ISSN 1831-9424

European Commission

Assessing the impact of Energy Efficiency on the EU Energy Consumption by using an index decomposition analysis in 2010-2021

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2024

Joint Research Centre

EUR 31971 EN

EU Science Hub
https://joint-research-centre.ec.europa.eu

JRC136466

EUR 31971 EN

PDF ISBN 978-92-68-17991-8 ISSN 1831-9424 doi:10.2760/96121 KJ-NA-31-971-EN-N

Luxembourg: Publications Office of the European Union, 2024

How to cite this report: European Commission, Joint Research Centre, Clementi, E., Tsemekidi-Tzeinaraki, S. and Bertoldi, P., Assessing the impact of Energy Efficiency on the EU Energy Consumption by using an index decomposition analysis in 2010-2021, Publications Office of the European Union, Luxembourg, 2024, https://data.europa.eu/doi/10.2760/96121, JRC136466.

Contents

Abstract

To track and understand the progress towards 2030 energy efficiency targets, this report examines the determinants of changes in primary and final energy consumption at EU27 and Member States levels over the period 2010 to 2021. Energy consumption trends are driven by several factors beyond energy efficiency improvements, which can have a profound effect in the aggregate energy use, irrespective of the impact of energy efficiency policies and measures. To understand the latest energy consumption trends in the EU, the Logarithmic-Mean Divisia Index (LMDI) method, a widely used Index Decomposition Analysis (IDA) method, was applied to study both aggregated and sectoral energy consumption changes at EU and Member States levels over the examined period and quantify the impact of factors such as economic activity, demography, productivity, lifestyle and weather changes. The results suggest that there have been important energy efficiency gains during the studied period, without which the progress achieved towards 2030 EU energy efficiency targets would have been difficult to attain. However, the results have been considerably influenced by both the exceptional year 2020, characterised by the global COVID-19 pandemic and the rebound effect occurred in 2021. With the aim to investigate the impact of COVID-19 pandemic on energy consumption, an analysis at European, country and sectoral level has been carried out. The analysis showed that the stringency index (an indicator expressing the stringency of the lockdown measures) affected the electricity consumption at Member State level, while among the different sectors, transport was the most affected one by the pandemics, while on the other hand, the residential sector was not significantly affected.

Executive summary

Policy context

Energy efficiency plays an integral role in the EU energy policy, with the 2030 target on energy efficiency expected to contribute towards a long-term vision for a climate neutral Europe. This target aims to accelerate energy efficiency efforts across the EU, while contributing to the decoupling of economic growth from future energy demand. The new 2030 binding targets for energy efficiency (to be achieved at EU level with the contribution of each of the 27 Member State) in the recast of the Energy Efficiency Directive (EED recast) that entered into force on 10 October 2023, are equal to 992.5 Mtoe for primary energy consumption and 763 Mtoe for final energy consumption. The primary energy consumption measures the total energy demand of a country. It covers consumption of the energy sector itself, losses during transformation (for example, from oil or gas into electricity) and distribution of energy, and the final consumption by end users (Tsemekidi Tzeiranak et. al., 2022).

This report is created in the context of monitoring the progress towards the 2030 EU energy targets defined by the Article 4 of the EED Recast. Monitoring progress towards the targets requires the identification 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.

To examine the progress towards the 2030 targets on energy efficiency, this report identifies and measures the impact of the main determinants of changes in primary and final energy consumption over the period 2010 to 2021. The study covers all EU27 Member States.

Main findings

In 2010-2021, the combined primary energy consumption (PEC) of the EU27 fell by −10%. Considering the decomposition of primary energy consumption changes in this period, it was found that lower final energy demand was the most decisive explanatory factor behind the decrease in primary energy consumption (-5%), followed by efficiency improvements in transformation (-2%), distribution and own energy sector systems (-3%).

Accounting for over 27% of the total final energy consumption (FEC), the productive sectors of the economy (industry, services and agriculture) followed a declining trend in terms of energy consumption in 2010-2021, with a total drop in consumption equivalent to a -4%. Industry experienced the smallest decline (-2%), followed by the service sector (-11%), while agriculture registered an increase of +11%. Considering the activity indicators separately (employment1 and labour productivity2), different trends are revealed. Labour productivity was a major driver in energy consumption in all productive sectors of the economy, with the highest relative impact in agriculture (+20%), followed by industry (+12%) and then services (+11%). On the other hand, the employment effect (Labour factor) was negative only in industry and service sectors. For services, the increase in the labour force was accompanied by higher labour productivity, which can be explained by an

[1] Calculated as the total number of hours worked.

[2] Gross Value Added (GVA)/total number of hours worked (L).

increase in the economic activity, but also by an improvement of the capital investment, that enables higher production.

The energy efficiency gains, associated with the productive sectors of the European economy during the examined period based on the above analysis, were also attained if a production-based indicator was used as proxy to energy efficiency. However, the comparison between decomposition analysis results using production-based units and monetary-based units for industry showed that the use of gross value added (GVA) generally overestimated efficiency improvements. Despite this, our analysis using the production-based units still indicate a strong inhibitor effect exerted by the production-based energy efficiency proxy (albeit of lower magnitude: -10% production-based versus -15% monetary-based against 2010 consumption levels).

Regarding the residential sector (corresponding to 26% of the total final energy consumption), a strong correlation between weather (HDD/HDD_{ref}[3]) and total effects was found, indicating the decisive impact of weather fluctuations on the overall energy consumption of the sector. The weather effect alone contributed to a reduction of -8% in 2010-2021. However, the biggest factor contributing to the residential final energy consumption decline of −8% compared to 2010 levels was found to be the intensity effect[4] (-14%), which counterbalanced the combined positive effects of population and wealth (+15% in total during the studied period). Among the residential drivers of final consumption, the wealth effect had the biggest impact (+13% compared to 2010 levels versus +2% associated with the population effect). Both of these effects represented a progressively increasing driving force of consumption over the years for the sector.

Finally, the transport sector's consumption (responsible for the remaining final energy consumption) increased in 2021. In 2020 it has been the most affected sector by the worldwide pandemic among the ones considered in this report; however, in 2021 we observe a reverse trend (rebound effect) due to the progressive end of the circulation restrictions. The energy consumption decreased by -5% in the period 2010-2021. In the examined period, passenger transport experienced a decrease of -4%, while freight transport increase of 3.8%, while a drop of -32% in air transport was observed. Considering the two main subsectors, passenger and freight transport (collectively covering the modes of rail, road and inland waterways) and air transport[5] as a separate sector, the decomposition results reveal different trends for some effects. In particular, activity (passenger-kilometres or tonnes-kilometres) drove up the consumption of all of them. Modal shift was negative for both passenger and freight transport. Energy efficiency reduction observed in both subsectors during the examined period, especially thanks to the rebound effect in 2021. With regard to air transport, the activity and productivity (expressed as tonnes/flights) effects constituted major driving forces of a consumption increase, while it has been observed a negative intensity effect in 2021 after a strong increase in 2020. The latter has consistently been an inhibitor force of air transport consumption since the beginning of the examined period until 2019 and in 2021.

The time period considered in this analysis allows to confirm the impact of the COVID-19 pandemic crisis occurred in 2020. Moreover, considering the most updated data at 2021, it has been possible to assess whether there was a rebound effect and calculate its intensity eventually in the different

[3] Heating Degree Days (HDD)/Heating Degree Days reference (HDD_{ref}).

[4] FEC_i (Final Energy Consumption)/GVA_i (Gross Value Added).

[5] Decomposed separately due to current statistical data limitations.

sectors. Results at country level differ for each of the studied sectors; these are presented and discussed in detail in the main body of the report.

Related and future JRC work

Various international organisations, research institutes and national agencies deploy decomposition analysis as a tool to inform policy makers in the field of energy analysis. 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 2010-2021. The results of the decomposition analysis offer valuable insights into the factors behind recent consumption trends at both EU and Member States 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 categories with energy consumption and monetary output data in national accounts. Future investigation can include the impact of appliances on residential energy consumption, the consideration of weather effect (including the distinction between heating and cooling) for more sectors. 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 EU27, 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 Member State levels over the period 2010-2021 in this report. All applications were run using the latest available Eurostat data[6], with a few exceptions where data from other sources were considered (namely, Odyssee database, JRC, DG MOVE pocketbook data and OECD library data). Based on the analysis conducted, the primary energy consumption trends in 2010-2021 were decomposed into final energy demand, transformation and distribution/energy sector effects. Changes in final energy consumption of end use sectors (industry, services, agriculture, transport and residential) were decomposed separately to best reflect the particularities of each sector and their specific underlying driving forces.

[6] Old methodology data from Energy Balances extracted in April 2022.

1 Introduction

As part of its 2050 decarbonisation objectives, the EU has set even more ambitious targets for 2030 to reduce primary and final energy consumption. The amended Energy Efficiency Directive[7] set an EU energy efficiency target for 2030 of at least 32.5% (compared to the 2030 baseline of the 2007 Reference scenario), with a clause for a possible upwards revision by 2023. However, as part of the Green Deal and the 'Fit for 55' package, the Commission adopted in July 2021 a proposal for a recast of the Energy Efficiency Directive.

The EED recast, that entered into force on 10 October 2023[8] sets more ambitious 2030 energy consumption targets, corresponding to a consumption reduction of -11.7% compared to the 2030 baseline of the 2020 Reference scenario at EU level. These are equal to a primary energy consumption of 992.5 Mtoe and a final energy consumption of 763 Mtoe by 2030.

The analysis of energy consumption trends is therefore essential in assessing policy impact and informing policy makers in the context of EU decarbonisation goals. 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 rely on energy savings and efficiency measures 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.

From 2010 to 2021, EU energy consumption followed a decreasing trend. The decrease in energy consumption was accompanied with an overall drop in energy intensity and energy consumption per capita, reflecting a possible increase in competitiveness in the same period. However, comparing the last year available (2021) to the previous one (2020) (Tsemekidi Tzeiranaki et. al., 2022), both primary and final energy consumption increased again reaching at 1,311 Mtoe (primary energy consumption) and 968 Mtoe (final energy consumption), still far from the 2030 energy efficiency targets.

