 2016 consumption and the 2020 energy efficiency target amounts to only 60 Mtoe, the EU28 primary energy consumption has been on a rising trend for the second consecutive year since 2014. The year 2014 represents the year when the lowest consumption was recorded (1508 Mtoe) over the period 2005-2016. In 2016, the EU28 consumption increased by +11 Mtoe compared to 2015 (from 1532 Mtoe), albeit at a lower rate compared to 2014-2015. Belgium, Italy, Spain, Germany and Poland contributed to around two thirds of the EU-wide consumption increase encountered in 2014-2016. In 2015-2016 alone, the EU consumption rose by +11 Mtoe.

According to the decomposition results, the main driver in reducing primary energy consumption is the drop in final energy demand (Figure 2). This contributed to a total drop of −122 Mtoe in primary energy, equivalent to −7% of the consumption in the beginning of the examined period. A further explanatory factor for the decrease in primary energy consumption was improvements in the transformation efficiency, which accounted for a drop in consumption by −39 Mtoe in 2005-2016, followed by decreases in distribution losses and the conversion sector consumption (−9.5 Mtoe). On one hand, the share of renewable energy in gross final energy consumption grew from 9% to 17% at EU level and on the other hand, there was a shift towards higher shares of electricity. These changes were counterbalanced and therefore led to the moderate transformation efficiency effect of −30 Mtoe for the whole period (equivalent to −2% decline compared to the 2005 primary energy consumption).

The year-on-year results (Figure 3) confirm the profound impact of the final energy on the primary energy consumption trends. While the impact of fuel mix must be examined in detail to get a clear picture, overall efficiency improvements in transformation, distribution and energy sector itself have had a somewhat secondary role in driving down energy consumption over the examined period. The primary energy hike of +0.7% (from 1532 to 1543 Mtoe) in 2015-2016 was driven by the increase in final energy demand (resulting to a positive final energy demand effect) in 2016 relative to 2015. The other two effects continued to restrict consumption in 2015-2016.

The country results are shown in Table 1. These confirm a decreasing tendency in primary energy consumption in nearly all Member States except Estonia and Poland, where a growth of +14% and +8% in 2016 compared to 2005 is noted, respectively. Countries with the largest primary energy consumption decline include Greece (−23%), Lithuania (−25%), Malta (−22%), UK (−18%) and Italy (−18%). This group of countries together achieved nearly half of the total EU primary energy consumption drop in the same period. The decomposition results show that the decline in final energy consumption in 2005-2016 played a major role in limiting primary energy consumption in 23 Member States. The final energy effect contributed to an increase in primary energy consumption only in Malta, Poland, Lithuania, while in Austria and Finland this positive effect was marginal. In all other Member States, lower final energy consumption attributed to a decline in primary energy consumption, with the largest impact being registered in Greece, Spain, Italy, Portugal and the UK. In terms of transformation efficiency of the energy sector, a total of 24 Member States experienced (to a varying level) improvements in the overall efficiency, thereby contributing to a drop in their overall primary energy consumption. This suggests an increasing share of renewable energy sources in the energy system. The strongest improvements are noted in Malta and Lithuania, while on the opposite side, transformation efficiency had a counteracting effect (i.e. drove up consumption, albeit at rate less than +8%) in Estonia, Latvia, Romania and the Netherlands. Improvements in distribution and energy sector efficiency acted as an inhibitor factor in 16 Member States, however in most cases this was of moderate impact (the strongest impact of −7% and −6% were found in Romania and Lithuania respectively). In contrast, worsening of distribution and energy sector efficiency effect was the strongest in Ireland (+11%), Estonia (+8%) and Greece (+6%).

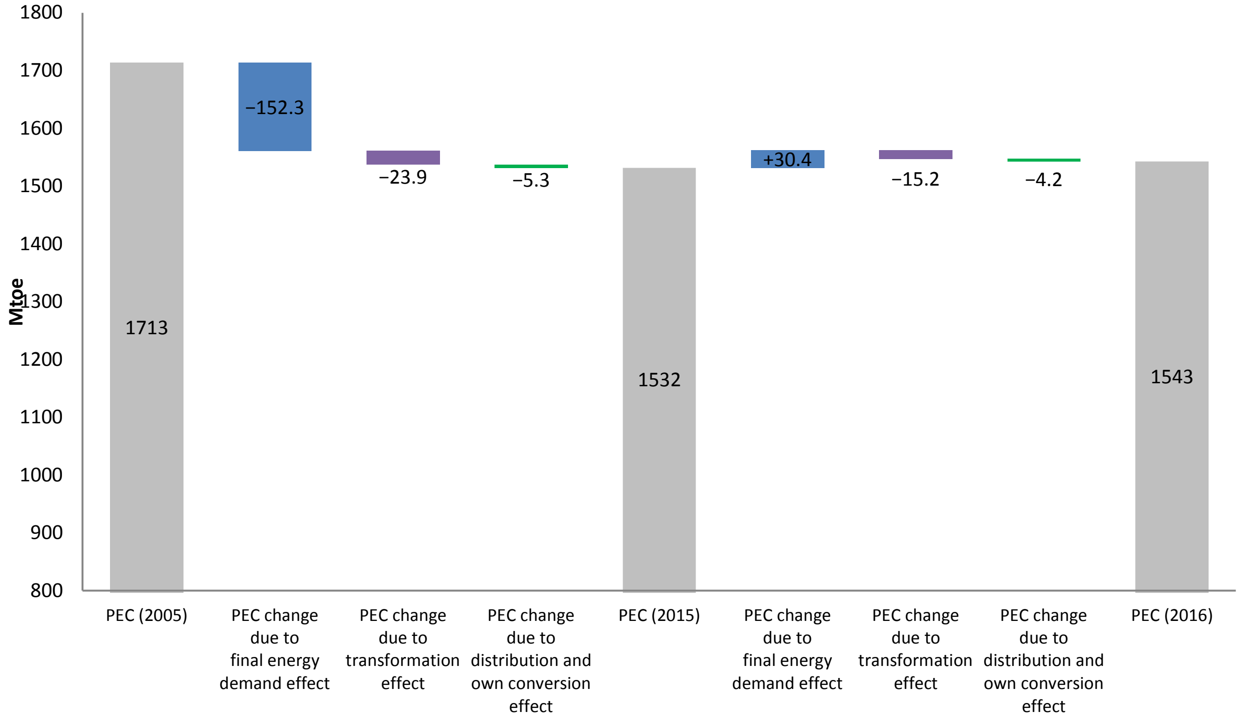

Figure 2. Decomposition of changes in EU-28 primary energy consumption (Mtoe) in 2005-2016 using the additive Logarithmic Mean Divisia Index approach (LMDI)

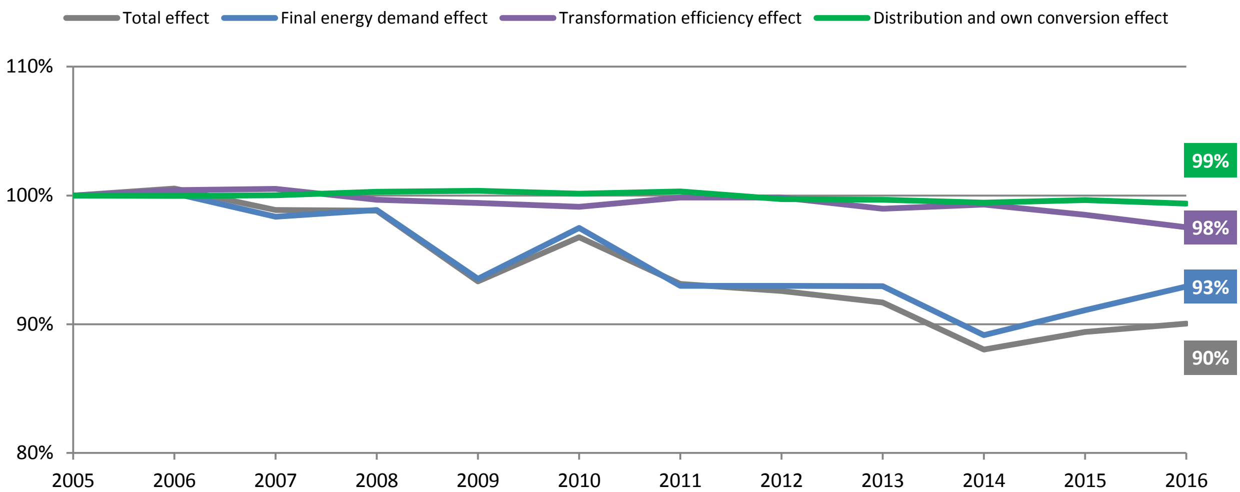

Figure 3. Yearly multiplicative LMDI decomposition results at EU level in 2005-2016

Table 1. Additive and multiplicative decomposition results of primary energy consumption changes at MS level in 2005-2016 and 2015-2016

	Period	Additive results [ktoe]				Multiplicative results [%]			
		Total effect	Final energy demand effect	Transformation efficiency effect	Distribution & own conversion effect	Total effect	Final energy demand effect	Transformation efficiency effect	Distribution & own conversion efficiency effect
BE	2005-2016	-2341	-482	-1690	-169	95%	99%	96%	100%
	2015-2016	3252	614	2641	-3	107%	101%	106%	100%
BG	2005-2016	-1273	-994	-917	638	93%	95%	95%	103%
	2015-2016	-272	288	-899	340	98%	102%	95%	102%
CZ	2005-2016	-2433	-2424	-778	769	94%	94%	98%	102%
	2015-2016	164	1030	-697	-170	100%	103%	98%	100%
DK	2005-2016	-2069	-1338	-1133	402	89%	93%	94%	102%
	2015-2016	571	521	110	-60	103%	103%	101%	100%
DE	2005-2016	-21428	-3383	-9434	-8611	93%	99%	97%	97%
	2015-2016	3131	5938	-1708	-1099	101%	102%	99%	100%
EE	2005-2016	743	-131	428	446	114%	98%	108%	108%
	2015-2016	-69	118	271	-459	99%	102%	104%	93%
IE	2005-2016	-148	-1268	-484	1604	99%	92%	97%	111%
	2015-2016	602	485	126	-9	104%	103%	101%	100%
EL	2005-2016	-7100	-6399	-2205	1505	77%	80%	91%	106%
	2015-2016	-200	286	-549	63	99%	101%	98%	100%
ES	2005-2016	-18638	-21589	-1600	4552	86%	84%	99%	103%
	2015-2016	128	3048	-2851	-69	100%	103%	98%	100%
FR	2005-2016	-24784	-22276	-2506	-2	90%	92%	99%	100%
	2015-2016	-3821	3085	-5943	-963	98%	101%	98%	100%
HR	2005-2016	-1038	-744	-18	-276	89%	92%	100%	97%
	2015-2016	74	65	79	-70	101%	101%	101%	99%
IT	2005-2016	-33032	-27819	-2349	-2864	82%	85%	99%	98%
	2015-2016	-1122	-386	102	-837	99%	100%	100%	99%
CY	2005-2016	-62	-107	-87	131	97%	96%	96%	106%
	2015-2016	155	134	27	-6	107%	106%	101%	100%
LV	2005-2016	-207	-219	97	-85	95%	95%	102%	98%
	2015-2016	21	37	-16	0	100%	101%	100%	100%
LT	2005-2016	-1988	540	-2102	-427	75%	109%	73%	94%
	2015-2016	192	283	-74	-17	103%	105%	99%	100%
LU	2005-2016	-610	-459	-159	8	87%	90%	96%	100%
	2015-2016	14	49	-42	8	100%	101%	99%	100%
HU	2005-2016	-2086	-1330	-148	-608	92%	95%	99%	97%
	2015-2016	578	648	-18	-51	102%	103%	100%	100%
MT	2005-2016	-198	201	-373	-26	78%	126%	64%	97%
	2015-2016	-34	14	-53	5	96%	102%	93%	101%
NL	2005-2016	-3976	-5678	899	802	94%	92%	101%	101%
	2015-2016	447	1341	146	-1040	101%	102%	100%	98%
AT	2005-2016	-491	401	-706	-187	98%	101%	98%	99%
	2015-2016	366	759	-213	-180	101%	102%	99%	99%
PL	2005-2016	6672	11894	-3427	-1795	108%	114%	96%	98%
	2015-2016	4360	6172	-2027	214	105%	107%	98%	100%
PT	2005-2016	-2773	-3677	-92	997	89%	85%	100%	105%
	2015-2016	427	104	-233	556	102%	100%	99%	103%
RO	2005-2016	-5480	-3697	898	-2681	85%	90%	102%	93%
	2015-2016	-45	549	-476	-118	100%	102%	98%	100%
SI	2005-2016	-347	-39	-279	-29	95%	100%	96%	100%
	2015-2016	226	261	-34	-1	104%	104%	99%	100%
SK	2005-2016	-2218	-1732	-230	-256	88%	90%	99%	99%
	2015-2016	154	515	-224	-137	101%	103%	99%	99%
FI	2005-2016	-295	42	-275	-61	99%	100%	99%	100%
	2015-2016	1288	1311	-177	154	104%	104%	99%	100%
SE	2005-2016	-1674	-1717	-1206	1249	97%	97%	97%	103%
	2015-2016	3267	1244	645	1378	107%	103%	101%	103%
UK	2005-2016	-41149	-27419	-9213	-4517	82%	88%	95%	98%
	2015-2016	-2813	1903	-3066	-1650	98%	101%	98%	99%

3.2 Final energy consumption of productive sectors

3.2.1 Monetary-based activity measure for productive sectors (industrial, services and agriculture)

Figure 5 illustrates the decomposition of final energy consumption changes in 2005-2016 at EU and MS levels into activity, structural and intensity effects. These confirm that the activity effect is the main driver but this is completely compensated by the intensity and structural effects in most countries. The EU energy consumption fell by −52 Mtoe, corresponding to a reduction of −10% compared to the 2005 consumption level. Only Malta, Latvia, Belgium, Poland and Germany experienced an overall growth in final energy consumption of their productive sectors over the period 2005-2016. While it is not surprising that the contribution of each effect was different among countries, the intensity effect was negative for all countries except Cyprus, Greece and Finland. In contrast, the EU tendency of negative structural effect was not universal at MS level; only 16 member states recorded an average decrease in energy consumption due to structural shifts in the period 2005–2016.

Increased activity in the period 2005-2016 acted as a driver of energy consumption in all countries except Italy, Greece, Spain, Portugal, Finland, Croatia and Cyprus, which had a negative activity effect linked to a prolonged or more severe economic recession. In absolute terms, the activity effect was a dominant force of rising energy consumption in Germany, Poland and the Czech Republic, UK, Romania and Slovakia. In terms of structural effect, the largest shift towards less intensive sectors are noted in Germany, the UK, Czech Republic, Slovakia and Romania while the opposite is true for Greece, Belgium, France, Spain and Italy. Intensity improvements acted as an important inhibitor in Italy, Spain, Poland, France and the UK.