After showing a decreasing trend since 2010, primary energy consumption started to growth again in 2015 (+1.7% with respect to 2014) and peaked in 2017. As of 2018, primary energy consumption started to fall again, reaching in 2020 the lowest values in the time period considered, 1,236 Mtoe (-15.2% compared to 2010). In 2021, it increased again by an annual growth rate of 6.1%. Final energy consumption followed the same pattern of PEC. It decreased till 2014 and started to rise from 2015 to 2018. As of 2019, final energy consumption started to fall again, reaching in 2020 the value of 906 Mtoe (-11.5% compared to 2010). In 2021, it increased again by an annual growth rate of +6.9%. The rebound effects of both energy consumption indicators were widely expected in 2021. The year 2020, heavily affected by the global pandemic, meant an exceptional fall (in some cases a complete stop) of the energy consumption in all sectors of the Member States (productive, residential and transport sectors). What is relevant in this study is to understand in which sectors the rebound effect has been stronger what effects contributed to the consumption growth.

[7] EU2018/2002.

[8] https://www.consilium.europa.eu/en/press/press-releases/2023/03/10/council-and-parliament-strike-deal-on-energy-efficiency-directive/

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.

To track and understand the progress towards the 2030 energy efficiency targets, this report examines the determinants of changes in primary and final energy consumption at EU and Member States levels over the period 2010-2021. The year 2021 represents the latest available year covered by energy balance statistics. This report builds up from the previous reports published by the EC Joint Research Centre (Economidou, 2017; Economidou and Román-Collado, 2019; Economidou, 2021) 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 applied in this report to study the aggregated and sectoral energy consumption changes at EU and Member State levels. The sectors considered include the productive sectors of the economy (that is, industry, services and agriculture) as well as transport and residential sectors. The application of the activity revaluation approach, proposed by Ang and Xu (2013) and applied by Román-Collado and Economidou (2021) in the EU, is used to decompose energy consumption changes in industry based on physical units. The hybrid model outlined by Xu and Ang (2014) is applied for the residential sector. For the decomposition of primary energy, a simplified version of Reuter, Patel and Eichhammer (2017) was used.

Finally, an analysis of the effect of COVID-19 on energy consumption has been carried out. The purpose of the chapter is to understand how the counteract measures established by the Member States have affected the energy consumption at both European and country level. Moreover, decomposition results have been used to investigate impact of COVID-19 at sectoral level. Where available, weekly and monthly data have been used, otherwise annual data have been employed.

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, Section 4 reports the Covid-19 analysis and conclusions are drawn in Section 5.

2 Methodology

The Logarithmic Mean Divisia Index (LMDI-I) is used to decompose changes in primary and final energy consumption in all EU Member States. In its simplest form, the following identity[9] is used to decompose energy consumption changes in activity, structure and intensity effects (Ang, 2005; Ang, 2015):

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

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

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

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-I decomposition of the ratio of energy consumption between 0 and t is defined as:

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

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:

$$D_{act} = \sum w_i ln\left(\frac{Y_t}{Y_0}\right),\ D_{str} = \sum_i w_i ln\left(\frac{S_{i,t}}{S_{i,0}}\right),\ D_{int} = \sum_i w_i ln\left(\frac{I_{i,t}}{I_{i,0}}\right)$$

$$R_{act} = e^{\sum_i \widetilde{w_i} ln\left(\frac{Y_t}{Y_0}\right)},\ R_{str} = e^{\sum_i \widetilde{w_i} ln\left(\frac{S_{i,t}}{S_{i,0}}\right)},\ R_{int} = e^{\sum_i \widetilde{w_i} ln\left(\frac{I_{i,t}}{I_{i,0}}\right)} \quad (4)$$

$$\text{where } w_i = \frac{E_{i,t} - E_{i.0}}{ln\left(\frac{E_{i,t}}{E_{i,0}}\right)} \text{ and } \widetilde{w_i} = \frac{(E_{i,t} - E_{i,0})/ln\left(\frac{E_{i,t}}{E_{i,t}}\right)}{(E_t - E_0)/ln\left(\frac{E_t}{E_0}\right)}$$

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 sub-sectoral level in European countries carried out by Economidou (2017), the LMDI-I was applied to decompose:

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9 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.

1. primary energy consumption into activity, transformation and distribution effects;
2. final energy consumption of productive end use sectors[10] (namely, industry, services and agriculture) into activity, productivity, intensity and wherever possible structural effects;
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.

The methodology used in this analysis is based on the approach adopted by Economidou and Román-Collado (2019) and Román-Collado and Economidou (2021). A schematic diagram summarising this approach is shown in Table 1.

Table 1. Decomposition identities and explanation of factors considered for various sectors of the economy

Sectors	Energy	Decomposition identity	Factors
All	Primary (PEC)	$PEC = \sum FEC \frac{EAT}{FEC} \frac{PEC}{EAT}$	• Final demand of the energy consumption for end users (FEC) It 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. • Global efficiency of the transformation sector ($PEAT$) It 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. • Global efficiency of the final part of the process ($EAFE$)

10 Freight transport was treated separately.

			It captures efficiency gains in the distribution system and is negative if losses during distribution processes and/or reduction in energy sector consumption are realised.
Productive sectors (industry, services, agriculture)	Final (FEC)	$FEC = \sum_i GVA \frac{GVA_i}{GVA} \frac{FEC_i}{GVA_i}$	• Activity (GVA) It shows the change in FEC due to a change in total GVA. The activity effect is positive if GVA grows due to additional energy demand of increased economic activity. • Structure (GVA_i/GVA) It accounts for changes in energy consumption due to change in the relative importance of sectors with different energy intensities (industry, services, agriculture). The structural effect is positive if sectors of high energy intensity grow more relative to less intensive sectors. • Intensity (FEC_i/GVA_i) It accounts for changes in total energy consumption due to technology improvements, policy effects and other factors (represented by final energy consumption per value added in monetary terms). The intensity effect is negative if there is a drop in energy intensity.
Productive sectors (industry, services, agriculture)	Final (FEC)	$FEC = \sum_i L \frac{GVA}{L} \frac{GVA_i}{GVA} \frac{FEC_i}{GVA_i}$	• Labour (L) – Employment effect It 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. • Labour productivity (GVA/L) It 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. • Structure (GVA_i/GVA)

			(See above – only available for services) • Intensity (FEC_i/GVA_i) (See above)
Industry (manufacturing, construction)	Final (FEC)	See box 1 for details	• Activity It accounts for the change in final energy demand due to the change in physical units produced. • Structure It shows the change in final energy demand due to a change in the relative importance of physical production of sectors on total production. The structural effect is positive if sectors of high energy intensity grow more relative to less intensive sectors. • Intensity It accounts for the change in final energy demand to a change in energy intensity measured in terms of physical units.
Transport (passenger*, freight*) *Excludes air transport	Final (FEC)	$FEC = \sum_i PKM \frac{PKM_i}{PKM} \frac{FEC_i}{PKM_i}$ $FEC = \sum_i TKM \frac{TKM_i}{TKM} \frac{FEC_i}{TKM_i}$	• Activity (PKM or TKM) It shows the change in final energy consumption due to a change in the physical units (passenger-kilometres or tonnes-kilometres). • Modal shift (PKM_i/PKM or TKM_i/TKM) It shows the change in final energy consumption due to the modal shift change. • Intensity (FEC_i/PKM_i or FEC_i/TKM_i) It shows the change in final energy consumption due to the change in final energy consumption by mode of transport per physical activity unit.
Transport (air, domestic)	Final (FEC)	$FEC_{air} = \sum NF \frac{GT}{NF} \frac{FEC_{air}}{GT}$	• Activity (NF) It accounts for the changes in final energy consumption of air transport due to the number of flights. • Productivity (GT/NF) It reflects the change in final energy consumption due to a change in the weight

			of tonnes of goods and passengers transported per flight. • Intensity (FEC_{air}/GT) It shows the change in final energy consumption due to a change in the energy consumption by tonnes transported.
Residential	Final (FEC)	$FEC = FEC_{heat} + FEC_{other} = POP.\frac{TFA}{POP}\frac{FEC'_{heat}}{TFA}\frac{HDD}{HDD_{ref}} + POP\frac{GDI}{POP}\frac{FEC_{other}}{GDI}$	• Population (POP) It accounts for changes in energy consumption due to a change in the population size. • Wealth (TFA/POP or GDI/POP) It reflects 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. • Weather (HDD/HDD_{ref}[11]) It 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}). • Intensity effect (FEC'_{heat}/TFA or FEC_{other}/GDI) It represents the final energy consumption per unit of physical activity; that is, TFA and GDI respectively for the space heating and other end-uses.

Source: Authors' elaboration

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

11 Heating degree day (HDD) index is a weather-based technical index designed to describe the need for the heating energy requirements of buildings. The calculation of HDD relies on the base temperature, defined as "the lowest daily mean air temperature not leading to indoor heating". The value of the base temperature depends in principle on several factors associated with the building and the surrounding environment. By using a general climatological approach, the base temperature is set to a constant value of 15°C in the HDD calculation. The formula of HDD index is: if Tm ≤ 15°C, then [HDD = $\sum_i$(18°C - Tim)] Else [HDD = 0], where Tm is the mean air temperature of day i. In the case of this study, HDD_{ref} is equal to the average of HDD of the years 2000-2020.

data quality, consistency and comparability across Member States. To complement current data shortcomings, the Odyssee-Mure database and OECD data were used to cover specific data needs. These are discussed in more details below.

The final energy consumption 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. 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 11 industrial subsectors[12]. Based on Román-Collado and Colinet (2018), the final energy consumption of each productive sector of the economy (services, industry and agriculture) was also decomposed using the factorisation identity that takes into account employment (labour) and labour productivity effects.

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 (see Box 1 for more details on the methodology).

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. Given that statistical data on transport energy consumption are scarce, various additional sources were considered in this analysis, e.g. Odyssee data were used to calculate the share of passenger versus freight transport for road and rail modes, while the Statistical Pocket book on EU Transport in Figures prepared by DG MOVE were used for passenger and freight kilometres by transport mode (European Commission, 2021). Furthermore, data from the OECD library has been used for the year 2021. 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. For this reason, the total number of passengers, tonnes of goods transported (GT) and number of flights (NF) were used instead.

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

12 Industrial subsectors considered: 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. Machinery, 8. Non-Metallic Minerals, 9. Other manufacturing, 10. Transport equipment, 11. Construction.

study. Due to data restrictions, residential energy consumption was split into two main end uses: (1) space heating, and (2) all other end-uses.

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 factorization (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:

$$A^t = \frac{Q_i^T}{Q_i^0} \cdot Y_i^0 \qquad (2)$$

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

$$E = \sum_{i=1}^{n} E_i = A \cdot \sum_{i=1}^{n} \cdot \frac{A_i}{A} \cdot \frac{E_i}{A_i} = A \cdot \sum_{i=1}^{n} \cdot S_i \cdot I_i \qquad (3)$$

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:

$$Q^{M-V} = \exp\left(\sum_{i=1}^{n} \frac{L(Y_i^t, Y_i^0)}{L(Y^t, Y^0)} \cdot \ln \frac{Q_i^t}{Q_i^0} \right) \qquad (4)$$

The multiplicative formulae are given by:

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

$$R_{\text{int}} = \exp\left(\sum_{i=1}^{n} \frac{L\left(E_i^t, E_i^0\right)}{L\left(E^t, E^0\right)} \cdot \ln \frac{UC_i^t}{UC_i^0} \right) \qquad (5)$$

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.

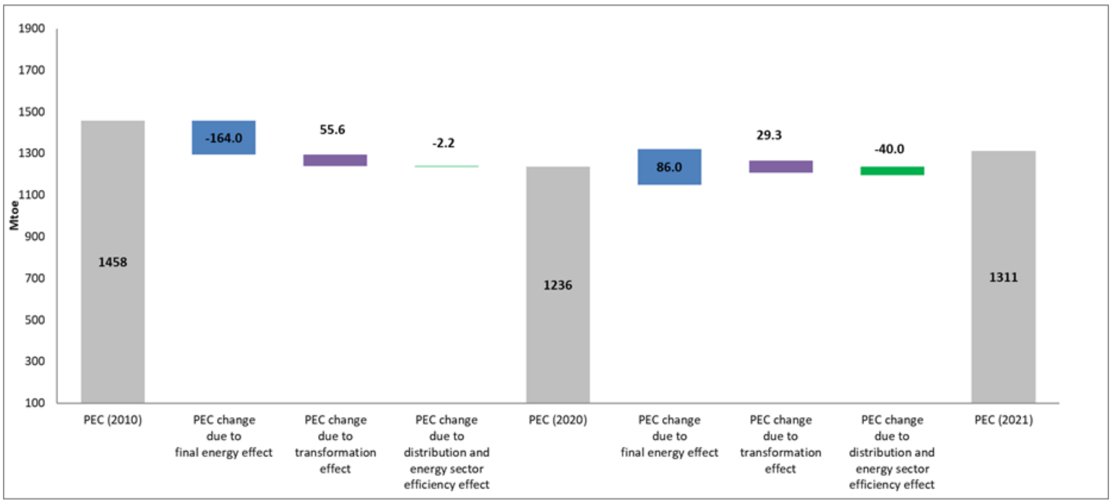
3 Decomposition results

3.1 Primary energy consumption

In 2010-2021, the EU primary energy consumption[13] decreased by −10% from 1,458 to 1,311 Mtoe (Figure 1). Over 81% of the overall decrease was attributed to five countries, namely Germany (−46 Mtoe), France (-29 Mtoe), Italy (−22 Mtoe), the Netherlands (-11 Mtoe) and Spain (−11 Mtoe). On the contrary, some countries experienced an increase over the study period, namely Poland (+7 Mtoe), Bulgaria (+1 Mtoe), Lithuania (+0.5 Mtoe) and Hungary (+0.3 Mtoe). These results have to be also analysed considering the year 2020, where the energy consumption has been heavily affected by the COVID-19 pandemic.

According to the decomposition results, the main explanation behind the fall in primary energy consumption in the period 2010-2021 is attributed to the lowering of final energy demand over the examined period (Figure 2). This contributed to a total drop of −78 Mtoe in primary energy, equivalent to −10% from the beginning of the examined period. However, the final energy demand experienced a strong rebound effect in 2021 (+86 Mtoe). This phenomenon in 2021 has led to a primary energy consumption reduction strongly offset by the increase of the final energy demand. The same dynamic is observed for the transformation efficiency improvements, that contributed to a primary energy reduction of -2% (-26 Mtoe) from 2010-2021, while it shows a rebound effect in 2021 (+29 Mtoe). On the contrary, the distribution losses decreased in both period (-42 Mtoe in 2010-2021 and -40Mtoe in 2020-2021). As expected, as a consequence of the extraordinary circumstances in 2020 due to the pandemic crisis that lowered in an exceptional way the energy demand, in 2021 we observed a rebound effect of the primary energy consumption driven mainly by the final energy demand. Notwithstanding this phenomenon, in 2021 the primary energy consumption did not reach the level of 2019.

Figure 1. Decomposition of changes in EU primary energy consumption (Mtoe) in 2010-2021 using the additive Logarithmic Mean Divisia Index approach (LMDI)

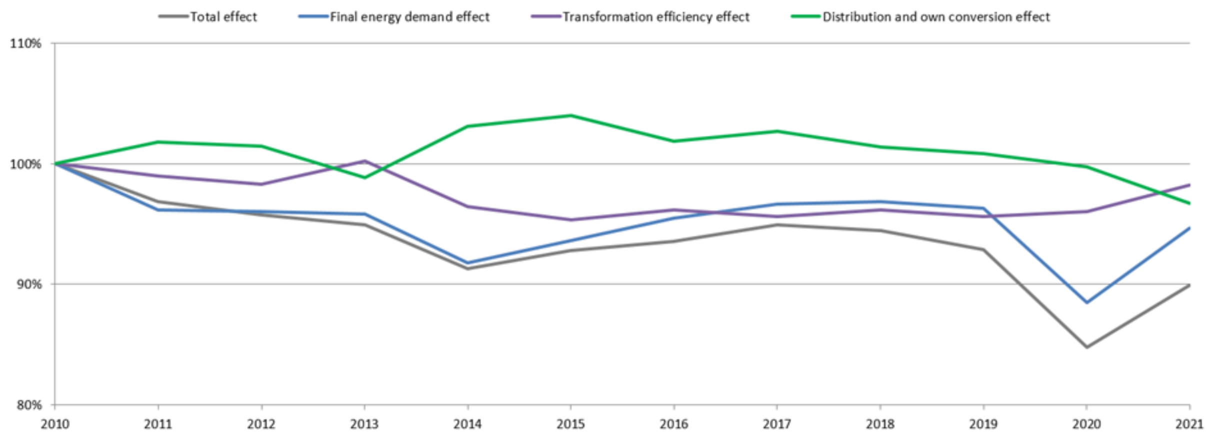


Source: JRC

13 Data source: ESTAT database "FINAL-ENERGY-CONSUMPTION-OLD-METHODOLOGY", ESTAT code: PEC2020-2030

The country results are shown in Table 2. In 2010-2021, the decline in final energy consumption[14] played a major role in limiting primary energy consumption in all Member States except Bulgaria, Czechia, Lithuania, Hungary, Malta, Poland, Romania, and Slovakia. On the latter group, the final energy effect contributed to an increase in primary energy consumption (compared to 2010 PEC levels) only in Bulgaria (+3 Mtoe or +15%), Czechia (+1 Mtoe or +4%), Lithuania (+1 Mtoe or +18%), Hungary (+2 Mtoe or +10%), Malta (+0.1 Mtoe or +18%), Poland (+12 Mtoe or +13%), Romania (+4 Mtoe or +13%) and Slovakia (+0.1 Mtoe or +2%). In all other Member States, lower final energy consumption was attributed to a decline in primary energy consumption, with the largest impact being registered in Denmark, Greece, and Netherlands (a drop equivalent to at least -15% compared to 2010 PEC levels was found in this group of countries). In terms of transformation efficiency of the energy sector, 15 Member States experienced (to a varying level) improvements in the overall efficiency, thereby contributing to a drop in their overall primary energy consumption. The strongest improvements are observed in Greece, Malta, Estonia, Netherlands, and Denmark with an equivalent drop of at least -25% compared to 2010 PEC levels. On the opposite side, transformation efficiency had a counteracting effect (i.e., drove up consumption) in 11 countries, among the worst performing we observed Bulgaria, France, Croatia, Lithuania, Luxembourg, Hungary, and Romania. Improvements in distribution and energy sector efficiency acted as an inhibitor factor in 14 Member States, with the largest drops identified in Bulgaria, Czechia, France, Croatia, Lithuania, Hungary, and Romania. In contrast, worsening of distribution and energy sector efficiency effect was the strongest in Greece, Netherlands, Sweden, and Denmark.

Figure 2. Yearly multiplicative LMDI decomposition results at EU level in 2010-2021



Source: JRC

14 Data source: ESTAT database "FINAL-ENERGY-CONSUMPTION-OLD-METHODOLOGY", ESTAT code: FEC2020-2030

Table 2. Additive and multiplicative decomposition results of primary energy consumption changes Member State level in 2010-2021 and 2020-2021