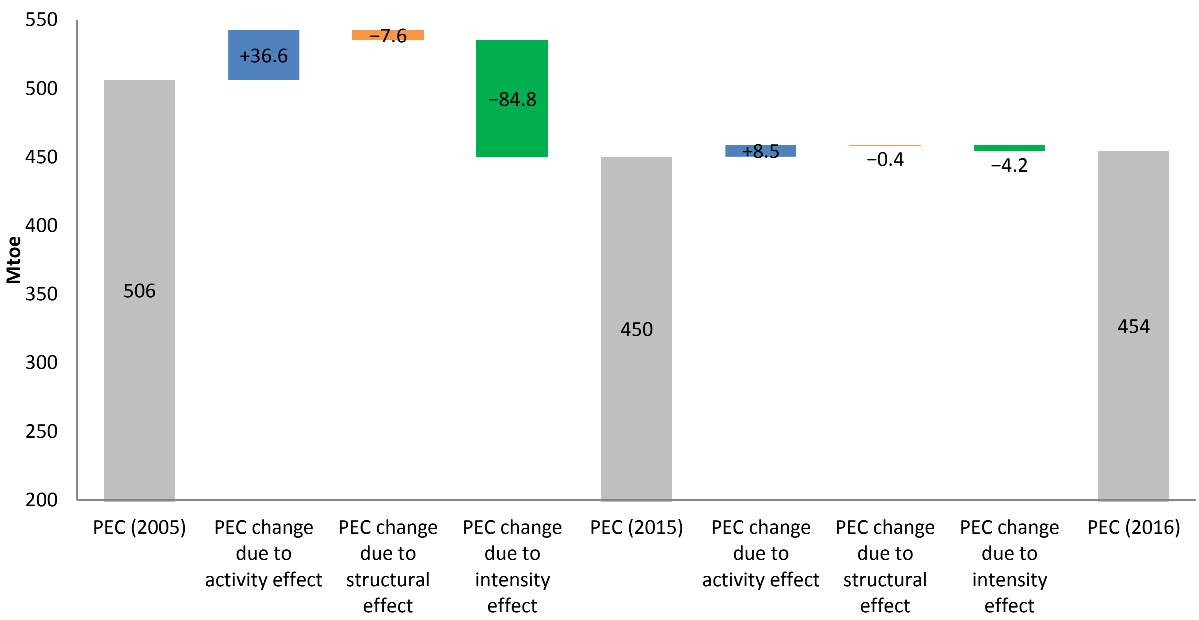

Figure 4. Decomposition of changes in EU-28 final energy consumption (Mtoe) of the productive sectors of the economy in 2005-2016 using the additive Logarithmic Mean Divisia Index approach (LMDI)

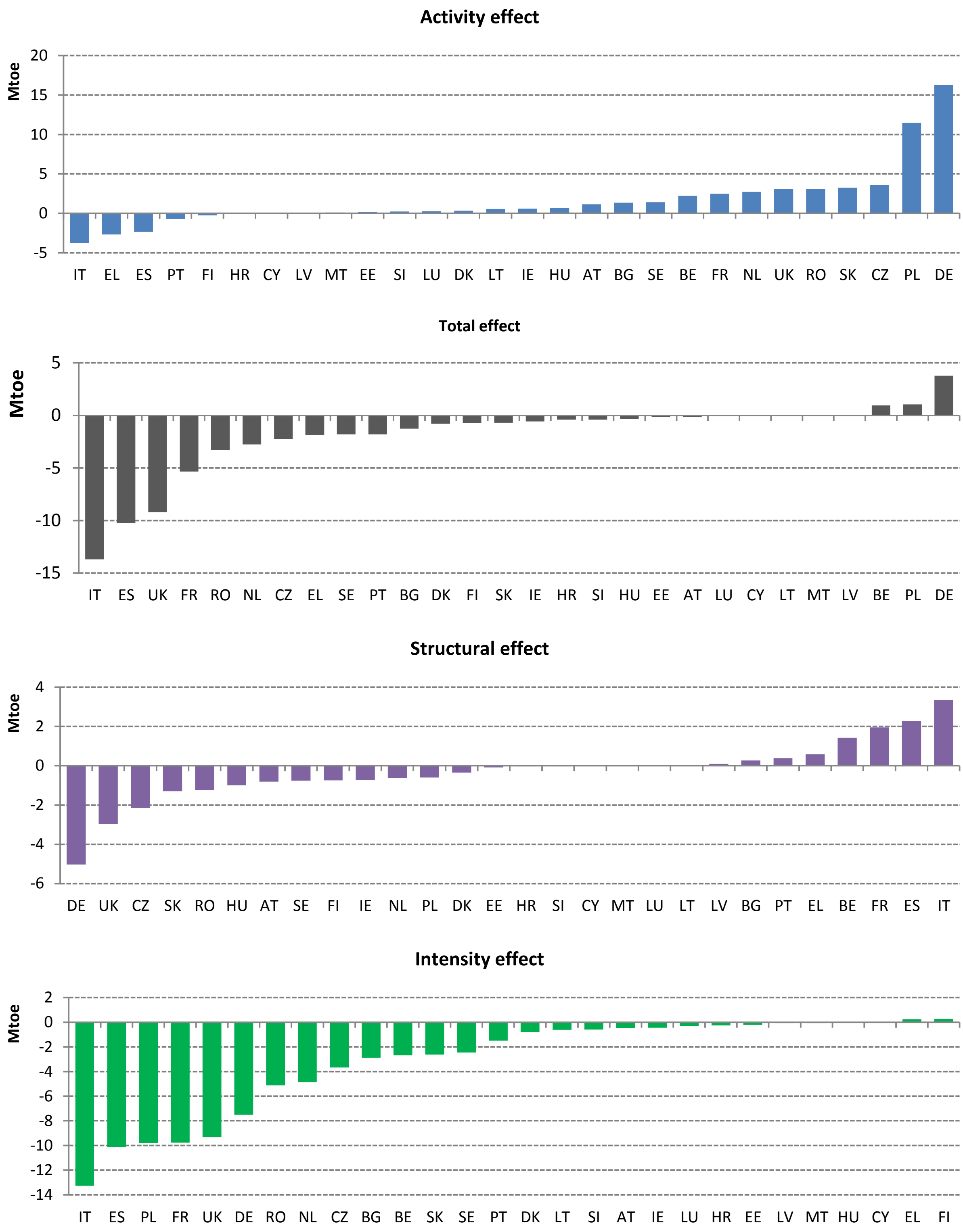

Figure 5. Decomposition of final energy consumption changes in 2005-2016 at EU and MS levels

3.2.2 Activity revaluation approach (Industry)

In order to further analyse the industry sector, this subsection explores the decomposition results when the output is measured in physical units instead of monetary units. The comparison of results is also analysed.

The activity effect in the monetary based approach accounts for changes in FEC due to changes in GVA. In the physical units approach, the activity effect shows changes in FEC due to changes in the physical production index.

A comparison of the EU28 decomposition results carried out using production-based activity measure (industrial production index) versus monetary-based activity measure (gross value added) is shown in Figure 6. The use of industrial physical index confirms the general trends previously identified. That is, over the examined period the intensity effect has been the dominant driver in reducing energy demand. As shown in Figure 6, a sharp reduction in energy demand due to reduced activity is observed in 2008-2009, linked to the EU economic recession. The activity effect generally drove up energy consumption since then, indicating a recovery from the recession. Unlike the marginal negative structural effect seen in the previous results (Figure 8), a positive structural effect is found in this analysis. This is rather linked to the lack of fine disaggregation of the industry by sub-sector in the latter case due to data restrictions discussed in the Methodology section; in contrast to the 11 subsectors considered before, two subsectors were considered here. The structural effect is influenced by the specific grouping considered, as the results are usually closely related to the disaggregation level considered.

In general, subtle differences can be observed between the production-based and monetary-based results. Both activity and structural effects seem to have a less dominant impact (if positive) on the energy consumption in the case of the production-based results. If negative, activity and structural effects generally have a more dominant role in driving down energy consumption. The negative IPI-based intensity effect is of lower magnitude, which may indicate that the use of GVA generally overestimates intensity (efficiency) improvements. At MS level, results vary and are sometimes counterintuitive which reflects the need of further, more detailed analysis including the study of potential differences in accounting of physical units by countries. This analysis highlights the need of collection of more detailed physical index data, at compatible disaggregation level with energy consumption and monetary output data in national accounts to better track efficiency improvements and allow the use of physical-based indicators in decomposition analysis in the future.

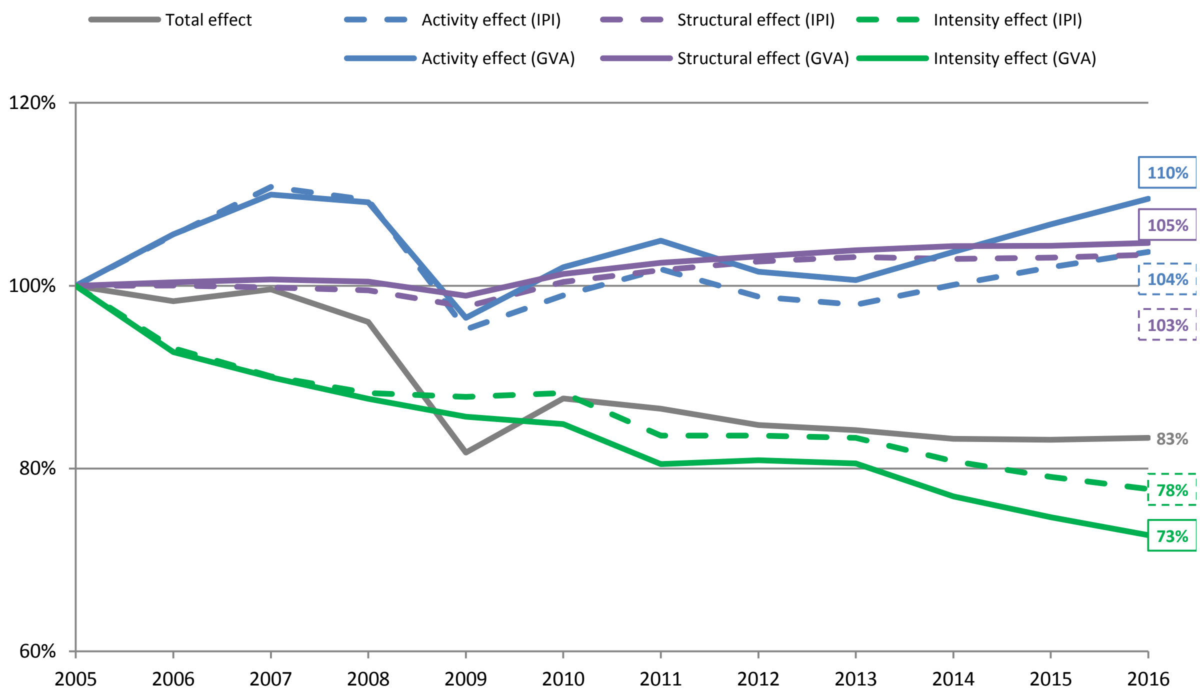

Figure 6. Differences in industrial decomposition results between the use of monetary-based (GVA) versus physical-based (IPI) units

3.2.3 Monetary-based activity measure (gross value added) combined with labour force

3.2.3.1 Industry

In the period 2005-2016, the energy consumption of the EU28 **industry**[9] as a whole decreased by −54.5 Mtoe, corresponding to a **drop of −17%** compared to 2005 consumption levels. Industry is the second most energy intensive sectors after agriculture and is responsible for nearly two thirds (61%) of the combined consumption of industry, services and agriculture. If structural and intensity effects would not have come into play, economic growth would have driven up industrial energy consumption by 21 Mtoe. If the energy consumption increase driven by activity effect is broken down into labour effect (hours worked) and labour productivity effect (GVA/hours worked), opposite driving forces are revealed. Industry is the only productive sector of the economy whose labour effect at EU level is negative (−28 Mtoe) over the examined period due to lower global number of hours worked over time. On the other hand, the labour productivity effect indicates an increase in energy consumption due to an improvement in productivity (50 Mtoe). This may be attributed to the fact that the industry sector is becoming more capital intensive, i.e. the global increase of labour productivity contributes to reducing the number of hours worked per unit of output produced and, therefore, the energy requirements to produce output are reduced.

The main driver of the overall industrial energy decline was associated with energy intensity improvements, which contributed to a drop in energy consumption by −68 Mtoe. The structural effect played a secondary role in limiting energy consumption as structural changes in the industrial sector (a shift from sub-sectors of higher energy intensity towards those of lower intensity) led to a reduction in energy consumption

[9] The results of the commercial sector (that is, combined industry, services and agriculture) correspond to the application of decomposition under option 2 (see Table 2).

equivalent to −8 Mtoe. The gross value added of the some of the most energy intensive industrial activities such as manufacture of textiles, leather, paper, pulp, print and non-metallic mineral products, dropped while the GVA of other less energy intensive activities increased. Intensity efficiency improvements have been achieved in all industrial activities except construction, wood and wood products. Most significant intensity improvements at EU level are noted in transport equipment, textile & leather, metals & machinery, non-metallic minerals & other manufacturing sectors.

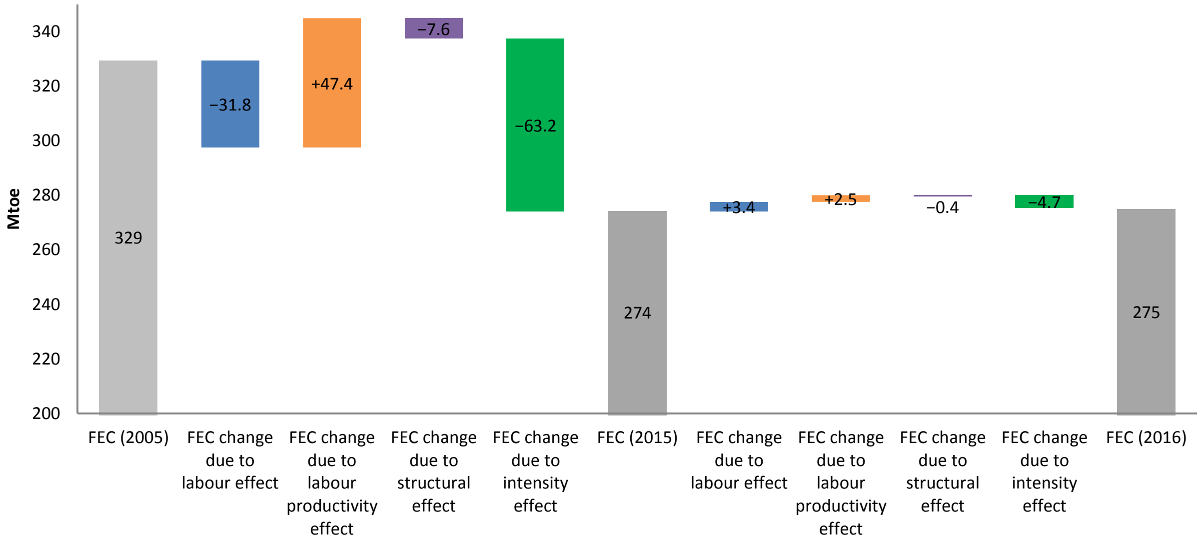

Figure 7. Decomposition of changes in EU-28 industrial energy consumption (Mtoe) in 2005-2016 using the additive LMDI approach

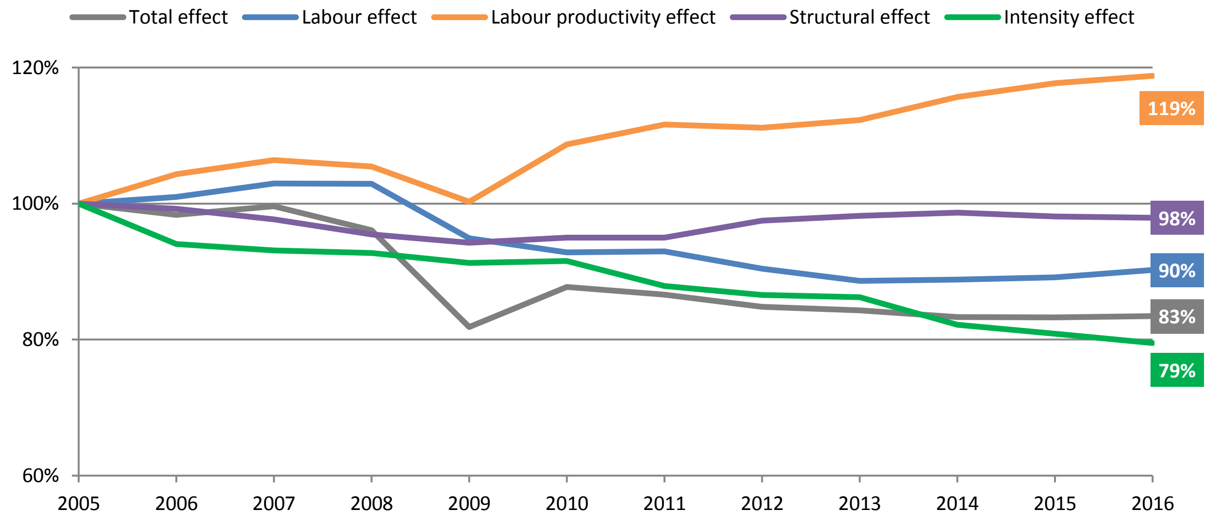

Figure 8. Yearly multiplicative LMDI decomposition results of industrial energy consumption changes at EU level in 2005-2016

While the industry sector grew fast only in Hungary (+25%) in 2005-2016[10], industry consumption declined in 22 Member States over the same period (Table 2). Energy consumption dropped by at least one third in 2016 relative to 2005 in Malta, Spain, Estonia, Romania, Bulgaria, Cyprus and Italy. The decomposition results show that

[10] This was followed by Austria where industrial energy consumption increased by 10% in 2005-2016.

employment in terms of reduced number of hours worked in industrial activities was one of the main inhibitors of industrial energy consumption, unlike the services sector where the opposite observation is true. The largest negative impact in terms of hours worked can be seen in Greece, Spain, Portugal, Latvia, Ireland, Cyprus, Italy and Lithuania. On the opposite side, the labour effect, in terms of higher overall number of hours worked, drove up consumption mostly in Poland and Luxembourg.

Labour productivity generally acted as a major driver of energy consumption in industry in 2005-2016, as labour productivity effect was positive in 26 Member States. In particular, labour productivity had the most profound impact as energy consumption driver in Slovakia, Lithuania, Romania, Ireland and Poland, while it acted as inhibitor in Cyprus and Greece, only. In terms of structural shift, the industrial sector moved to less intensive sectors in just over half of the Member States. Greece, Latvia, Malta, Spain and Italy were the countries with the largest increase in consumption due to shift towards more intensive activities. In contrast, countries with significant shift towards less intensive industrial subsectors included Ireland, Hungary, Slovakia, the Czech Republic and Denmark. Intensity improvements drove down consumption in all Member States except Hungary, Greece, Cyprus, Austria, Ireland and Finland.

Table 2. Additive and multiplicative decomposition results of industrial energy consumption changes at MS level in 2005-2016 and 2015-2016

	Period	Additive results[ktoe]					Multiplicative results [%]				
		Total effect	Labour effect	Labour productivity effect	Structural effect	Intensity effect	Total effect	Labour effect	Labour productivity effect	Structural effect	Intensity effect
BE	2005-2016	495	-894	2495	1430	-2536	104%	92%	124%	113%	81%
	2015-2016	305	63	94	85	62	103%	101%	101%	101%	101%
BG	2005-2016	-1402	84	1001	272	-2759	64%	92%	141%	112%	44%
	2015-2016	-72	1	20	-44	-50	97%	100%	101%	98%	98%
CZ	2005-2016	-2295	-95	2990	-2150	-3040	76%	99%	141%	80%	68%
	2015-2016	-32	145	4	55	-235	100%	102%	100%	101%	97%
DK	2005-2016	-666	-421	693	-343	-595	76%	84%	134%	87%	77%
	2015-2016	62	51	40	-18	-10	103%	103%	102%	99%	100%
DE	2005-2016	2376	2247	9520	-5031	-4361	104%	103%	117%	92%	93%
	2015-2016	171	-50	1399	23	-1202	100%	100%	102%	100%	98%
EE	2005-2016	-266	-107	188	-92	-255	62%	85%	136%	89%	60%
	2015-2016	-71	11	-10	6	-78	86%	102%	98%	101%	85%
IE	2005-2016	-149	-650	1074	-734	160	94%	72%	167%	72%	109%
	2015-2016	60	126	-41	-111	87	103%	106%	98%	95%	104%
EL	2005-2016	-1080	-1849	-343	587	525	73%	56%	95%	118%	115%
	2015-2016	-49	79	87	-76	-138	98%	103%	103%	98%	96%
ES	2005-2016	-11979	-11362	6562	2269	-9448	61%	60%	134%	114%	66%
	2015-2016	24	632	-117	69	-560	100%	103%	99%	100%	97%
FR	2005-2016	-7411	-2949	2112	1953	-8528	80%	90%	108%	107%	77%
	2015-2016	-129	-272	606	-50	-414	100%	99%	102%	100%	99%
HR	2005-2016	-473	-181	43	-39	-296	69%	85%	105%	98%	78%
	2015-2016	-2	54	-3	-10	-43	100%	105%	100%	99%	96%
IT	2005-2016	-13631	-6216	2307	3352	-13073	66%	81%	109%	113%	66%
	2015-2016	348	377	-181	36	116	101%	101%	99%	100%	100%
CY	2005-2016	-110	-45	-71	6	0	66%	73%	75%	101%	118%
	2015-2016	5	14	0	-6	-3	102%	107%	100%	97%	99%
LV	2005-2016	48	-216	181	97	-15	107%	72%	127%	118%	99%
	2015-2016	-39	-11	-26	46	-48	95%	99%	97%	106%	94%
LT	2005-2016	-65	-171	545	50	-490	94%	81%	171%	107%	63%
	2015-2016	6	39	-43	23	-13	101%	104%	96%	102%	99%
LU	2005-2016	-107	81	80	18	-285	86%	111%	112%	103%	67%
	2015-2016	33	15	-18	-10	46	105%	102%	97%	99%	107%
HU	2005-2016	850	21	377	-997	1449	125%	99%	110%	73%	158%
	2015-2016	13	108	-152	109	-52	100%	103%	96%	103%	99%
MT	2005-2016	-30	-4	10	11	-48	60%	96%	130%	116%	41%
	2015-2016	-1	2	-1	1	-3	98%	104%	98%	102%	94%
NL	2005-2016	-2340	-1467	2301	-620	-2555	86%	90%	116%	96%	85%
	2015-2016	397	50	591	-192	-52	103%	100%	104%	99%	100%
AT	2005-2016	808	-25	564	-806	1075	110%	100%	106%	91%	114%
	2015-2016	311	22	107	-160	342	103%	100%	101%	98%	104%
PL	2005-2016	162	2579	6066	-603	-7879	101%	117%	154%	96%	58%
	2015-2016	559	470	-529	479	139	104%	103%	97%	103%	101%
PT	2005-2016	-1398	-1872	1006	392	-923	75%	70%	121%	108%	82%
	2015-2016	-79	53	-16	27	-143	98%	101%	100%	101%	97%
RO	2005-2016	-3654	-1335	4381	-1243	-5457	63%	83%	168%	89%	51%
	2015-2016	-157	262	198	-330	-287	98%	104%	103%	95%	96%
SI	2005-2016	-408	-207	327	-22	-507	75%	84%	125%	101%	71%
	2015-2016	14	-14	45	46	-62	101%	99%	104%	104%	95%
SK	2005-2016	-229	188	2450	-1299	-1567	95%	103%	173%	75%	71%
	2015-2016	22	112	228	321	-639	100%	103%	105%	108%	87%
FI	2005-2016	-939	-1118	384	-738	533	92%	89%	103%	96%	105%
	2015-2016	281	160	212	-88	-3	103%	102%	102%	99%	100%
SE	2005-2016	-1366	-517	621	-753	-717	89%	95%	105%	94%	94%
	2015-2016	-110	219	165	-34	-460	99%	102%	102%	100%	96%
UK	2005-2016	-9219	-1970	2050	-2973	-6326	72%	94%	107%	89%	80%
	2015-2016	-1210	638	-183	-642	-1024	95%	103%	99%	97%	96%

3.2.3.2 Services

The services sector, representing over three quarters of the EU28 GVA in 2016, is the only productive sector of the economy whose energy consumption increased over the examined period, albeit in a fluctuating manner (Figure 9). In 2016, the energy consumption of services was above the 2005 consumption levels by +4%. The services sector became more relevant in terms of its energy consumption over the examined period, to the detriment of industry whose consumption, as discussed in section 3.2.3.1, decreased by −17% in 2005-2016. The services sector, however, remained the least intensive sector at 17 toe/EUR as opposed to the industrial energy intensity of 110 toe/EUR, and represented one third of the consumption of industry, services and agriculture combined in 2016. It, however, remains the fastest growing productive sector in the EU both in terms of energy and economic output.

The services sector is the sector with the least evident impact from the financial crisis. The decomposition results show that in this period the economic growth of the service sector (i.e. the combined effect of labour effect and labour productivity effect) was the main factor that led to the increase in total energy consumption. Specifically, labour effect (measured in hours worked) resulted an increase in consumption equivalent to +17 Mtoe, the only sector among the productive sectors of the economy with a positive trend in labour effect. Labour productivity effect was associated with a consumption growth of 6 Mtoe compared to 2005. The intensity effect restricted this growth, but to a limited extent as the improvements in energy intensity drove down consumption by −17 Mtoe, resulting to an increase in total effect of +5 Mtoe. Further examination behind the evolution of energy intensity effect of the services sector is required, specifically through the separation of intensity from structural changes and the inclusion of the weather effect. Studies suggest that space heating and cooling is a major end use in this sector, which highlights the need of taking into account the impact of the weather fluctuations in the decomposition analysis of this sector. As explained in the Methodology section, the structural effect within the services sector cannot be currently examined as the breakdown of energy consumption by service sub-sectors is not yet available. On-going efforts made by Eurostat and statistical offices to address some of these challenges ─that is breakdown of the services sector by type of activity and end use─ are welcome and will certainly strengthen the analytical capability of tools such as the LMDI method in the future.

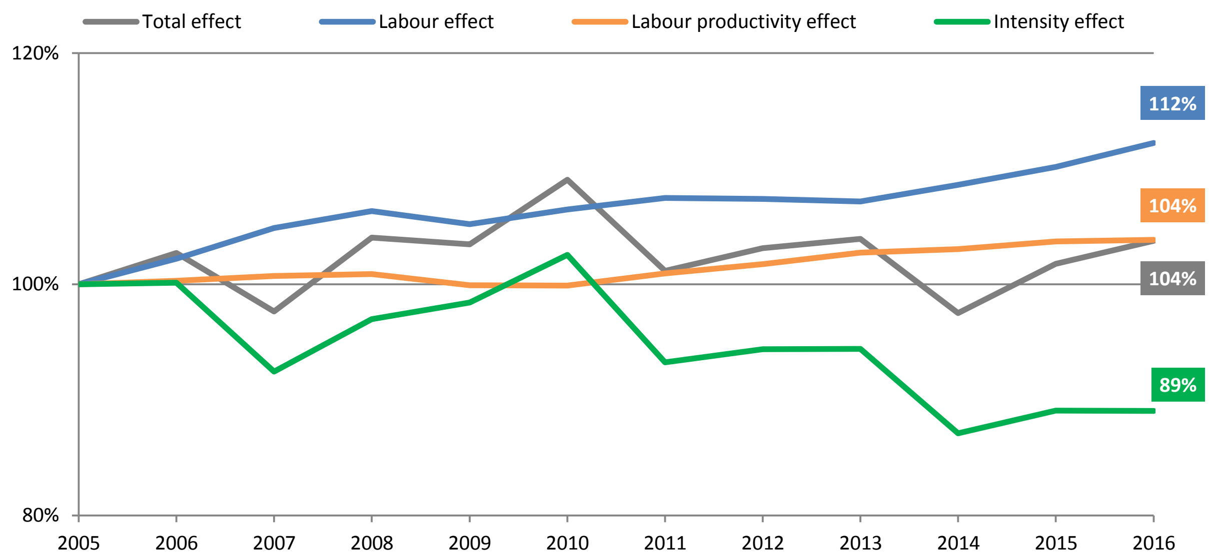

Figure 9. Yearly multiplicative LMDI decomposition results of energy consumption changes in services at EU level in 2005-2016