	Period	Additive results [ktoe]				Multiplicative results [%]			
		Total effect	Final energy demand effect	Transformation efficiency effect	Distribution and own conversion effect	Total effect	Final energy demand effect	Transformation efficiency effect	Distribution and own conversion effect
BE	2010-2021	-4611	-3276	-2249	914	91%	94%	96%	101%
	2020-2021	4873	3582	-372	1662	111%	108%	99%	104%
BG	2010-2021	1179	2540	3690	-5050	107%	115%	123%	75%
	2020-2021	1388	1176	1314	-1102	108%	107%	108%	94%
CZ	2010-2021	-2972	1293	25	-4289	93%	104%	100%	89%
	2020-2021	1981	2562	-1389	808	105%	107%	96%	102%
DK	2010-2021	-3559	-2154	-5960	4555	82%	89%	71%	129%
	2020-2021	900	841	313	-254	106%	105%	102%	98%
DE	2010-2021	-46467	-18245	-26203	-2019	85%	94%	91%	99%
	2020-2021	6537	9802	1282	-4548	102%	104%	100%	98%
EE	2010-2021	-1382	-129	-1632	379	76%	97%	74%	106%
	2020-2021	130	131	-132	131	103%	103%	97%	103%
IE	2010-2021	-845	-613	-1932	1700	94%	96%	87%	113%
	2020-2021	399	270	445	-316	103%	102%	103%	98%
EL	2010-2021	-6904	-5735	-14267	13098	75%	80%	55%	171%
	2020-2021	1093	976	-50	167	106%	105%	100%	101%
ES	2010-2021	-10868	-12897	-11832	13861	91%	90%	91%	112%
	2020-2021	7114	9265	2454	-4605	107%	109%	102%	96%
FR	2010-2021	-29697	-17316	51222	-63603	88%	93%	125%	76%
	2020-2021	16807	21896	18057	-23147	108%	111%	109%	90%
HR	2010-2021	-593	-314	2194	-2474	93%	97%	130%	74%
	2020-2021	509	594	380	-465	107%	108%	105%	94%
IT	2010-2021	-21972	-19556	3634	-6050	87%	88%	102%	96%
	2020-2021	12963	13541	-3097	2519	110%	110%	98%	102%
CY	2010-2021	-363	-334	-277	248	86%	88%	88%	112%
	2020-2021	114	160	1	-48	105%	107%	100%	98%
LV	2010-2021	-90	-70	-107	88	98%	98%	97%	103%
	2020-2021	203	223	-185	165	105%	105%	96%	104%
LT	2010-2021	460	1007	1230	-1776	107%	118%	121%	75%
	2020-2021	400	413	297	-310	106%	107%	105%	95%
LU	2010-2021	-424	-279	985	-1131	91%	94%	125%	78%
	2020-2021	251	258	132	-138	106%	107%	103%	97%
HU	2010-2021	314	2194	6221	-8101	101%	110%	130%	71%
	2020-2021	1046	1493	1000	-1447	104%	106%	104%	94%
MT	2010-2021	-161	138	-250	-49	83%	118%	75%	94%
	2020-2021	27	64	17	-54	104%	109%	102%	93%
NL	2010-2021	-10885	-11268	-21361	21743	85%	84%	72%	140%
	2020-2021	2364	2355	-3689	3698	104%	104%	94%	106%
AT	2010-2021	-1309	-254	-2258	1202	96%	99%	93%	103%
	2020-2021	1703	1910	1828	-2035	106%	106%	106%	94%
PL	2010-2021	7388	12330	847	-5789	108%	113%	100%	95%
	2020-2021	7091	5502	2413	-824	107%	106%	102%	99%
PT	2010-2021	-3123	-3110	-2259	2246	86%	86%	89%	112%
	2020-2021	35	920	1048	-1933	100%	105%	106%	91%
RO	2010-2021	146	3778	3393	-7026	100%	113%	110%	81%
	2020-2021	2167	2413	2684	-2930	107%	108%	109%	91%
SI	2010-2021	-699	-488	-753	542	90%	93%	89%	108%
	2020-2021	188	427	490	-730	103%	107%	108%	89%
SK	2010-2021	-223	49	245	-518	99%	100%	102%	97%
	2020-2021	1259	1752	134	-627	108%	112%	101%	96%
FI	2010-2021	-3938	-1763	2361	-4536	89%	95%	109%	86%
	2020-2021	1571	1969	4809	-5206	105%	107%	117%	84%
SE	2010-2021	-4843	-3440	-10993	9590	90%	93%	78%	124%
	2020-2021	2220	1551	-905	1574	105%	104%	98%	104%
EU27	2010-2021	-146441	-77911	-26285	-42245	90%	95%	98%	97%
	2020-2021	75333	86047	29282	-39996	106%	107%	102%	97%

Source: JRC

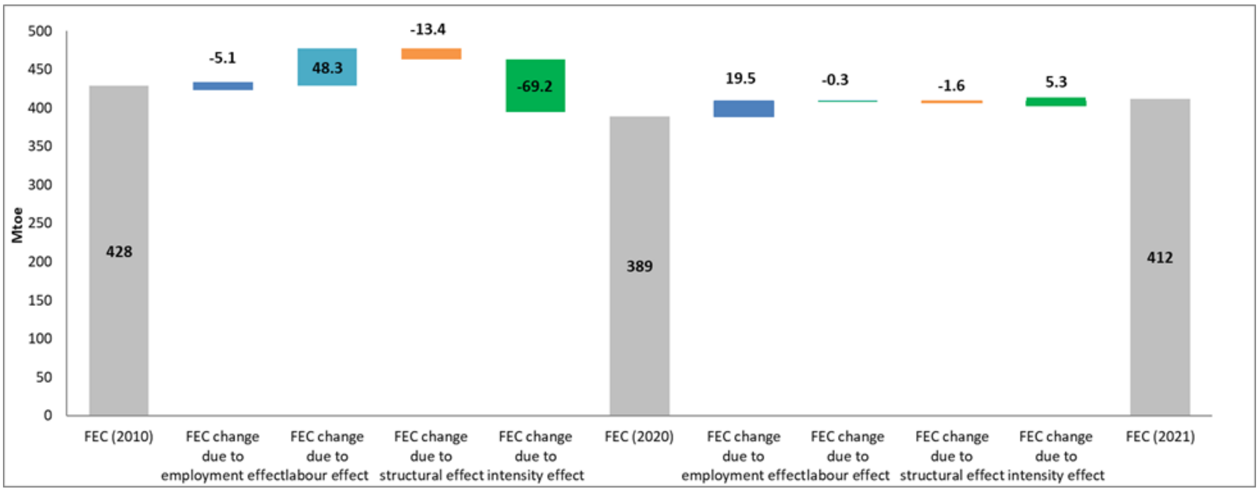
3.2 Final energy consumption of productive sectors

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

Figure 3 illustrates the decomposition of final energy consumption changes in 2010–2021 at EU level into activity, structural and intensity effects. The EU27 energy consumption fell by −16 Mtoe, corresponding to a reduction of −4% compared to the 2010 consumption level. Among the various productive sectors, the largest drop was experienced by service sector (-11%) followed by industry (-2%), while agriculture's consumption increased by +11%. These are discussed in more detail in Section 3.2.2. As shown in Figure 4, the overall drop in FEC of productive sectors was explained by positive activity effects (employment and labour productive), which were totally offset by the negative structural and intensity effects. In particular, activity effect alone accounted for a +62 Mtoe increase (of which +43 Mtoe in 2010-2020, and +19 Mtoe in 2020–2021) and structural effect for a –15 Mtoe drop (-13 Mtoe in 2010–2020, and -2 Mtoe in 2020–2021). The intensity effect had the biggest impact, responsible for a fall in consumption by -64 Mtoe (-69 Mtoe in 2010–2020 and +5 in 2020–2021).

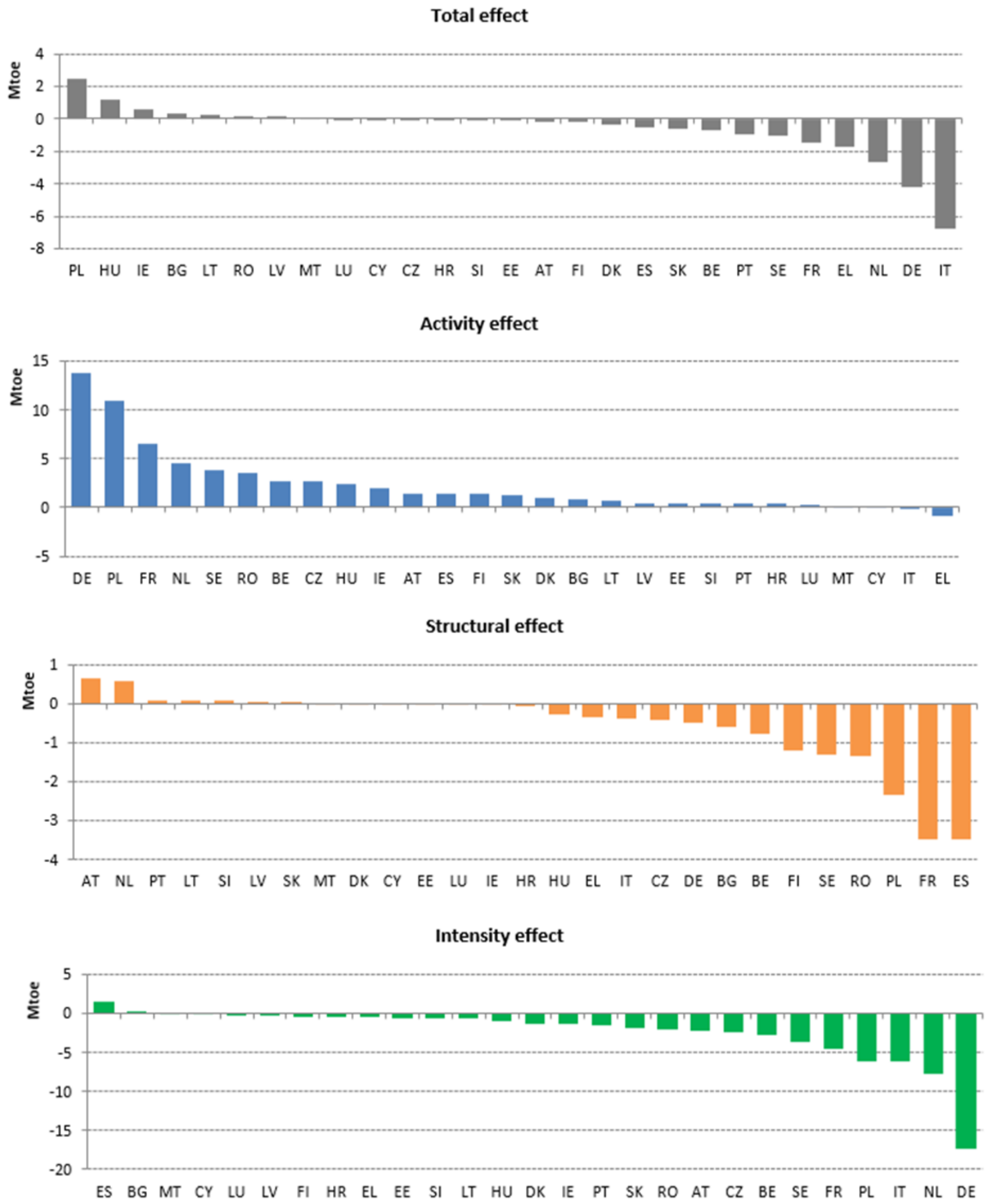
The country results for the period 2010–2021 are shown in Figure 4. Based on these, Poland, Hungary, Ireland, Bulgaria, Lithuania, Romania, Latvia, and Malta experienced an overall growth in final energy consumption of their productive sectors over the period 2010–2021. In relative terms, this growth was the largest in Malta (26% compared to 2010 levels), Hungary (18%), Ireland (17%), Lithuania (12%), Bulgaria (10%), Latvia (10%), Poland (10%) and Romania (2%). While it is not surprising that the contribution of each effect was different among countries, the intensity effect was negative for all countries except for Spain and Bulgaria whose intensity effect drove up consumption by 4.5% and 2%, respectively. In absolute terms, the countries with the largest drop accounted by intensity gains were Germany, Poland, France, Italy, and the Netherlands. In contrast, the EU tendency of negative structural effect was not universal at Member State level; 20 countries recorded an average decrease in energy consumption due to structural shifts towards less intensive sectors in the period 2010–2021. Increased activity in the period 2010–2021 acted as a driver of energy consumption in all countries except for Greece and Italy, which have a negative activity effect linked to a prolonged or more severe economic recession for Greece and the COVID-19 crisis for Italy that has firstly affected this country in early 2020. In absolute terms, the activity effect was a dominant force of rising energy consumption in Germany, Poland, France, the Netherlands, and Sweden. In terms of structural effect, the largest shift towards less intensive sectors were noted in Spain, France, Poland, Romania and Sweden, while the opposite is true for Austria, Netherlands, Portugal, Lithuania and Slovenia.