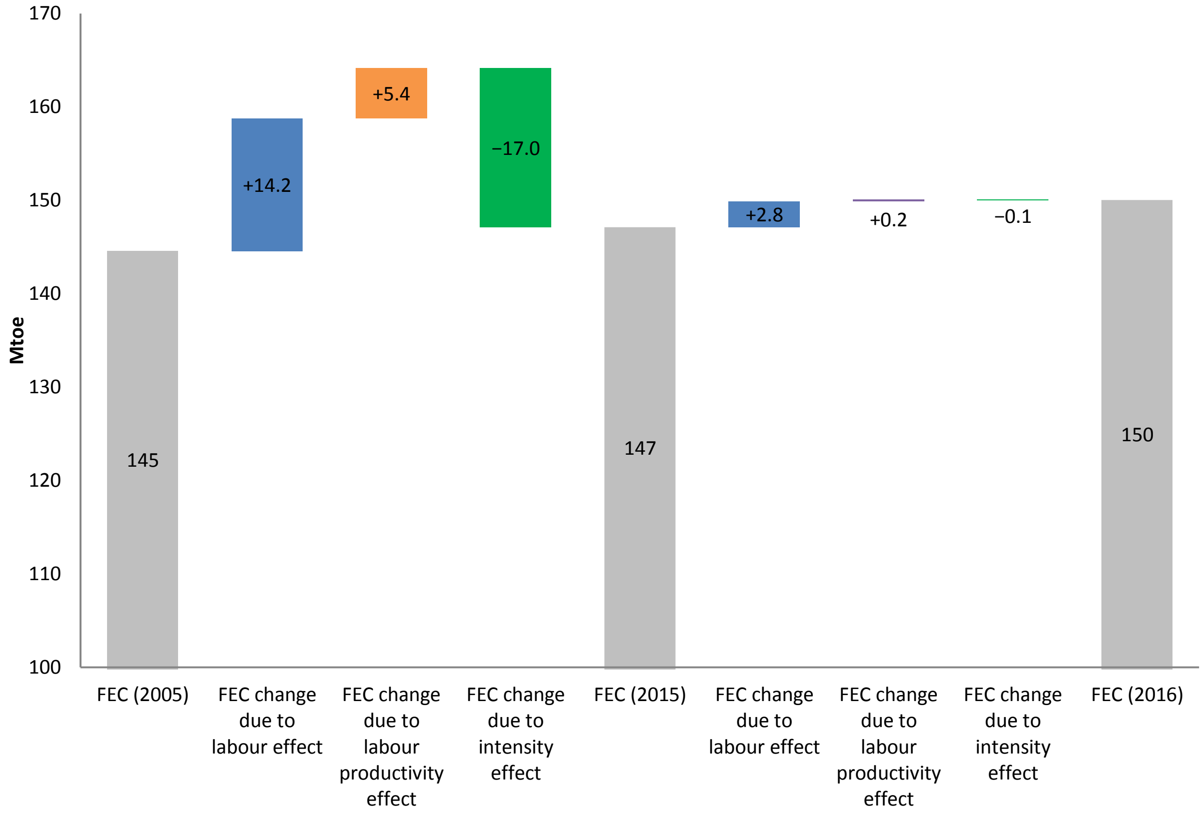

Figure 10. Decomposition of changes in EU-28 services energy consumption (Mtoe) in 2005-2016 using the additive LMDI approach

In terms of energy consumption at MS level, the services sector grew fastest in Malta (+96%), Cyprus (+40%), Bulgaria (+30%), Estonia (+27%) and Poland (+26%). The increase in consumption in Poland represented one third of the EU-wide increase in services consumption in 2005-2016. The growth of services consumption in Spain and France, although moderate at +26% and +11% respectively, each represented 41% of the EU wide increase in consumption. In total, the services consumption of 10 Member States increased in this period. On the opposite side, the consumption of services sector declined the most in Hungary (−36%), Austria (−27%), Slovakia (−25%), Ireland (−17%) and Portugal (−12%).

The decomposition results show that employment in terms of increased hours worked was one of the main drivers of services energy consumption, as the labour effect was positive in all Member States except Greece. The largest impact can be seen in Hungary, Luxembourg, Malta, Poland and Sweden. Reduction in employment in Greece resulted in a drop of consumption of −154 ktoe. Labour productivity also contributed towards growing consumption of services in 2005-2016, even though the analysis shows that labour productivity effect was positive in 20 Member States only. Labour productivity had the most profound impact as energy consumption driver in Malta, Bulgaria, Poland, Slovakia and Czech Republic and as inhibitor in Hungary, Romania, Luxembourg, Denmark and Greece. Improvements in energy intensity of services were noted in 22 Member States, and restricted growth in the services consumption at the largest extent in Slovakia, Hungary, Austria, Ireland and Sweden. Worsening of energy intensity in Greece, Cyprus, Estonia, Spain and Romania and Italy all resulted in a small increase in the consumption of the services sectors of these countries.

Table 3. Additive and multiplicative decomposition results of services energy consumption changes at MS level in 2005-2016 and 2015-2016

	Period	Additive results [ktoe]				Multiplicative results [%]			
		Total effect	Labour effect	Labour productivity effect	Intensity effect	Total effect	Labour effect	Labour productivity effect	Intensity effect
BE	2005-2016	504	641	19	-156	112%	115%	100%	97%
	2015-2016	50	72	8	-31	101%	102%	100%	99%
BG	2005-2016	251	62	262	-73	130%	107%	132%	93%
	2015-2016	83	15	22	47	108%	101%	102%	105%
CZ	2005-2016	-51	326	396	-773	98%	112%	114%	77%
	2015-2016	111	114	1	-4	104%	104%	100%	100%
DK	2005-2016	-28	135	-126	-37	99%	107%	94%	98%
	2015-2016	70	40	-10	39	104%	102%	100%	102%
DE	2005-2016	808	3121	1840	-4153	102%	110%	106%	88%
	2015-2016	-715	409	129	-1254	98%	101%	100%	96%
EE	2005-2016	105	21	44	41	127%	105%	112%	108%
	2015-2016	29	6	8	15	106%	101%	102%	103%
IE	2005-2016	-276	126	-31	-370	83%	111%	102%	73%
	2015-2016	64	39	38	-13	105%	103%	103%	99%
EL	2005-2016	89	-154	-110	354	105%	92%	94%	120%
	2015-2016	163	17	-52	198	109%	101%	97%	111%
ES	2005-2016	2211	1132	614	465	126%	114%	106%	104%
	2015-2016	607	266	30	311	106%	103%	100%	103%
FR	2005-2016	2259	2262	1034	-1037	111%	111%	105%	95%
	2015-2016	457	413	-34	78	102%	102%	100%	100%
HR	2005-2016	70	49	34	-14	110%	108%	104%	98%
	2015-2016	20	7	12	1	103%	101%	102%	100%
IT	2005-2016	387	532	-457	312	103%	104%	97%	102%
	2015-2016	49	354	-267	-38	100%	102%	98%	100%
CY	2005-2016	65	31	14	19	140%	116%	106%	114%
	2015-2016	19	8	-1	12	109%	104%	100%	106%
LV	2005-2016	-2	34	27	-63	100%	104%	106%	91%
	2015-2016	6	4	14	-11	101%	101%	102%	98%
LT	2005-2016	43	74	75	-106	108%	113%	113%	84%
	2015-2016	28	30	-12	10	105%	105%	98%	102%
LU	2005-2016	63	137	-24	-50	117%	143%	94%	88%
	2015-2016	28	13	0	15	107%	103%	100%	104%
HU	2005-2016	-1270	1555	-1326	-1499	64%	176%	63%	58%
	2015-2016	27	101	-35	-39	101%	105%	98%	98%
MT	2005-2016	61	36	44	-19	196%	143%	157%	87%
	2015-2016	-2	11	-2	-11	98%	109%	98%	92%
NL	2005-2016	-125	813	443	-1381	98%	113%	106%	82%
	2015-2016	253	153	-22	122	104%	102%	100%	102%
AT	2005-2016	-960	278	273	-1511	73%	109%	109%	62%
	2015-2016	12	59	-21	-26	100%	102%	99%	99%
PL	2005-2016	1777	1730	1280	-1233	126%	126%	117%	86%
	2015-2016	675	74	317	285	109%	101%	104%	104%
PT	2005-2016	-256	156	-7	-406	88%	108%	100%	82%
	2015-2016	-22	34	-4	-52	99%	102%	100%	97%
RO	2005-2016	137	318	-279	98	108%	118%	89%	104%
	2015-2016	44	23	23	-2	103%	101%	101%	100%
SI	2005-2016	17	71	8	-62	104%	118%	102%	86%
	2015-2016	38	5	9	24	108%	101%	102%	105%
SK	2005-2016	-442	242	268	-952	75%	115%	116%	56%
	2015-2016	9	17	13	-21	101%	101%	101%	98%
FI	2005-2016	243	215	39	-11	109%	108%	101%	100%
	2015-2016	147	15	37	95	105%	101%	101%	103%
SE	2005-2016	6	832	410	-1236	100%	122%	111%	74%
	2015-2016	298	145	-19	172	107%	104%	100%	104%
UK	2005-2016	-228	2153	817	-3198	99%	114%	105%	82%
	2015-2016	363	314	21	27	102%	102%	100%	100%

3.2.3.3 Agriculture

Agriculture is the smallest sector among the productive sectors of the EU economy (industry, services and agriculture), accounting for just 6% of the final energy consumption and 2% of gross value added of these combined sectors in 2016. Agriculture represents the most energy intensive end-use sector with its energy intensity amounting to 150 toe/EUR[11]; over a third higher than the intensity of industry in 2016. As shown in Figure 11, the agricultural energy consumption fell by 9% over the period 2005-2016. In terms of GVA, the agriculture grew at the same rate as the industry at around +5% overall in the examined period.

Labour has been on a gradual declining trend since 2005, reflecting a negative labour effect throughout the examined period. In 2016, this has been the largest inhibitor of the agricultural energy consumption (−6 Mtoe), more than the intensity effect (−4 Mtoe). On the other hand, rapid improvements in labour productivity have been a major driver of energy consumption (+7 Mtoe in 2016 compared to 2005). The opposite forces exerted by the labour and labour productivity effects may point out to the fact that production processes in the agricultural sector are most likely becoming less labour-intensive and more capital-intensive instead. The intensity effect has overall had an inhibitor effect on the agricultural sector. As in the case of services, it is not possible to study structural shifts within the agricultural sector and their impact of structural changes on the consumption of the agricultural sector.

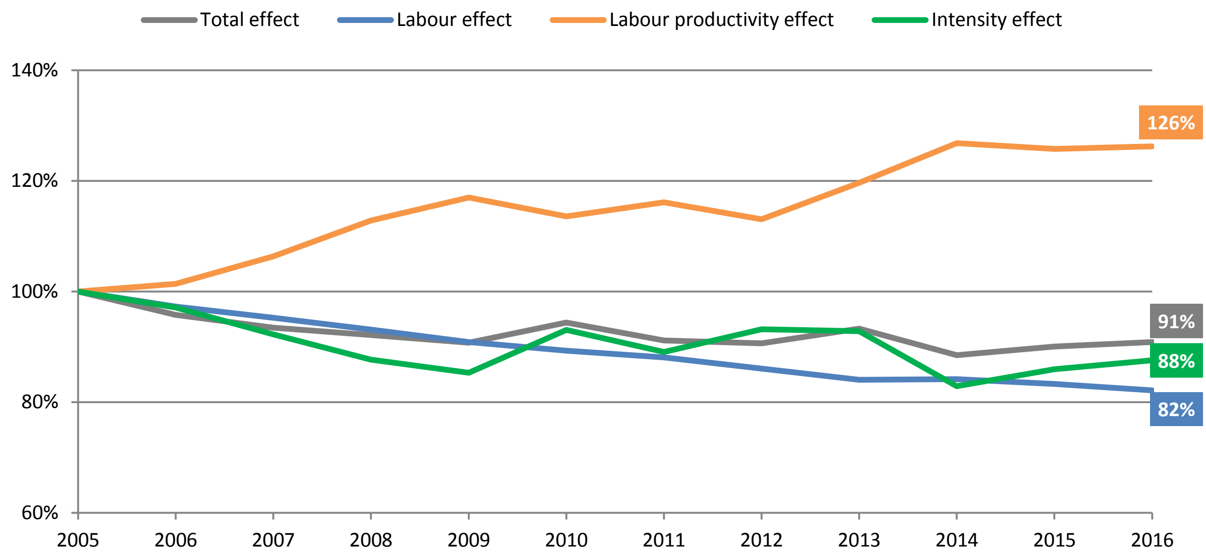

Figure 11. Yearly multiplicative LMDI decomposition results of agricultural energy consumption changes at EU level in 2005-2016

[11] In contrast, industry's energy intensity amounted to 110 toe/EUR

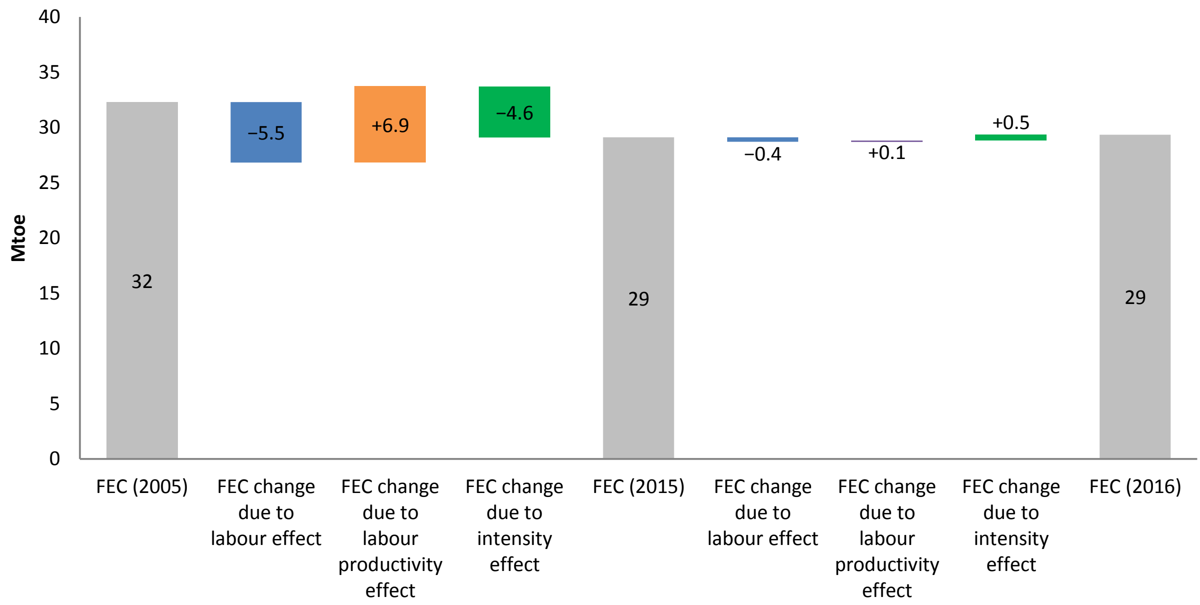

Figure 12. Decomposition of changes in EU-28 agricultural energy consumption (Mtoe) in 2005-2016 using the additive LMDI approach

In terms of energy consumption at MS level, the agricultural sector grew fastest in Romania, UK, Estonia, Cyprus and Germany. Except Romania's agricultural sector whose consumption more than doubled over the period 2005-2016, all other countries had a consumption growth ranging from 18 to 24%. In total, the agricultural energy consumption of 16 Member States increased in this period. The EU-wide consumption was mainly driven by a drop in consumption in Poland (−9 Mtoe), Greece (−9 Mtoe), Spain (−5 Mtoe), Italy (−5 Mtoe) and Sweden (−5 Mtoe).

The decomposition results show that employment in terms of fewer hours worked was one of the main inhibitor of energy consumption in all Member States except Luxembourg, Malta, Sweden and the UK. The largest drop in consumption due to reduction in employment is observed in Croatia (−47%), Lithuania (−41%), Romania (−41%), Portugal (−33%) and Austria (−30%). As in the case with the EU-wide results, labour productivity was a main driver of consumption growth in the agriculture across many EU countries. This was indeed the case for all Member States except Bulgaria, Greece, Cyprus, Luxembourg and the UK. Labour productivity had the most profound impact as energy consumption driver in Slovakia, Lithuania, Estonia, Finland and Latvia. Improvements in energy intensity were noted in 20 Member States, with largest inhibiting impact in Greece, Sweden, Ireland, Slovakia and Spain. On the other hand, energy intensity drove up the consumption of the agricultural sectors in Romania, Cyprus, Luxembourg, Czech Republic, Germany, UK, Croatia, Hungary and Malta. Further investigation to identify the extent to which structural shifts have contributed to these intensity effects is necessary in the future.

Table 4. Additive and multiplicative decomposition results of agriculture energy consumption changes at MS level in 2005-2016 and 2015-2016

	Period	**Additive results [ktoe]**				**Multiplicative results [%]**			
		Total effect	Labour effect	Labour productivity effect	Intensity effect	Total effect	Labour effect	Labour productivity effect	Intensity effect
BE	2005-2016	-42	-109	72	-5	95%	87%	109%	99%
	2015-2016	51	27	-98	122	107%	104%	88%	118%
BG	2005-2016	-119	-36	-26	-56	61%	84%	95%	77%
	2015-2016	-1	-7	17	-10	100%	96%	109%	95%
CZ	2005-2016	93	-60	18	136	117%	90%	102%	128%
	2015-2016	34	-4	25	13	106%	99%	104%	102%
DK	2005-2016	-109	-236	287	-160	87%	76%	140%	82%
	2015-2016	-5	-27	18	4	99%	97%	102%	101%
DE	2005-2016	582	-720	302	1000	118%	83%	111%	127%
	2015-2016	-490	-139	50	-401	89%	97%	101%	91%
EE	2005-2016	23	-28	54	-4	122%	74%	182%	90%
	2015-2016	-5	5	-31	22	96%	104%	79%	118%
IE	2005-2016	-155	-17	92	-230	59%	96%	146%	42%
	2015-2016	-14	6	18	-39	94%	103%	108%	85%
EL	2005-2016	-870	-117	-113	-639	25%	87%	93%	30%
	2015-2016	12	-6	-20	38	104%	98%	93%	114%
ES	2005-2016	-463	-569	1272	-1166	85%	81%	159%	66%
	2015-2016	150	93	110	-53	106%	104%	104%	98%
FR	2005-2016	-181	-995	1018	-204	96%	80%	125%	96%
	2015-2016	17	-21	-570	608	100%	100%	88%	114%
HR	2005-2016	-9	-146	94	43	96%	53%	151%	119%
	2015-2016	3	-27	44	-13	101%	89%	121%	94%
IT	2005-2016	-451	-348	415	-518	86%	89%	115%	84%
	2015-2016	19	57	-51	14	101%	102%	98%	100%
CY	2005-2016	8	-13	-7	27	120%	73%	85%	193%
	2015-2016	3	0	2	1	106%	100%	104%	102%
LV	2005-2016	23	-51	73	0	115%	71%	166%	97%
	2015-2016	15	-10	-7	32	109%	94%	96%	121%
LT	2005-2016	0	-60	78	-17	100%	59%	195%	87%
	2015-2016	6	-10	4	11	106%	91%	104%	111%
LU	2005-2016	2	3	-8	6	107%	113%	74%	129%
	2015-2016	0	0	-2	2	102%	102%	94%	106%
HU	2005-2016	90	-166	227	29	116%	73%	145%	110%
	2015-2016	71	-10	86	-5	112%	98%	115%	99%
MT	2005-2016	1	1	0	0	113%	107%	101%	104%
	2015-2016	1	1	0	1	112%	109%	95%	108%
NL	2005-2016	-303	-347	981	-938	93%	91%	130%	78%
	2015-2016	100	33	51	16	103%	101%	101%	100%
AT	2005-2016	22	-181	242	-39	104%	70%	162%	92%
	2015-2016	5	-4	18	-9	101%	99%	103%	98%
PL	2005-2016	-892	-1171	984	-704	80%	73%	131%	84%
	2015-2016	207	-260	363	105	106%	93%	111%	103%
PT	2005-2016	-159	-178	187	-169	73%	67%	152%	71%
	2015-2016	-19	-18	2	-3	96%	96%	100%	99%
RO	2005-2016	239	-225	223	241	211%	59%	159%	223%
	2015-2016	-5	-50	71	-26	99%	90%	117%	94%
SI	2005-2016	-2	-18	30	-13	98%	77%	150%	84%
	2015-2016	-1	0	0	-2	99%	100%	101%	98%
SK	2005-2016	-17	-36	121	-101	90%	78%	232%	50%
	2015-2016	-2	-1	11	-12	99%	99%	108%	92%
FI	2005-2016	-34	-207	431	-259	95%	76%	176%	71%
	2015-2016	-11	-50	99	-60	98%	93%	115%	92%
SE	2005-2016	-454	20	40	-515	43%	103%	105%	40%
	2015-2016	-24	-20	3	-7	94%	95%	101%	98%
UK	2005-2016	225	116	-88	198	124%	113%	89%	123%
	2015-2016	137	40	-103	200	113%	104%	91%	120%

3.3 Transport

Taking into account all transport modes, transport energy consumption remained relatively stable with a recorded **−0.5% drop in consumption** in the period 2005-2016. Air transport consumption alone increased by nearly 7% over this period, however this was compensated by a drop in consumption of all other transport modes: inland waterways transport consumption fell by nearly a quarter (−24%), rail transport consumption by −17% and road transport consumption by −0.4%. The EU-wide stable overall transport consumption trend is not reflected at MS level as only 12 Member States recorded a drop in their transport energy consumption, while the consumption in all other Member States has increased in 2005–2016. Countries with the most pronounced increase in their overall transport energy consumption included Poland (+53%), Romania (+41%), Lithuania (+36.8%) and Slovenia (+27.6%). In contrast, transport consumption decline was more evident in Greece (−17%), Italy (−13%), Luxembourg (−13%) and Spain (−12%).

In relation to the EU passenger transport, the year-on-year results are shown in Figure 13. While the total effect has been on a declining trend for a consecutive 6-year period starting from 2007, this trend was completely reversed in 2014. In 2016, the passenger transport consumption increased by over 5% since the lowest recorded consumption in 2013, and 1% compared to 2005. The influence of the economic recession on the passenger transport is evident from the subtle decline in activity effect (measured in passenger kilometres) in the period 2008-2012. Since 2013, the activity effect has had a strong positive drive on the overall energy consumption. Indeed the activity effect is the only driver of passenger transport consumption, and, as seen from the results, this is only partially compensated by the intensity and modal shift effects. Notably, while a constant shift towards cleaner transport modes (i.e. negative modal shift effect) is noted at EU level for the entire period, this is rather marginal. The intensity effect has been mostly negative throughout the study period, albeit fluctuating with the biggest drop in 2012-2013. In 2016, intensity gains were responsible for a −5% drop in the overall consumption. The latest change in EU passenger transport consumption is captured in Figure 14. As in the last couple of years, activity effect in 2016 continued to play a dominant role in driving up energy consumption to the extent that modal shift changes and energy intensity improvements were not sufficient to offset this increase, resulting to a +1% increase of overall passenger transport consumption compared to 2005 levels.

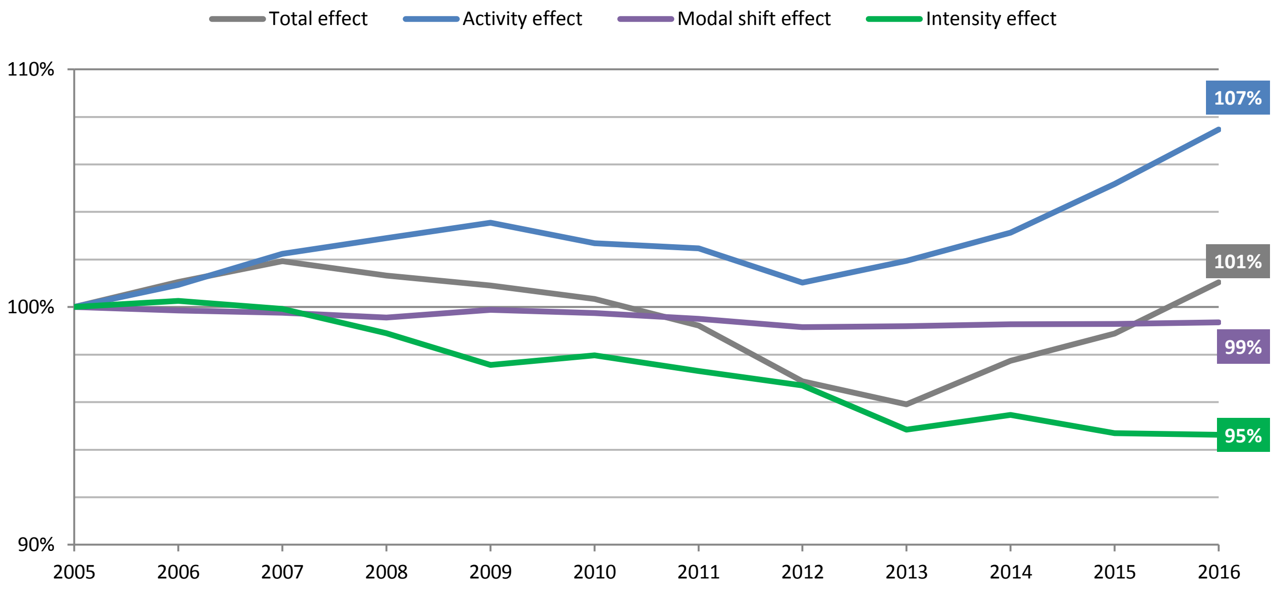

Figure 13. Yearly multiplicative LMDI decomposition results of passenger transport energy consumption changes at EU level in 2005-2016

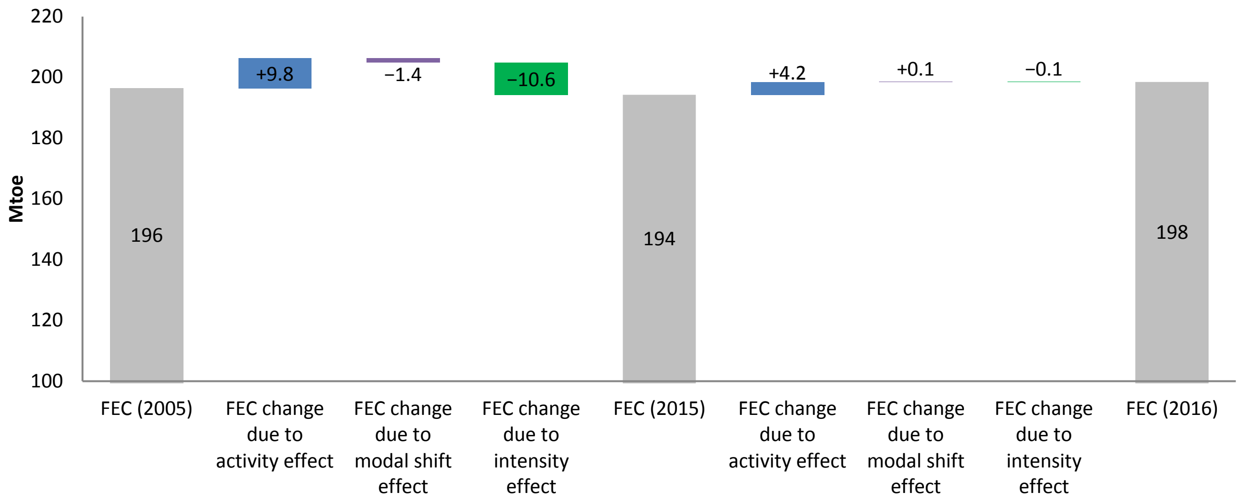

Figure 14. Decomposition of changes in EU-28 passenger transport energy consumption (Mtoe) in 2005-2016 using the additive LMDI approach

At Member State level, most countries experienced growth in their passenger energy consumption except Greece, Italy, Luxembourg, the Netherlands, Austria and Portugal which experienced a drop of −25%, −16%, −10%, −12% and −20%, respectively (Table 5). Poland and Romania, on the other hand, had a considerable increase in passenger transport at +73% and +41%. More frequent and/or longer passenger trips constituted a driving force in most Member States except Spain, Lithuania, the Netherlands and Finland. In Lithuania this had the highest impact (−26%), while in Spain, the Netherlands and Finland this constituted to a much milder impact (less than −5%). A shift to cleaner modes was noted in just over half of the Member States: Bulgaria, Czech Republic, Germany, Ireland, Spain, France, Italy, Lithuania, Luxembourg, the Netherlands, Austria, Portugal, Finland, Sweden and the UK. These countries experienced relatively moderate shifts, corresponding to a −3% (or less) reduction in consumption compared to 2005 levels, except Bulgaria where the modal shift effect drove down consumption by −7%. Improvements in intensity were registered in all Member States except the Czech Republic, Spain, Croatia, Latvia, Lithuania, Poland, Slovenia, Slovakia and Finland.

With regards to the EU freight transport, the total energy consumption at EU level (Figure 15) is on a recovering trajectory following a decline in 2008-2013. Negative activity effect (i.e. lower tonne kilometres) noted in this period was the main reason behind the decline, even though intensity effect has also played some role in driving down consumption in certain years. While the latest freight transport consumption has yet to reach the pre-2008 levels, it has been rising since 2014. In 2016, the EU consumption was just −5% below the 2005 levels. Improvements in energy intensity were not a strong contributing factor for the reduction in freight transport's consumption and in several years (e.g. 2006, 2009, 2011, 2014, 2015, 2016) worsening of energy intensity (i.e. positive intensity effect) was registered. Fluctuations in the modal shift effect are also noted, albeit milder ones, during the entire period 2005-2016.