Figure 3. Decomposition of changes in final energy consumption (Mtoe) of the productive sectors of the economy in 2010-2021 in EU using the additive Logarithmic Mean Divisia Index approach (LMDI)



Source: JRC

Figure 4. Decomposition of final energy consumption changes in the productive sectors in 2010-2021 at Member State level



Source: JRC

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

3.2.2.1 Industry[15]

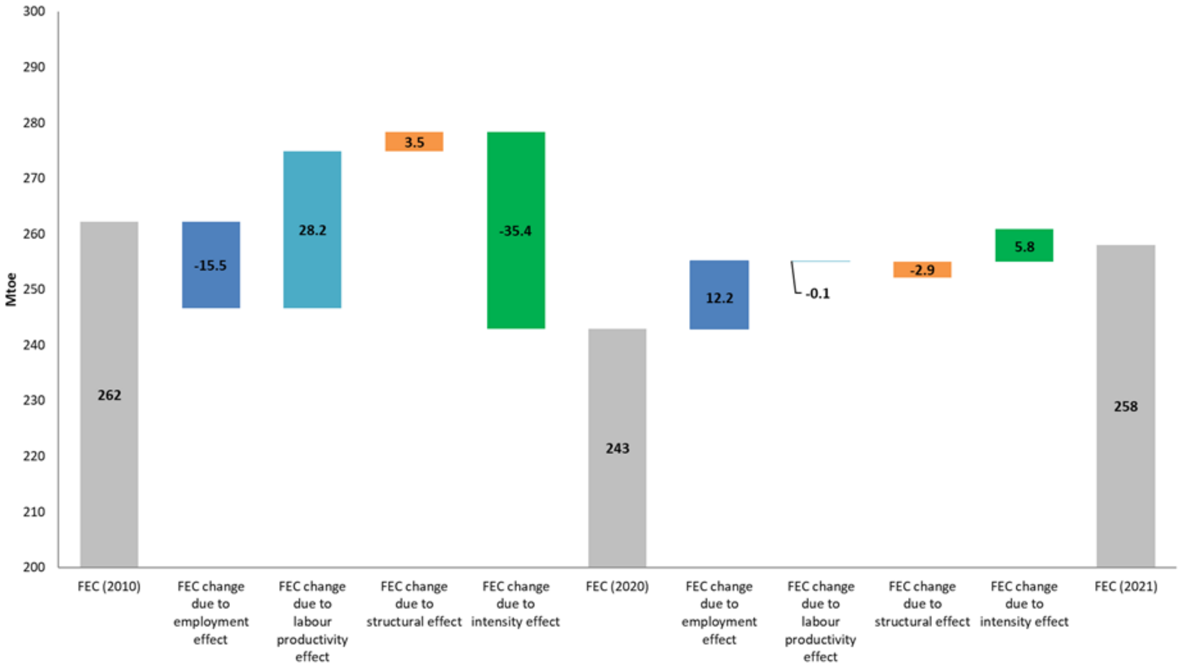
In the period 2010-2021, the energy consumption of the EU industry decreased by −4.7 Mtoe, corresponding to a drop of −2% compared to 2010 consumption levels. Industry is the most energy intensive sector and is responsible for nearly two thirds (63%) of the combined consumption of industry, services, and agriculture. If structural and intensity effects would not have come into play, economic growth would have driven up industrial energy consumption by +24.8 Mtoe (+12.7 Mtoe in 2010-2020 and +12.1 Mtoe in 2020-2021). If the energy consumption increase driven by activity effect is broken down into employment effect (hours worked) and labour productivity effect (GVA/hours worked), opposite driving forces are revealed. Industry is one of the two (the other is agriculture) productive sectors of the economy whose labour effect at EU level is negative (−3.2 Mtoe) over the examined period due to lower global number of hours worked overtime. On the other hand, the labour productivity effect indicates an increase in energy consumption due to an improvement in productivity (+28.1 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 −29.6 Mtoe (-35.4 Mtoe in 2010-2020 and +5.8 Mtoe in 2020-2021). The structural effect played a secondary role in limiting energy consumption as structural changes in the industrial sector (a shift from subsectors of higher energy intensity towards those of lower intensity[16]) led to a reduction in energy consumption equivalent to −0.6 Mtoe (+3.5 Mtoe in 2010-2020 and -2.9 Mtoe in 2020-2021). The gross value added of all industry sectors increased in 2021, after the dramatic fall as a consequence of the pandemic crisis in 2020. Looking at 2021 results, it has been observed a trend reversal for employment effect (+12.2 Mtoe in 2021, -16.8 Mtoe in 2020) and structural effect (-2.9 Mtoe in 2021, +1.3 Mtoe in 2020), while for the intensity effect is confirmed the trend started in 2020 (+5.8 Mtoe in 2021, +2.7 Mtoe in 2020). The structural effect was the main driver responsible in driving down the energy consumption. In the last year, from 2020 to 2021, both intensity and employment effects have contributed in increasing the industry FEC, with the latter being the main driver of this increase. Given that, we observed a rebound effect in 2021 compared to 2020. The gradual end of the restrictions due to the pandemic crisis, with positive effects on both industry productions and employment, has led to an economic and production recovery already in 2021. This phenomenon will likely continue in 2022.

15 Industry sector includes the subsectors: 1. Food & tobacco (ESTAT code: B_101830); 2. Textile & leather (ESTAT code: B_101835); 3. Wood, paper, etc. (ESTAT code: B_1018851+B_101840); 4. Chemical & petrochemical (ESTAT code: B_101815); 5. Metals and machinery (ESTAT code: B_101847+B_101805+B_101810); 6. Non-metallic minerals (ESTAT code: B_101820+B_101853); 7. Transport equipment (ESTAT code: B_101846); 8. Construction (ESTAT code: B_101852).

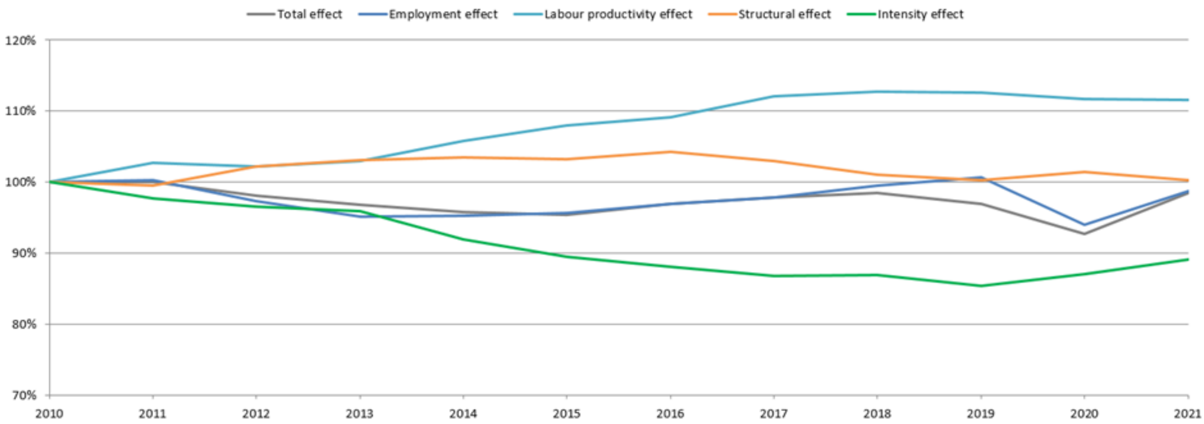
16 Energy intensive subsectors include Food & tobacco, Pulp and paper, Chemicals, Metals and Non-metallic minerals. Less intensive subsectors include: Wood, Construction, Textile & leather, Machinery and Transport equipment.

Figure 5. Decomposition of changes in EU industrial energy consumption (Mtoe) in 2010-2021 using the additive LMDI approach



Source: JRC

Figure 6. Yearly multiplicative LMDI decomposition results of industrial energy consumption changes at EU level in 2010-2021



Source: JRC

At country level, the industry sector grew in 13 countries, among the fastest we observed Hungary (+67%), Malta (+25%), Ireland (+18%), Hungary (+18%), Lithuania (+16%) and Latvia (15%) in 2010-2021, while all other 14 countries experience a decline in industry consumption over the same period (Table 3). The decomposition results show that employment effect (Labour) in terms of reduced number of hours worked in industrial activities was one of the main drivers of industrial energy consumption. In relative terms, the largest negative impact in terms of hours worked can be seen in Ireland, Lithuania, Malta, and Hungary.

Labour productivity generally acted as a major driver of energy consumption in industry in 2010-2021, as it was positive in 25 Member States. In particular, labour productivity had the most relatively profound impact as energy consumption driver in Estonia, Latvia, Lithuania, Denmark, Slovenia and Poland, while it acted as inhibitor in Greece and Finland. In terms of structural shift, the industrial sector moved to less intensive sectors in 16 Member States. On the other end of the spectrum, Belgium, Ireland, Greece, Spain, France, Italy, Portugal, Romania and Finland were the countries with the largest increase in consumption due to shift towards more intensive activities in relative terms (in comparison to 2010 consumption levels). In contrast, countries with significant shift towards less intensive industrial subsectors included Czechia, Hungary, and Malta. Intensity improvements drove down consumption in all Member States except for Bulgaria, Czechia, Hungary, and Malta. Countries with the largest inhibitor effect due to intensity included Estonia, Denmark, Croatia, Lithuania, Luxembourg, the Netherlands, Portugal, and Slovenia.