Table 5. Additive and multiplicative decomposition results of passenger transport energy consumption changes at MS level in 2005-2016 and 2015-2016

	Period	Additive results [ktoe]				Multiplicative results [%]			
		Total effect	Activity effect	Modal shift effect	Intensity effect	Total effect	Activity effect	Modal shift effect	Intensity effect
BE	2005-2016	311	55	65	190	106%	101%	101%	104%
	2015-2016	26	-79	23	82	100%	99%	100%	102%
BG	2005-2016	353	611	-137	-120	119%	138%	93%	93%
	2015-2016	57	-17	-8	81	103%	99%	100%	104%
CZ	2005-2016	459	391	-145	213	112%	110%	97%	105%
	2015-2016	166	190	-36	13	104%	105%	99%	100%
DK	2005-2016	115	394	35	-315	104%	115%	101%	89%
	2015-2016	34	83	11	-60	101%	103%	100%	98%
DE	2005-2016	659	3760	-95	-3007	102%	111%	100%	92%
	2015-2016	922	803	-10	129	102%	102%	100%	100%
EE	2005-2016	61	101	7	-47	115%	125%	101%	91%
	2015-2016	15	6	5	3	103%	101%	101%	101%
IE	2005-2016	142	588	-54	-392	106%	128%	98%	85%
	2015-2016	-44	154	-12	-186	98%	107%	99%	93%
EL	2005-2016	-993	476	128	-1597	75%	112%	103%	65%
	2015-2016	94	32	9	53	103%	101%	100%	102%
ES	2005-2016	1935	-163	-120	2219	113%	98%	99%	116%
	2015-2016	934	582	21	331	106%	104%	100%	102%
FR	2005-2016	275	2394	-596	-1523	101%	109%	98%	95%
	2015-2016	-131	634	90	-856	100%	102%	100%	97%
HR	2005-2016	144	100	15	29	111%	108%	101%	102%
	2015-2016	31	5	-5	31	102%	100%	100%	102%
IT	2005-2016	-4050	722	-6	-4766	84%	104%	100%	81%
	2015-2016	-269	716	99	-1085	99%	103%	100%	95%
CY	2005-2016	28	124	6	-102	107%	131%	101%	80%
	2015-2016	15	19	0	-4	103%	104%	100%	99%
LV	2005-2016	56	9	39	8	110%	104%	107%	99%
	2015-2016	16	11	3	2	103%	102%	100%	100%
LT	2005-2016	257	-298	-1	556	130%	74%	100%	175%
	2015-2016	88	34	1	53	109%	103%	100%	105%
LU	2005-2016	-147	301	-15	-433	90%	123%	99%	74%
	2015-2016	-58	33	2	-93	96%	102%	100%	93%
HU	2005-2016	242	159	115	-31	110%	107%	105%	98%
	2015-2016	152	66	16	69	106%	103%	101%	103%
MT	2005-2016	26	24	2	0	129%	126%	102%	100%
	2015-2016	1	4	0	-3	101%	103%	100%	98%
NL	2005-2016	-883	-202	-159	-522	88%	97%	98%	93%
	2015-2016	-145	76	-11	-211	98%	101%	100%	97%
AT	2005-2016	-73	795	-95	-773	99%	116%	98%	87%
	2015-2016	93	140	6	-53	102%	103%	100%	99%
PL	2005-2016	4311	1325	461	2525	173%	118%	106%	139%
	2015-2016	1111	160	-45	996	112%	102%	100%	111%
PT	2005-2016	-813	182	-9	-986	80%	107%	100%	75%
	2015-2016	1	235	-2	-232	100%	108%	100%	93%
RO	2005-2016	898	1007	137	-246	141%	146%	105%	92%
	2015-2016	230	178	9	43	108%	106%	100%	101%
SI	2005-2016	355	187	8	160	135%	117%	101%	115%
	2015-2016	96	22	2	73	108%	102%	100%	106%
SK	2005-2016	117	14	17	85	112%	102%	102%	108%
	2015-2016	84	27	-5	62	108%	103%	99%	106%
FI	2005-2016	89	-131	-40	260	104%	95%	98%	111%
	2015-2016	108	-291	-36	434	105%	89%	99%	119%
SE	2005-2016	97	442	-122	-222	102%	109%	98%	96%
	2015-2016	215	104	6	104	104%	102%	100%	102%
UK	2005-2016	-1919	704	-699	-1924	93%	103%	97%	93%
	2015-2016	403	313	-5	95	102%	101%	100%	100%

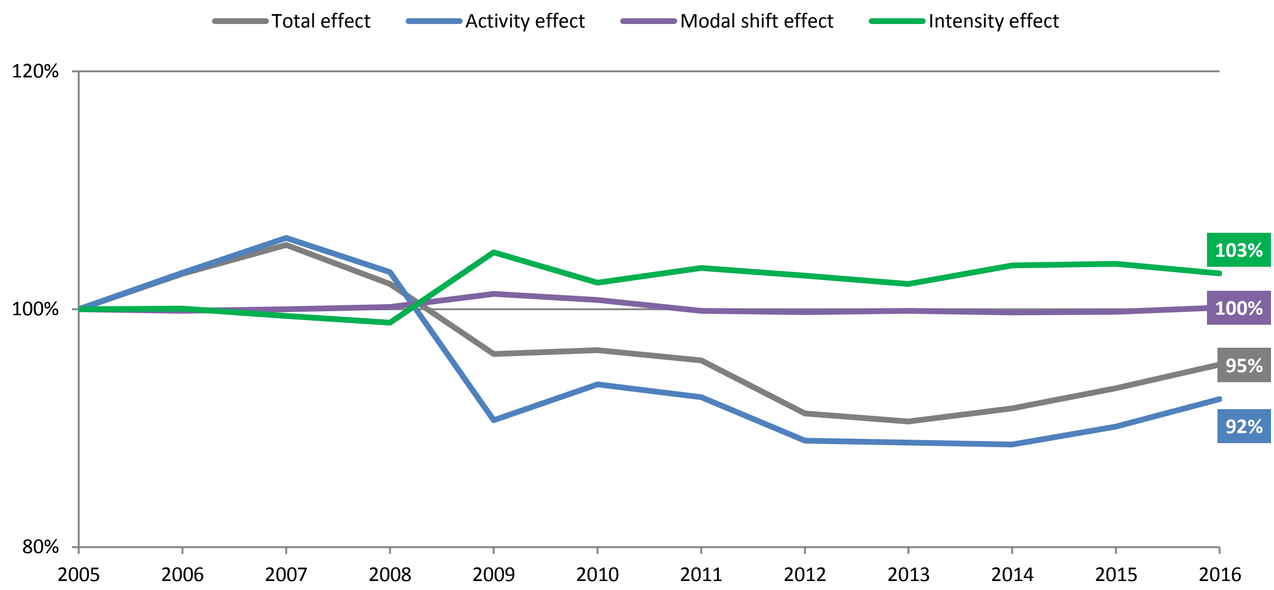

Figure 15. Yearly multiplicative LMDI decomposition results of freight transport energy consumption changes at EU level in 2005-2016

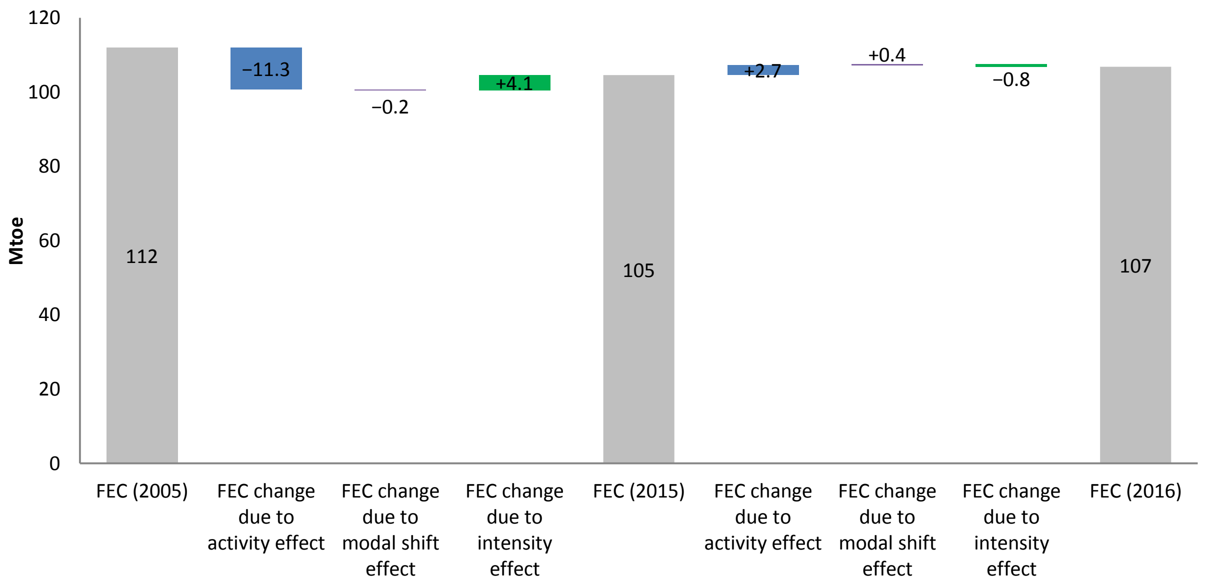

Figure 16. Decomposition of changes in EU-28 freight transport energy consumption (Mtoe) in 2005-2016 using the additive LMDI approach

The results at MS level are shown in Table 6. Freight transport energy consumption dropped in half of the EU28 Member States in 2005-2016. The largest drops were registered in Spain (−38%), Luxembourg (−36%), Denmark (−27%), Cyprus (−24%), and Ireland (−17%). On the opposite side, freight transport consumption increased considerably in Slovakia (+53%), Bulgaria (+48%), Lithuania (+43%), Romania (+40%) and Poland (+31%). The activity effect was a main driver of freight transport consumption in Bulgaria, Czech Republic, Germany, Greece, Croatia, Latvia, Lithuania, Luxembourg, Hungary, Poland, Slovenia, Slovakia and Sweden. In most of these countries (except Latvia, Luxembourg and Greece[12]), modal shift and intensity improvements were not enough to offset the positive activity effect in this period. The largest positive activity effect is found in Poland, Bulgaria, Slovenia, Lithuania and Hungary. On the opposite side, Cyprus, Estonia, Italy, Ireland and Belgium all had strong negative activity effects.

A shift to cleaner transport modes is noted in 10 Member States (Belgium, Denmark, Germany, France, Italy, Lithuania, the Netherlands, Austria, Portugal and Finland), while improvements in energy intensity are observed in 13 Member States (Bulgaria, Estonia, Greece, Spain, Croatia, Latvia, Lithuania, Luxembourg, Hungary, Malta, Poland, Slovenia and Slovakia).

[12] The activity effect of these countries was relatively small (Table 6).

Table 6. Additive and multiplicative decomposition results of freight transport energy consumption changes at MS level in 2005-2016 and 2015-2016

	Period	**Additive results [ktoe]**				**Multiplicative results [%]**			
		Total effect	Activity effect	Modal shift effect	Intensity effect	Total effect	Activity effect	Modal shift effect	Intensity effect
BE	2005-2016	95	-1043	-119	1257	103%	73%	97%	145%
	2015-2016	72	-76	-15	163	102%	98%	100%	105%
BG	2005-2016	280	499	105	-323	148%	199%	116%	64%
	2015-2016	-6	67	9	-82	99%	108%	101%	91%
CZ	2005-2016	270	204	31	36	116%	113%	102%	101%
	2015-2016	76	-225	-56	357	104%	89%	97%	120%
DK	2005-2016	-394	-465	-71	142	73%	74%	95%	104%
	2015-2016	32	33	5	-6	103%	103%	100%	99%
DE	2005-2016	1548	986	-528	1091	110%	107%	97%	107%
	2015-2016	452	18	25	409	103%	100%	100%	103%
EE	2005-2016	-1	-171	173	-3	100%	55%	179%	101%
	2015-2016	8	-10	24	-6	103%	97%	109%	98%
IE	2005-2016	-216	-641	6	419	83%	64%	100%	128%
	2015-2016	13	163	1	-151	101%	117%	100%	86%
EL	2005-2016	-203	7	29	-239	91%	102%	101%	88%
	2015-2016	20	443	7	-430	101%	124%	100%	81%
ES	2005-2016	-6877	-1389	28	-5517	62%	93%	100%	67%
	2015-2016	-211	362	36	-609	98%	103%	100%	95%
FR	2005-2016	-1339	-3877	-118	2656	92%	77%	99%	121%
	2015-2016	120	45	147	-71	101%	100%	101%	100%
HR	2005-2016	49	56	36	-43	110%	111%	107%	92%
	2015-2016	15	37	6	-27	103%	107%	101%	95%
IT	2005-2016	-1777	-7248	-944	6414	87%	58%	93%	163%
	2015-2016	-353	-204	-227	78	97%	98%	98%	101%
CY	2005-2016	-61	-141	0	80	76%	50%	100%	151%
	2015-2016	17	42	0	-25	109%	125%	100%	87%
LV	2005-2016	-33	34	139	-206	92%	107%	139%	62%
	2015-2016	-21	-45	23	2	95%	90%	106%	100%
LT	2005-2016	216	261	89	-135	143%	158%	116%	78%
	2015-2016	26	70	31	-74	104%	110%	104%	90%
LU	2005-2016	-323	23	9	-355	64%	104%	101%	61%
	2015-2016	5	29	1	-24	101%	105%	100%	96%
HU	2005-2016	8	668	116	-776	100%	148%	106%	64%
	2015-2016	1	76	-2	-73	100%	104%	100%	96%
MT	2005-2016	0	0	0	0	100%	100%	100%	100%
	2015-2016	1	0	0	1	101%	100%	100%	101%
NL	2005-2016	-427	-653	-65	291	88%	83%	98%	108%
	2015-2016	54	-35	-6	94	102%	99%	100%	103%
AT	2005-2016	-242	-357	-336	451	90%	85%	86%	123%
	2015-2016	27	82	-22	-34	101%	104%	99%	98%
PL	2005-2016	1886	5257	1178	-4549	131%	211%	118%	53%
	2015-2016	853	690	98	66	112%	110%	101%	101%
PT	2005-2016	-88	-352	-37	300	96%	84%	98%	117%
	2015-2016	34	188	9	-163	102%	109%	100%	93%
RO	2005-2016	716	-173	55	834	140%	91%	102%	151%
	2015-2016	175	385	100	-310	107%	117%	104%	88%
SI	2005-2016	55	241	22	-208	112%	162%	104%	67%
	2015-2016	13	22	0	-9	103%	104%	100%	98%
SK	2005-2016	398	325	117	-45	153%	139%	113%	98%
	2015-2016	129	63	15	51	113%	106%	101%	105%
FI	2005-2016	87	-215	-46	348	106%	87%	97%	124%
	2015-2016	65	154	-6	-83	104%	110%	100%	95%
SE	2005-2016	272	168	87	17	111%	106%	103%	101%
	2015-2016	112	80	-4	37	104%	103%	100%	101%
UK	2005-2016	886	-672	243	1314	107%	94%	102%	112%
	2015-2016	482	205	181	96	104%	102%	101%	101%

3.3.1 Air transport

In the period 2005-2016, energy consumption of the EU28 **air transport** as a whole increased by 3.3 Mtoe, corresponding to a +**7% increase** compared to 2005 levels (Figure 17). As in the case with other sectors of the economy, the increasing trend in consumption came to a halt in 2008 as a result of the change in the activity effect trend linked to the impact of the financial crisis. For air transport, this plateaued for several years after 2008, and only in the past two years, the activity effect has ramped up to pre-2008 levels. Productivity (expressed as tonnes/flights) increased over the time, which was a major driving force of the air transport consumption. These were mostly counterbalanced by i**mprovements in energy intensity, which contributed to a reduction** of −13 Mtoe over the study period. The latter has been consistently an inhibitor force of the air transport consumption since the beginning of the examined period.