Table 3. Additive and multiplicative decomposition results of industrial energy consumption changes at Member State level in 2010-2021 and 2020-2021

		Additive results [ktoe]					Multiplicative results [%]				
	Period	Total effect	Employment effect	Labour productivity effect	Structural effect	Intensity effect	Total effect	Employment effect	Labour productivity effect	Structural effect	Intensity effect
BE	2010-2021	-295	153	1053	205	-1706	98%	101%	109%	102%	87%
	2020-2021	756	855	-648	-1	550	107%	108%	95%	100%	105%
BG	2010-2021	155	-259	156	-59	316	106%	90%	106%	98%	114%
	2020-2021	139	35	-219	-268	591	106%	101%	92%	90%	126%
CZ	2010-2021	150	-219	1566	-2192	995	102%	97%	124%	75%	113%
	2020-2021	490	217	61	-2013	2225	107%	103%	101%	77%	134%
DK	2010-2021	-35	193	585	-155	-659	98%	109%	131%	93%	74%
	2020-2021	128	99	11	4	14	106%	105%	100%	100%	101%
DE	2010-2021	-357	1800	6194	-1254	-7097	99%	103%	110%	98%	89%
	2020-2021	2257	920	260	286	791	104%	102%	100%	100%	101%
EE	2010-2021	-191	38	202	-48	-383	66%	107%	149%	91%	46%
	2020-2021	-26	4	25	2	-56	94%	101%	107%	100%	87%
IE	2010-2021	320	613	413	139	-845	118%	136%	123%	109%	65%
	2020-2021	100	144	156	59	-260	105%	107%	108%	103%	88%
EL	2010-2021	-952	-723	-290	207	-145	72%	80%	93%	108%	89%
	2020-2021	74	180	42	-1	-147	103%	108%	102%	100%	94%
ES	2010-2021	-1116	-3831	341	3458	-1084	95%	84%	101%	118%	95%
	2020-2021	1418	932	-478	506	458	107%	105%	98%	103%	102%
FR	2010-2021	895	-781	962	2201	-1488	103%	97%	103%	107%	96%
	2020-2021	4757	2696	-505	-698	3265	118%	110%	98%	98%	112%
HR	2010-2021	-134	20	178	-14	-318	90%	102%	118%	98%	76%
	2020-2021	19	51	37	-32	-37	102%	104%	103%	97%	97%
IT	2010-2021	-4876	-3280	2903	972	-5471	84%	89%	111%	103%	83%
	2020-2021	1847	3139	-248	-1020	-25	108%	113%	99%	96%	100%
CY	2010-2021	2	14	32	-8	-36	101%	99%	116%	93%	94%
	2020-2021	-2	18	-1	-2	-18	99%	108%	100%	99%	93%
LV	2010-2021	115	25	273	-33	-150	115%	104%	141%	95%	83%
	2020-2021	25	31	-33	32	-6	103%	104%	96%	104%	99%
LT	2010-2021	152	158	405	-11	-400	116%	117%	148%	99%	68%
	2020-2021	83	60	-6	7	23	108%	106%	99%	101%	102%
LU	2010-2021	-144	75	72	0	-291	81%	112%	112%	100%	64%
	2020-2021	28	46	1	-4	-15	105%	108%	100%	99%	98%
HU	2010-2021	1972	748	497	-592	1320	167%	118%	114%	85%	147%
	2020-2021	194	287	84	-36	-140	104%	106%	102%	99%	97%
MT	2010-2021	11	14	8	-12	0	125%	128%	117%	80%	104%
	2020-2021	3	7	-6	-1	3	107%	115%	89%	98%	106%
NL	2010-2021	-978	484	3009	-251	-4220	94%	103%	122%	98%	76%
	2020-2021	183	360	478	56	-712	101%	103%	103%	100%	95%
AT	2010-2021	-91	613	1174	4	-1881	99%	107%	114%	100%	81%
	2020-2021	531	502	170	-39	-103	106%	106%	102%	100%	99%
PL	2010-2021	2853	1309	4292	-1308	-1440	121%	109%	132%	92%	91%
	2020-2021	333	420	597	66	-750	102%	103%	104%	100%	96%
PT	2010-2021	-878	-450	760	66	-1255	84%	92%	117%	101%	76%
	2020-2021	79	277	-50	8	-156	102%	106%	99%	100%	97%
RO	2010-2021	52	34	1009	134	-1124	101%	101%	118%	101%	84%
	2020-2021	414	281	131	457	-455	106%	104%	102%	107%	93%
SI	2010-2021	18	50	332	-35	-330	101%	104%	130%	97%	77%
	2020-2021	39	94	34	-17	-72	103%	108%	103%	99%	94%
SK	2010-2021	116	-185	1098	-38	-760	103%	95%	128%	99%	86%
	2020-2021	587	41	130	-128	545	115%	101%	103%	97%	114%
FI	2010-2021	-67	-224	-131	343	-55	99%	98%	99%	104%	99%
	2020-2021	643	130	-166	-243	922	106%	101%	98%	98%	109%
SE	2010-2021	-862	379	952	-1126	-1067	93%	103%	109%	91%	91%
	2020-2021	-42	413	28	132	-614	100%	104%	100%	101%	95%
EU27	2010-2021	-4165	-3232	28045	595	-29574	98%	99%	112%	100%	89%
	2020-2021	15058	12239	-115	-2888	5822	106%	105%	100%	99%	102%

Source: JRC

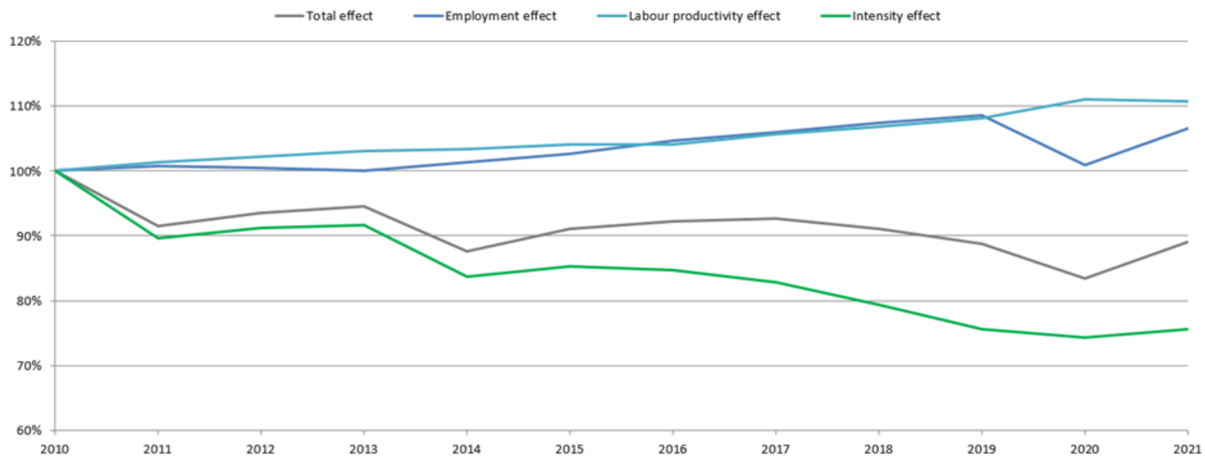
3.2.2.2 Services[17]

The energy consumption of the service sector decreased by -15.7 Mtoe (-11%) from 2010 to 2021 (Figure 7). 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 3.2.2.1, decreased by −2% in 2010-2021. However, the services sector remains the second intensive sector compared to industry and represents the 30% of the total consumption of industry, services and agriculture combined in 2021. Despite this, it remains the fastest growing productive sector in the EU both in terms of energy and economic output.

The decomposition results (Figure 7) show that until 2019 the economic growth of the service sector (i.e., the combined effect of employment effect and labour productivity effect) was the main factor that led to the increase in total energy consumption. However, in 2020 the drop of both employment and intensity effects result in a decrease of the total energy consumption. Only labour productivity remained on a growth trend. In 2021, both employment and intensity effects started to growth again (rebound effect from 2020). Specifically, employment effect (measured in hours worked) resulted of an increase in consumption equivalent to +8.1 Mtoe (+1.7 Mtoe in 2010-2020; +6.4 Mtoe in 2020-2021). Labour productivity effect was associated with a consumption growth of +12.8 Mtoe compared to 2010 level (+13.3 Mtoe in 2010-2020 and -0.5 Mtoe in 2020-2021). The intensity effect restricted this growth (−36.4 Mtoe in 2010-2021), resulting to a drop in total effect of -15.4 Mtoe. As the industry sector, services have been affected by COVID-19 restrictions in 2020 and has experienced a rebound effect that partially offset the results of 2020. 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 subsectors 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.

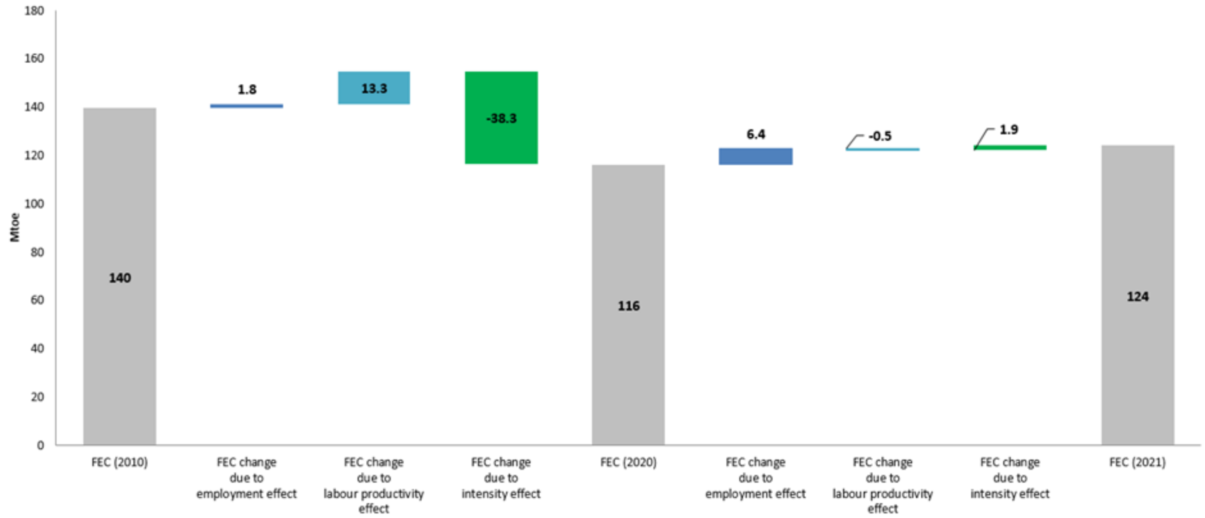
17 ESTAT code: B_10235

Figure 7. Yearly multiplicative LMDI decomposition results of energy consumption changes in services at EU level in 2010-2021



Source: JRC

Figure 8. Decomposition of changes in EU services energy consumption (Mtoe) in 2010-2020 using the additive LMDI approach



Source: JRC

In terms of energy consumption at Member States level, the services sector grew fastest in Luxembourg (+31%), Malta (+28%), Ireland (+22%), Estonia (+21%) and Bulgaria (+18%). In total, the services consumption of 8 Member States increased in this period. On the opposite side, the consumption of services sector declined the most in Slovakia (-34%), Hungary (−32%), Netherlands (-19%), Slovenia (-21%), Greece (-13%) and Germany (−18%). The decomposition results show that employment in terms of increased hours worked was one of the main drivers of services energy consumption, as the employment effect (Labour) was positive in almost all Member States (from 2010 to 2021) apart from Italy, Latvia and Slovakia. Labour productivity effect also contributed towards growing consumption of services in 2010-2021, with the analysis showing that the above-mentioned effect was positive in 25 Member States. Labour productivity had the most profound impact a driver in Bulgaria, Czechia, Hungary, Romania, Latvia, Lithuania, Ireland, Estonia, Poland, Slovakia, and Malta. As inhibitor, labour productivity in Greece and Luxembourg resulted in a drop of consumption, which ranged from -17% (compared to 2010 consumption) in Greece to -8% in Luxembourg. Improvements in energy intensity of services were noted in 25 Member States, only Greece and Luxembourg resulted in a small increase in the consumption of the services sectors (+1% and 3%, respectively).

Table 4. Additive and multiplicative decomposition results of services energy consumption changes at Member State level in 2010-2020 and 2020-2021

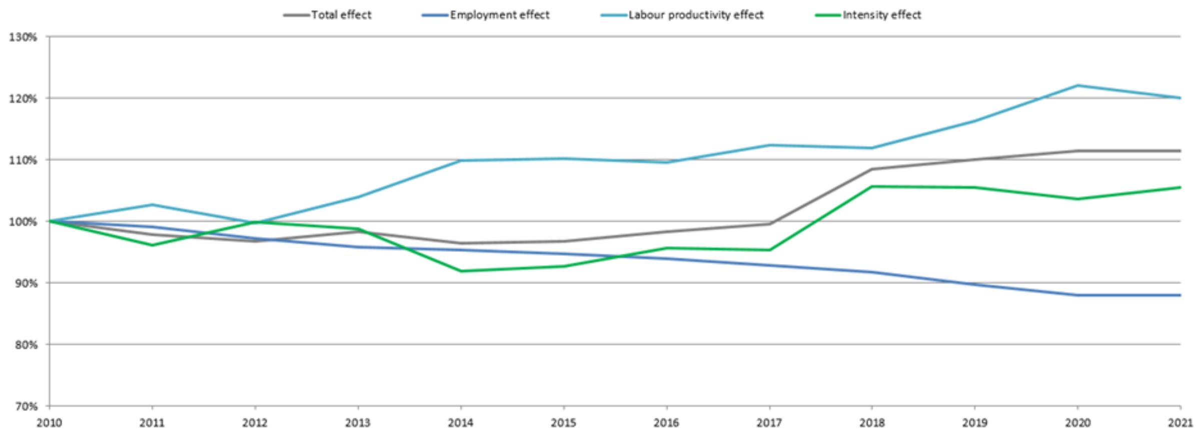
		Additive results [ktoe]				Multiplicative results [%]			
	Period	Total effect	Employment effect	Labour productivity effect	Intensity effect	Total effect	Employment effect	Labour productivity effect	Intensity effect
BE	2010-2021	-481	441	362	-1283	90%	110%	108%	76%
	2020-2021	127	332	-26	-180	103%	108%	99%	96%
BG	2010-2021	178	24	286	-132	118%	102%	131%	88%
	2020-2021	206	30	70	106	121%	103%	107%	111%
CZ	2010-2021	-307	128	706	-1141	91%	104%	126%	69%
	2020-2021	-26	95	17	-138	99%	103%	101%	95%
DK	2010-2021	-123	147	197	-466	94%	108%	111%	79%
	2020-2021	203	90	5	108	111%	105%	100%	106%
DE	2010-2021	-6136	1275	3493	-10903	82%	104%	112%	71%
	2020-2021	1909	533	9	1367	107%	102%	100%	105%
EE	2010-2021	88	54	138	-105	121%	113%	134%	80%
	2020-2021	45	6	38	1	110%	101%	108%	100%
IE	2010-2021	324	340	519	-534	122%	124%	136%	72%
	2020-2021	-14	126	15	-155	99%	107%	101%	92%
EL	2010-2021	-253	62	-355	41	87%	103%	83%	101%
	2020-2021	105	179	-56	-18	107%	111%	97%	99%
ES	2010-2021	-319	355	512	-1185	97%	104%	105%	88%
	2020-2021	451	725	-199	-74	105%	108%	98%	99%
FR	2010-2021	-2486	1602	1383	-5471	90%	108%	106%	78%
	2020-2021	1427	1706	-443	164	107%	109%	98%	101%
HR	2010-2021	51	23	123	-96	106%	103%	117%	89%
	2020-2021	90	-5	111	-15	112%	99%	115%	98%
IT	2010-2021	-1918	-479	468	-1907	89%	97%	103%	89%
	2020-2021	883	1046	-431	268	106%	107%	97%	102%
CY	2010-2021	-25	36	13	-74	90%	117%	106%	73%
	2020-2021	21	10	2	9	110%	105%	101%	104%
LV	2010-2021	2	-21	187	-164	100%	96%	138%	76%
	2020-2021	51	-13	44	20	109%	98%	108%	104%
LT	2010-2021	43	39	185	-181	107%	107%	135%	74%
	2020-2021	69	11	29	29	112%	102%	105%	105%
LU	2010-2021	134	139	-37	32	131%	139%	92%	103%
	2020-2021	62	38	-15	39	112%	107%	97%	108%
HU	2010-2021	-977	365	405	-1747	68%	118%	120%	48%
	2020-2021	75	67	113	-104	104%	103%	106%	95%
MT	2010-2021	26	52	25	-51	128%	157%	126%	65%
	2020-2021	6	11	2	-7	106%	110%	102%	94%
NL	2010-2021	-1529	909	204	-2642	81%	114%	103%	68%
	2020-2021	209	210	93	-94	103%	103%	101%	99%
AT	2010-2021	-100	111	115	-326	96%	105%	105%	88%
	2020-2021	168	118	-40	91	107%	105%	98%	104%
PL	2010-2021	-364	1207	2319	-3890	96%	116%	133%	62%
	2020-2021	906	571	135	200	112%	107%	102%	103%
PT	2010-2021	-180	71	31	-281	90%	103%	102%	86%
	2020-2021	6	70	2	-66	100%	104%	100%	96%
RO	2010-2021	-26	269	705	-1001	99%	116%	147%	58%
	2020-2021	20	80	47	-107	101%	104%	103%	94%
SI	2010-2021	-112	32	61	-204	79%	108%	114%	65%
	2020-2021	3	23	5	-26	101%	106%	101%	94%
SK	2010-2021	-713	-12	280	-981	66%	98%	125%	54%
	2020-2021	297	-1	32	266	127%	100%	103%	124%
FI	2010-2021	-89	276	111	-477	97%	110%	104%	85%
	2020-2021	287	89	30	169	111%	103%	101%	106%
SE	2010-2021	-70	701	428	-1199	98%	119%	111%	74%
	2020-2021	256	246	-42	52	106%	106%	99%	101%
EU27	2010-2021	-15363	8145	12861	-36369	89%	106%	111%	76%
	2020-2021	7842	6394	-455	1902	107%	105%	100%	102%

Source: JRC

3.2.2.3 Agriculture[18]

Agriculture is the smallest sector among the productive sectors of the EU economy (industry, services, and agriculture), accounting for just 7% of the final energy consumption of these combined sectors in 2021. The agricultural energy consumption increased by +11% over the period 2010-2021. As shown in Figure 9, employment has been on a gradual declining trend from 2010 to 2020, with a small increase in 2021, reflecting a negative employment effect throughout the examined period. In the period 2010-2021, this has been the largest inhibitor of the agricultural energy consumption (−3.5 Mtoe). On the other hand, rapid improvements in labour productivity and intensity have been a major driver of energy consumption (+5 Mtoe and +1.5 Mtoe in 2021 compared to 2010, respectively). The opposite forces exerted by the employment 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. Moreover, the agriculture sector has been less affected by the 2020 pandemic crisis compared to industry and services. This can be seen looking at the effect trends that are relatively stable over the examined period. The reasons behind these results may be related to the nature of the agricultural sector; it provides goods of first necessity that have been mostly excluded by the Member States COVID-19 control measures. That said, we observed a rebound effect for the intensity effect between 2020 and 2021.

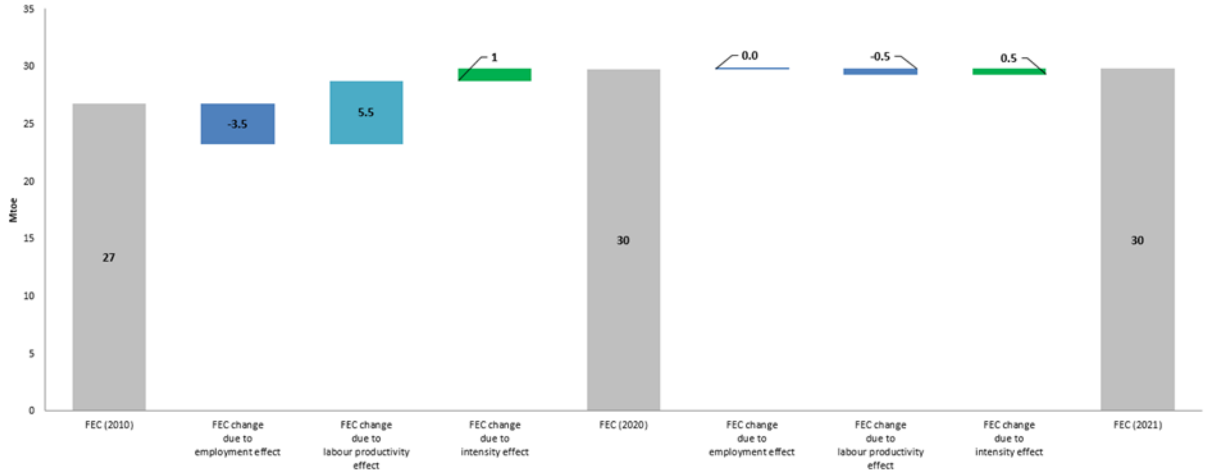
Figure 9. Yearly multiplicative LMDI decomposition results of agricultural energy consumption changes at EU level in 2010-2021



Source: JRC

[18] ESTAT code: B_102020+B_102030

Figure 10. Decomposition of changes in EU agricultural energy consumption (Mtoe) in 2010-2021 using the additive LMDI approach



Source: JRC

In terms of country level trends, the agricultural sector grew fastest in Germany, Czechia, Spain, Cyprus, Hungary, and Romania (Table 5). In total, the agricultural energy consumption of 17 Member States increased in this period. The decomposition results show that employment in terms of fewer hours worked was one of the main inhibitors of energy consumption in all Member States except Malta, Czechia, Netherlands and Belgium. All the other countries showed a drop in consumption due to reduction in employment. As in the case with the EU-wide results, labour productivity was an important explanation behind consumption growth in agriculture across many EU countries. This was indeed the case for all Member States except for Malta. Improvements in energy intensity were noted in 15 countries, with largest inhibiting impact in Bulgaria, Ireland, Greece, Malta and Slovakia. On the other hand, energy intensity drove up the consumption of the agricultural sectors in Romania, Poland, Cyprus, Italy, France, Spain, Germany, Belgium, Czechia, Croatia, Latvia, and Hungary. Further investigation to identify the extent to which structural shifts have contributed to these intensity effects is necessary in the future.