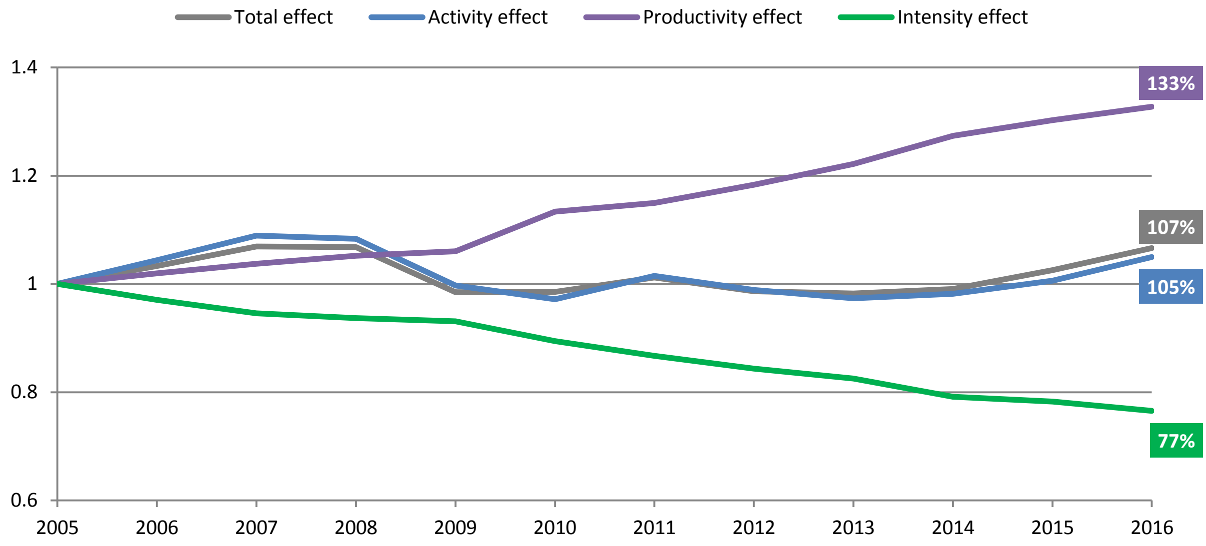

Figure 17. Yearly multiplicative LMDI decomposition results of air transport energy consumption changes at EU level in 2005-2016

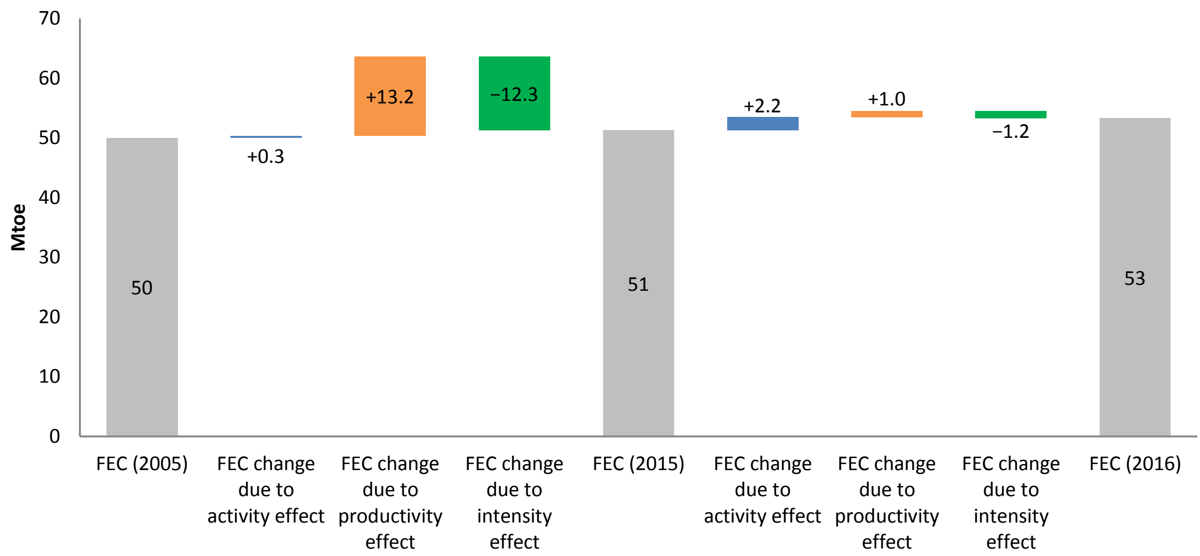

Figure 18. Decomposition of changes in EU-28 air transport energy consumption (Mtoe) in 2005-2016 using the additive LMDI approach

At MS level, air transport consumption increased in all but 7 Member States (Estonia, Greece, Cyprus, Hungary, Slovenia, Slovakia and the UK). Countries with the most pronounced decline in air transport energy consumption included Estonia (−55%), Hungary (−27%), Cyprus (−10%) and Greece (−10%). In contrast, air transport consumption more than doubled in Romania (+132%), Poland (+119%), Latvia (+109%), and Lithuania (+103%). The activity effect contributed to an increase in consumption in all countries except the Czech Republic, France, Hungary, Austria, Slovenia, Slovakia and Finland where lower air transport activity in 2005-2016 caused a drop in energy consumption. Productivity in terms of goods/passengers transferred per flight has increased in all countries, leading to an increase in energy consumption. This had most dominant impact in Romania, Poland and Lithuania. Likewise, intensity improvements caused a drop in energy consumption in all countries, with the most notable results in Estonia, Hungary, Poland, Romania and Slovakia.

Table 7. Additive and multiplicative decomposition results of air transport energy consumption changes at MS level in 2005-2016 and 2015-2016

	Period	Additive results [ktoe]				Multiplicative results [%]			
		Total effect	Activity effect	Productivity effect	Intensity effect	Total effect	Activity effect	Modal shift effect	Intensity effect
BE	2005-2016	157	287	373	-503	112%	127%	132%	67%
	2015-2016	-14	-90	62	14	99%	94%	104%	101%
BG	2005-2016	30	67	47	-83	115%	137%	129%	65%
	2015-2016	42	36	5	1	122%	119%	102%	100%
CZ	2005-2016	14	-49	117	-54	104%	86%	142%	85%
	2015-2016	26	18	13	-5	108%	105%	104%	99%
DK	2005-2016	81	13	422	-355	109%	101%	159%	68%
	2015-2016	68	31	39	-2	107%	103%	104%	100%
DE	2005-2016	1112	240	2706	-1834	113%	103%	136%	81%
	2015-2016	653	221	89	343	107%	102%	101%	104%
EE	2005-2016	-27	12	8	-47	45%	130%	121%	28%
	2015-2016	-3	0	0	-3	88%	100%	101%	87%
IE	2005-2016	8	83	191	-266	101%	106%	128%	74%
	2015-2016	23	70	9	-55	103%	108%	101%	94%
EL	2005-2016	-113	211	159	-483	90%	121%	119%	63%
	2015-2016	77	62	20	-5	108%	106%	102%	100%
ES	2005-2016	698	333	1324	-959	113%	106%	127%	84%
	2015-2016	389	403	191	-205	107%	107%	103%	97%
FR	2005-2016	379	-623	2837	-1835	106%	90%	155%	76%
	2015-2016	-68	156	86	-310	99%	102%	101%	95%
HR	2005-2016	36	41	33	-38	136%	140%	132%	74%
	2015-2016	7	13	3	-9	106%	111%	103%	93%
IT	2005-2016	290	217	1352	-1278	108%	106%	142%	72%
	2015-2016	142	160	54	-72	104%	104%	101%	98%
CY	2005-2016	-30	18	48	-95	90%	107%	119%	71%
	2015-2016	32	45	-4	-10	113%	119%	99%	96%
LV	2005-2016	64	58	30	-23	209%	203%	133%	77%
	2015-2016	16	-1	6	10	114%	99%	105%	109%
LT	2005-2016	49	27	47	-25	203%	145%	222%	63%
	2015-2016	14	6	4	4	118%	107%	105%	105%
LU	2005-2016	81	38	101	-58	119%	109%	127%	86%
	2015-2016	56	32	12	11	112%	107%	103%	102%
HU	2005-2016	-71	-56	130	-146	73%	79%	186%	50%
	2015-2016	18	12	13	-7	110%	107%	107%	96%
MT	2005-2016	37	26	35	-23	142%	126%	141%	80%
	2015-2016	9	5	6	-2	108%	104%	105%	99%
NL	2005-2016	245	717	476	-948	107%	122%	114%	77%
	2015-2016	70	223	46	-199	102%	106%	101%	95%
AT	2005-2016	115	-44	262	-103	117%	94%	145%	86%
	2015-2016	62	-9	19	52	109%	99%	103%	107%
PL	2005-2016	385	346	360	-321	219%	224%	201%	49%
	2015-2016	40	12	64	-36	106%	102%	110%	95%
PT	2005-2016	398	421	279	-302	145%	148%	131%	75%
	2015-2016	117	121	31	-35	110%	110%	103%	97%
RO	2005-2016	181	28	273	-120	232%	116%	362%	55%
	2015-2016	47	43	12	-8	117%	116%	104%	97%
SI	2005-2016	-1	-6	10	-5	96%	82%	145%	81%
	2015-2016	-4	0	0	-4	84%	99%	99%	86%
SK	2005-2016	-2	-9	30	-23	96%	80%	196%	61%
	2015-2016	6	5	0	1	114%	111%	100%	103%
FI	2005-2016	177	-73	324	-74	134%	91%	163%	90%
	2015-2016	2	-45	69	-21	100%	94%	110%	97%
SE	2005-2016	149	67	343	-261	117%	108%	148%	73%
	2015-2016	127	27	23	78	115%	103%	102%	109%
UK	2005-2016	-1122	179	1913	-3214	91%	102%	117%	77%
	2015-2016	101	672	117	-689	101%	106%	101%	94%

3.4 Residential

In the period 2005-2016, energy consumption of the EU28 **residential sector** as a whole decreased by 25 Mtoe, corresponding to a **drop of −8%** compared to 2005 levels (Figure 19). **Improvements in energy intensity contributed to a reduction** of −61 Mtoe in this sector (−20% compared to 2005 consumption levels). **Warmer winters** over this period resulted in an energy consumption **drop** of −13 Mtoe in 2016 compared to 2005. Both of these effects more than offset the driving forces behind residential consumption, namely the population and wealth effects which together accounted for an increase of 50 Mtoe in the same period. At MS level, residential consumption dropped in all but 9 Member States. Countries with the most pronounced decline in residential energy consumption included Greece (−22%), Latvia (−24%), Slovakia (−21%), Portugal (−18%) and Belgium (−18%). In contrast, residential consumption increased in Malta (+14%), Bulgaria (+7%), Austria (+6%), Czech Republic (+5%), Estonia (+5%) and Finland (+5%), Cyprus (+3%), Poland (+2%) and Sweden (+2%).

In 2015-2016, a small increase in consumption (+11 Mtoe) was recorded at EU level. Based on the decomposition results, this increase was driven by all effects: an increase in consumption due to colder weather with respect to 2015 (equivalent to +4.5 Mtoe), an increase in intensity effect (+1.8 Mtoe) and increase in population and wealth effects (both at +1 Mtoe). Indeed, residential consumption increased in most countries in 2016 compared to 2015 except in Belgium, Ireland, Greece, Croatia, Italy and Luxembourg.

The yearly results (Figure 20) show a strong correlation between the weather and total effects, indicating the strong impact the weather effect has on the total energy consumption of the residential sector. Both population and wealth effects have been on constant rise in the period 2005-2016, while the opposite is true for intensity effect. The intensity gains represent the factor that contributed the most to the drop in the overall residential consumption.

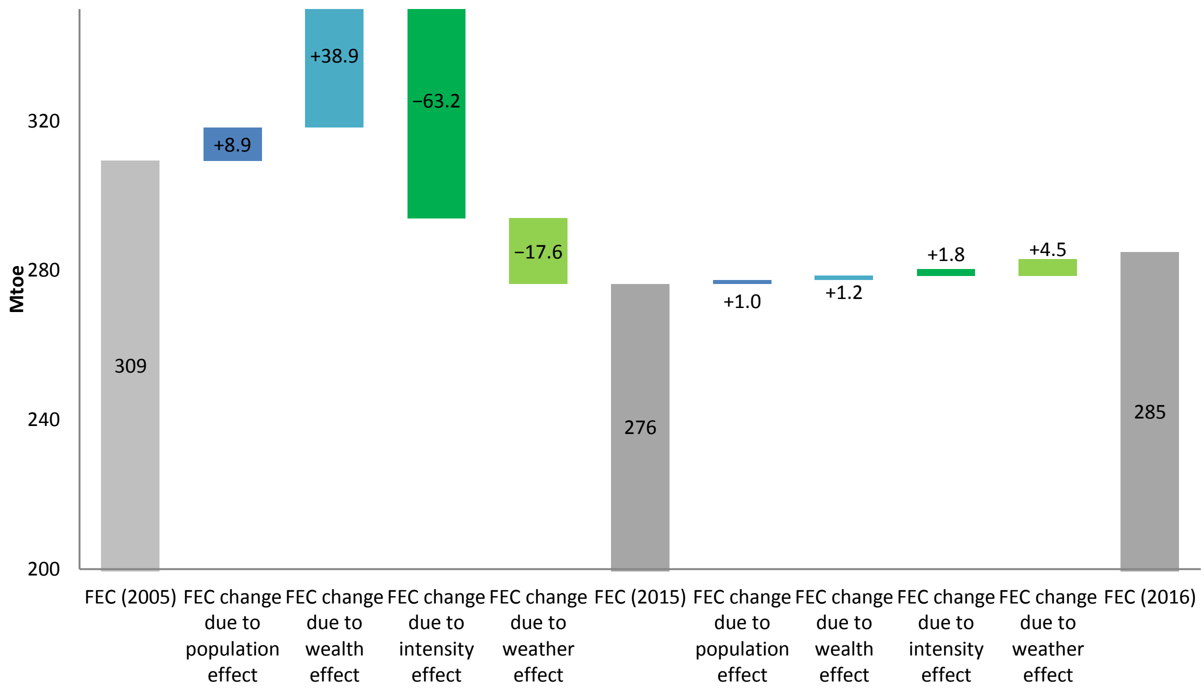

Figure 19. Decomposition of changes in EU-28 residential energy consumption (Mtoe) in 2005-2016 using the additive LMDI approach

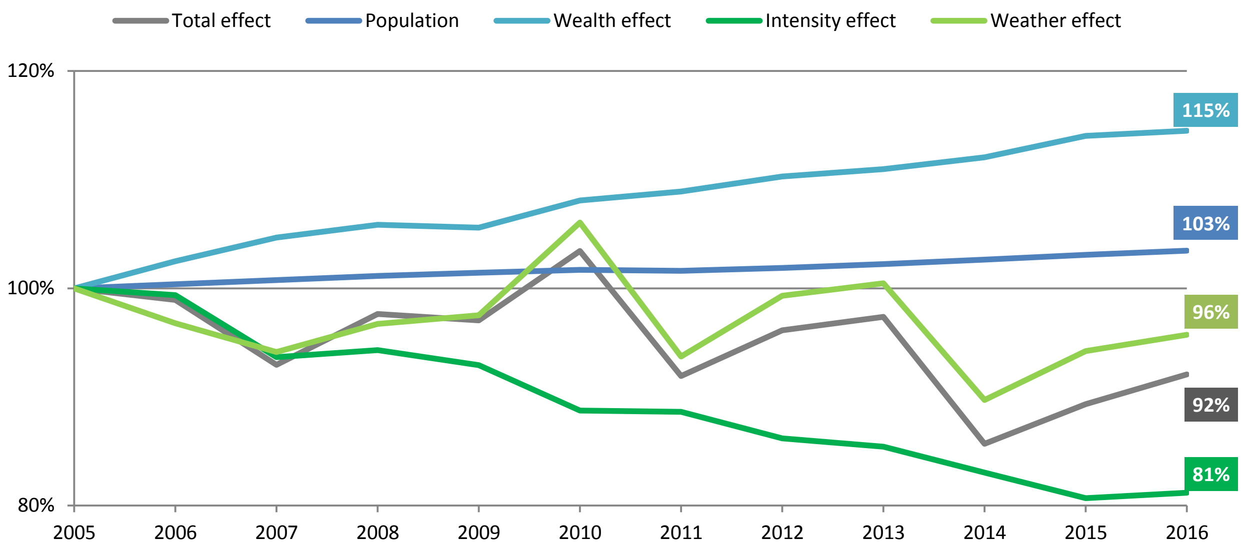

Figure 20. Yearly multiplicative LMDI decomposition results of residential energy consumption changes at EU level in 2005-2016

As shown in Table 8, residential energy consumption dropped or remained stable in most Member States. In 2005-2016, Malta was the only country whose residential energy consumption grew at the fastest rate (+13%), followed by Bulgaria (+6%). Finland, Austria, Czech Republic, Estonia, Cyprus, Sweden Poland and the UK experience a slight increase of 5% or less. In all other countries, residential energy consumption dropped, with the most pronounced decline observed in Latvia (−24%), Greece (−20%), Slovakia (−20%), Portugal (−19%) and Belgium (−18%).

The decomposition results show that intensity and weather effects were the two main factors restricting energy consumption growth in the residential sector in most of these countries. Intensity acted as a limiting factor in 27 Member States, while weather in 22 Member States. The largest impact energy intensity improvements had on the residential sectors can be seen in Luxembourg, Belgium, Slovakia, Romania, Latvia, Ireland and the UK. The only country which recorded worsening of energy intensity (and thereby energy intensity acted as a driver of consumption) was Italy. Following the relatively warm winter of 2014, heating degree days at EU level continued to increase in 2016, up by +4% compared to 2015 and +8% compared to 2014. Despite the fact that 2016 was a relatively colder year relative to 2015 in all countries except Ireland, Greece, Italy, Cyprus, Malta and United Kingdom, this was not enough to shift the overall trend of negative weather effect in the entire period 2005-2016. Indeed, the weather effect in 2005-2016 drove down consumption in all counties except Ireland, UK, Belgium, the Netherlands, and Finland. The largest drop in residential energy consumption due to warmer winters in 2005-2016 was noted in Malta (−55%), Italy (−19%), Croatia (−16%), Greece (−15%) and Slovenia (−14%). On the opposite side, the population and wealth effects were the main determinants of growth in residential energy consumption in many Member States in 2005-2016. The population effect was positive in all countries except Germany, Croatia, Latvia, Lithuania, Luxembourg, Hungary, Portugal and Romania. In Luxembourg, Cyprus, Ireland, Malta and Sweden, the population effect was associated with over +20% increase in residential energy consumption. The wealth effect was a driver in all countries except Greece, with the highest impact in Romania, Bulgaria, Lithuania, Poland and Estonia.

Table 8. Additive and multiplicative decomposition results of residential energy consumption changes at MS level in 2005-2016 and 2015-2016

	Period	Additive results [ktoe]					Multiplicative results [%]				
		Total effect	Population effect	Wealth effect	Intensity effect	Weather effect	Total effect	Population effect	Wealth effect	Intensity effect	Weather effect
BE	2005-2016	-1790	671	623	-3153	70	82%	117%	122%	38%	101%
	2015-2016	-28	41	-12	-187	130	100%	101%	99%	93%	102%
BG	2005-2016	137	-158	934	-500	-138	106%	87%	244%	63%	90%
	2015-2016	59	-16	84	-34	25	103%	99%	108%	97%	102%
CZ	2005-2016	342	228	1203	-633	-455	105%	107%	155%	94%	91%
	2015-2016	307	13	70	-8	231	105%	100%	101%	100%	105%
DK	2005-2016	12	243	740	-860	-111	100%	112%	146%	64%	96%
	2015-2016	166	34	-22	134	20	104%	102%	99%	104%	101%
DE	2005-2016	-7452	-197	9485	-14839	-1902	88%	100%	143%	51%	95%
	2015-2016	2875	441	-84	1295	1223	105%	102%	100%	103%	103%
EE	2005-2016	40	-27	288	-200	-20	105%	94%	197%	62%	97%
	2015-2016	72	0	12	10	50	108%	100%	103%	104%	111%
IE	2005-2016	-287	396	252	-1011	76	90%	131%	119%	47%	105%
	2015-2016	-44	30	2	21	-97	98%	102%	100%	98%	94%
EL	2005-2016	-1223	-74	-267	-548	-334	78%	96%	90%	84%	85%
	2015-2016	-113	-18	-51	144	-189	97%	99%	97%	108%	93%
ES	2005-2016	-69	985	1611	-1747	-919	100%	113%	125%	78%	88%
	2015-2016	187	12	106	-278	346	101%	100%	101%	96%	105%
FR	2005-2016	-3090	2432	3603	-7848	-1278	93%	113%	124%	64%	96%
	2015-2016	1745	156	-38	98	1529	105%	101%	100%	101%	106%
HR	2005-2016	-422	-81	540	-568	-313	85%	94%	161%	59%	84%
	2015-2016	-22	-20	56	-74	16	99%	98%	105%	92%	101%
IT	2005-2016	-1737	1495	722	994	-4947	95%	109%	108%	120%	81%
	2015-2016	-309	-55	119	206	-579	99%	100%	101%	100%	97%
CY	2005-2016	9	49	41	-75	-5	103%	133%	134%	66%	89%
	2015-2016	9	1	3	21	-17	103%	101%	102%	118%	92%
LV	2005-2016	-360	-183	381	-516	-43	76%	77%	189%	39%	96%
	2015-2016	38	-10	21	-31	58	103%	98%	104%	97%	108%
LT	2005-2016	-69	-224	561	-353	-53	95%	75%	228%	57%	95%
	2015-2016	75	-18	74	-62	81	106%	97%	109%	95%	109%
LU	2005-2016	-35	111	94	-243	3	93%	157%	135%	35%	100%
	2015-2016	-18	11	-2	-43	16	97%	104%	98%	81%	104%
HU	2005-2016	-818	-172	672	-750	-568	88%	95%	135%	68%	89%
	2015-2016	187	-18	130	-116	191	103%	99%	104%	96%	104%
MT	2005-2016	9	9	24	-11	-13	113%	127%	158%	85%	45%
	2015-2016	3	2	2	6	-7	104%	105%	102%	162%	59%
NL	2005-2016	-889	452	1284	-2592	-33	92%	109%	127%	59%	101%
	2015-2016	298	52	-39	154	131	103%	101%	99%	103%	102%
AT	2005-2016	324	363	578	-72	-545	105%	113%	127%	114%	88%
	2015-2016	169	67	10	-38	129	103%	102%	100%	98%	103%
PL	2005-2016	293	-104	5993	-4540	-1057	102%	99%	206%	61%	93%
	2015-2016	830	-8	304	-155	689	104%	100%	103%	99%	106%
PT	2005-2016	-603	-42	328	-844	-46	81%	97%	127%	90%	92%
	2015-2016	82	-8	-18	-34	142	103%	99%	98%	95%	115%
RO	2005-2016	-575	-614	4006	-3399	-568	93%	85%	314%	39%	90%
	2015-2016	40	-42	486	-622	219	101%	99%	115%	84%	105%
SI	2005-2016	-41	38	101	-50	-129	97%	107%	124%	101%	86%
	2015-2016	37	1	5	16	15	103%	100%	101%	102%	102%
SK	2005-2016	-510	23	455	-832	-155	80%	102%	168%	38%	90%
	2015-2016	43	3	2	-10	48	102%	100%	100%	101%	104%
FI	2005-2016	272	242	848	-837	19	105%	110%	150%	69%	101%
	2015-2016	394	15	8	175	196	108%	101%	100%	108%	106%
SE	2005-2016	157	684	1108	-1637	2	102%	121%	140%	62%	100%
	2015-2016	265	92	137	-136	172	104%	103%	103%	97%	104%
UK	2005-2016	-6184	3357	3863	-13753	348	86%	118%	122%	48%	102%
	2015-2016	1122	268	-182	1331	-293	103%	101%	99%	107%	99%

4 Conclusions

This study applied the logarithmic-mean Divisia index method to study both aggregated and sectoral energy consumption changes at both EU and MS levels over the period 2005–2016. The LMDI-I decomposition analysis has enabled to determine the influence on the energy consumption change exerted by the different effects considered in this study.

In 2005-2016, the EU28 primary energy consumption decreased by 10% with the largest contribution from the UK, Italy, France, Germany and Spain. While the gap between 2016 consumption and the 2020 energy efficiency target amounts to only 60 Mtoe, the EU28 primary energy consumption has been on a rising trend since 2014. Belgium, Italy, Spain, Germany and Poland contributed to around two thirds of the EU-wide consumption increase encountered in 2014-2016.

The main driver behind the overall primary energy decline in 2005-2016 was the drop in final energy demand, followed by the transformation efficiency effect and efficiency improvements in distribution losses and own energy sector consumption. While the EU share of renewable energy grew considerably over the examined period, the shift towards higher shares of electricity acted as a counteracting effect, leading to a moderate transformation efficiency effect impact. The final energy demand remained the most decisive explanatory factor behind the decrease in primary energy consumption, despite the hike of just over +2% over the period 2014-2016 which is mainly attributed to a hike seen in final energy demand. Over the entire period 2005-2016, final energy demand has been declining, with the most important drops found in the industry, residential and agricultural sectors.

In terms of individual end-use sectors, the intensity effect has been shown to be the main dominant driver in reducing final energy demand, while the activity effect counteracted this effect. For industry, the sharp reduction in energy demand was mainly explained by the reduced activity observed in 2008-2009, linked to the EU economic recession. Activity generally drove up energy consumption since then, indicating a recovery from the recession. While labour (in terms of hours worked) contributed a reduction in industrial energy consumption, a considerable increase in labour productivity consistently drove up energy demand in 2005-2016. In 2016, the combined labour and labour productivity effects contributed to an increase in final energy consumption of industry equivalent to +7% relative to 2005 consumption levels. Over the whole period analysed, the structural effect has been shown to have a secondary importance in terms of limiting energy consumption, although our analysis showed that the specific grouping of subsectors has a decisive impact on the structural effect results. Our analysis also indicates that the use of GVA seems to generally overestimate efficiency improvements as the negative IPI-based intensity effect is of lower magnitude compared to the GVA-based one. This work highlights the of more detailed industrial physical index data that will allow a more comprehensive use of physical-based indicators in decomposition analysis in the future.

In terms of the other productive sectors of the economy, the services sector was the only sector whose energy consumption increased over the examined period. Economic growth was the main factor that led to the increase in total energy consumption of the service sector with both labour and labour productivity effect contributing to this growth. The services sector is also the sector with the least economic recession impact. While the intensity effect restricted this growth, this was not enough to counteract the overall augmentative activity effect. Further examination behind the evolution of energy intensity effect of the services sector is strongly recommended, through the separation of intensity from structural changes and the inclusion of the weather effect. The energy consumption of the agricultural sector, the smallest productive sector of the EU economy fell by −9% in 2005-2016. The main factor contributing to this change was the labour and intensity effects. In 2016, the labour effect was the largest inhibitor of the agricultural energy consumption. On the other hand, rapid improvements in labour productivity have been a major driver of energy consumption, indicating the fact that production processes in the agricultural sector are most likely becoming less labour-intensive and more capital-intensive instead.

Transport energy consumption remained relatively stable in 2005-2016, with a marginal increase in passenger energy consumption, a drop in freight energy consumption and a more considerable growth of air transport consumption. In general, the activity effect played a dominant role in driving up energy consumption, despite the moderate influence of the economic recession on the passenger transport in 2008-2012. In 2016, modal shift changes towards cleaner transport modes and energy intensity improvements were not sufficient to offset the increase in passenger transport energy consumption, resulting to a +1% increase of the consumption compared to 2005 levels. With regards to the EU freight transport, the total EU energy consumption is on a recovering trajectory following a decline in 2008-2013, mainly driven by the negative activity effect noted in this period including 2016. Improvements in energy intensity were not a strong contributing factor for the reduction in freight transport's consumption and in several years (including 2014-2016) worsening of energy intensity was observed. The modal shift effect had a minimal impact on freight consumption in the entire period 2005-2016.

In terms of the residential sector, the main factor contributing to the drop of −8% compared to 2005 levels was found to be the intensity effect. A strong correlation between the weather and total effects is also found, indicating the decisive impact the weather effect has on the total energy consumption of the residential sector. Both population and wealth effects are found to be positive in the period 2005-2016, however these have been counterbalanced mainly by the decreasing intensity effect. Future investigation can include the impact of appliances on residential energy consumption as well as the inclusion of the cooling effect.

While the overall results of the decomposition analysis offered valuable insights into the factors behind recent consumption trends at both EU and MS levels, this study has also highlighted the need for further investigation to provide a more comprehensive analysis. To strengthen the analytical framework of tools such as the LMDI method, this research has shown that finer levels of disaggregation are necessary to conduct more detailed decomposition as disaggregated data are often accompanied with various data gaps and quality issues. Sectors with significant challenges include the transport sector as no full compatibility is currently offered between energy and activity data, and the services sector as the breakdown of energy consumption by subsector and end use is currently not available in official statistics. The JRC welcomes on-going efforts made by Eurostat and national statistical offices that aim to increase the level of detail in their statistics. In the future, it also plans to consider alternative databases which are fully compliant with the EUROSTAT energy balances but provide very detailed annual information on the energy system and its underlying drivers such as the JRC Integrated Database of the European Energy System (JRC-IDEES).

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