Table 5. Additive and multiplicative decomposition results of agriculture energy consumption changes at Member State level in 2010-2021 and 2020-2021

		Additive results [ktoe]				Multiplicative results [%]			
	Period	Total effect	Employment effect	Labour productivity effect	Intensity effect	Total effect	Employment effect	Labour productivity effect	Intensity effect
BE	2010-2021	37	47	-67	57	104%	106%	93%	106%
	2020-2021	2	-14	-20	36	100%	98%	98%	104%
BG	2010-2021	15	-49	118	-54	108%	77%	186%	75%
	2020-2021	10	-11	60	-39	106%	94%	136%	82%
CZ	2010-2021	99	18	71	11	118%	104%	111%	102%
	2020-2021	7	5	-109	111	101%	101%	84%	119%
DK	2010-2021	-190	-124	6	-72	78%	84%	101%	92%
	2020-2021	8	-8	-105	120	101%	99%	86%	119%
DE	2010-2021	2324	-637	1108	1853	281%	77%	133%	276%
	2020-2021	1	-121	179	-57	100%	97%	105%	98%
EE	2010-2021	-7	-47	43	-2	93%	67%	151%	92%
	2020-2021	-21	-10	-7	-5	81%	90%	94%	95%
IE	2010-2021	-43	-26	154	-172	85%	91%	189%	50%
	2020-2021	1	5	-4	0	101%	102%	98%	100%
EL	2010-2021	-490	5	32	-527	39%	98%	108%	37%
	2020-2021	21	22	-29	28	107%	107%	91%	110%
ES	2010-2021	866	-107	652	322	139%	96%	127%	114%
	2020-2021	108	77	-14	46	104%	103%	100%	102%
FR	2010-2021	123	-784	609	298	103%	84%	115%	107%
	2020-2021	-114	50	-80	-84	98%	101%	98%	98%
HR	2010-2021	7	-140	112	34	103%	55%	161%	115%
	2020-2021	1	20	0	-20	100%	108%	100%	93%
IT	2010-2021	70	-189	11	247	102%	94%	100%	109%
	2020-2021	49	45	-84	88	102%	102%	97%	103%
CY	2010-2021	8	-6	3	11	121%	87%	106%	130%
	2020-2021	1	0	0	1	101%	100%	100%	101%
LV	2010-2021	41	-7	47	2	127%	97%	129%	101%
	2020-2021	-14	-3	-22	12	93%	98%	90%	106%
LT	2010-2021	11	-44	68	-12	110%	67%	185%	88%
	2020-2021	8	-9	-6	23	107%	93%	95%	121%
LU	2010-2021	-2	-2	0	0	93%	93%	102%	97%
	2020-2021	-1	0	0	-1	97%	102%	98%	97%
HU	2010-2021	181	-195	276	100	137%	75%	156%	117%
	2020-2021	-38	-85	72	-25	95%	88%	111%	96%
MT	2010-2021	1	2	2	-3	109%	122%	124%	72%
	2020-2021	0	1	2	-4	97%	112%	128%	67%
NL	2010-2021	-130	242	228	-600	97%	106%	106%	86%
	2020-2021	23	29	68	-75	101%	101%	102%	98%
AT	2010-2021	14	-98	192	-81	103%	83%	143%	86%
	2020-2021	30	3	20	6	106%	101%	104%	101%
PL	2010-2021	8	-671	181	499	100%	83%	105%	115%
	2020-2021	-131	135	-581	315	97%	104%	86%	109%
PT	2010-2021	68	-226	289	4	115%	62%	186%	100%
	2020-2021	28	-74	103	-1	105%	87%	122%	100%
RO	2010-2021	174	-223	369	27	144%	61%	226%	104%
	2020-2021	36	23	8	4	107%	104%	102%	101%
SI	2010-2021	4	-6	16	-5	106%	92%	123%	94%
	2020-2021	2	-2	-5	9	102%	97%	93%	114%
SK	2010-2021	-3	-18	70	-54	98%	88%	163%	69%
	2020-2021	0	-5	-2	7	100%	96%	98%	106%
FI	2010-2021	-48	-164	287	-171	94%	81%	144%	81%
	2020-2021	-7	-13	-17	23	99%	98%	98%	103%
SE	2010-2021	-97	-39	114	-172	86%	93%	119%	77%
	2020-2021	-6	-50	69	-25	99%	92%	112%	96%
EU27	2010-2021	3042	-3490	4993	1538	111%	88%	120%	105%
	2020-2021	3	10	-504	496	100%	100%	98%	102%

Source: JRC

3.2.3 Activity revaluation approach (Industry)

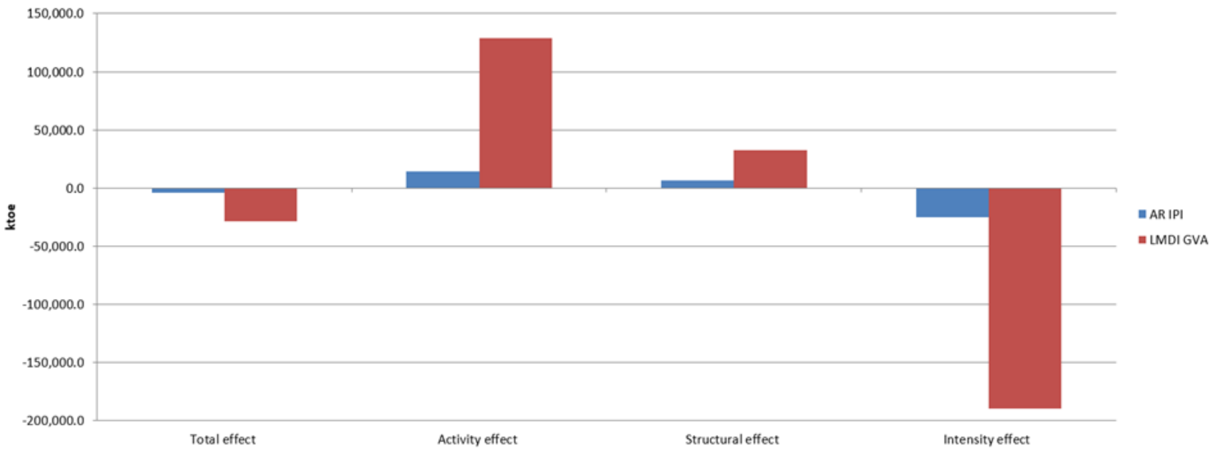
The change in industrial energy consumption in 2010-2021, disaggregated into manufacturing and construction, is decomposed using two approaches, the monetary LMDI and the AR, as described in the methodology section. As discussed in Section 2, the activity effect in the monetary-based approach accounts for changes in FEC due to changes in GVA, while in the physical units (AR) approach, the activity effect shows changes in FEC due to changes in the physical production index.

The use of the 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 the energy demand. A positive structural effect is found in this analysis. The structural effect is influenced by the specific grouping considered (the 11 subsectors), as the results are usually closely related to the disaggregation level used in the analysis.

A comparison of the EU27 decomposition results carried out using production-based activity measure (industrial production index - IPI) versus monetary-based activity measure (gross value added) is shown in Figure 1. The use of industrial physical index confirms the general trends previously identified. Over the examined period, in both methodologies, the intensity effect has been the dominant driver in reducing energy demand. A positive structural effect is found in this analysis. However, this result could be linked to the lack of fine disaggregation of the industry by subsector in the latter case due to data restrictions discussed in the methodology section; in contrast to the 11 subsectors considered before, the analysis here is based on two subsectors only. The structural effect is thus influenced by the specific grouping of subsectors, and the accuracy of the results is usually closely related to the granularity level of the underlying input data.

Considering the AR approach, the industrial energy consumption decreased by −4.2 Mtoe, which is mainly attributed to the intensity effect (−25 Mtoe) and partially compensated by structural effect (+6.3 Mtoe) and activity effect (+14.5 Mtoe). In general, differences can be observed between the production-based and monetary-based results. Structural effects seem to have a less dominant impact (if positive) on the energy consumption in the case of the production-based results. The negative IPI-based intensity effect is of lower magnitude, which may indicate that the use of GVA generally overestimates intensity (efficiency) improvements. At Member States 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 future decomposition analyses.

Figure 11. Differences in industrial decomposition results between the use of monetary-based (GVA) versus physical-based (IPI) units



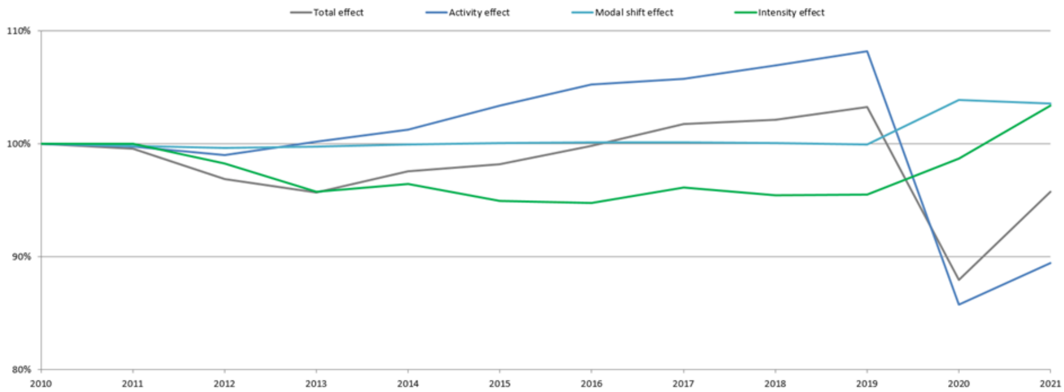
Source: JRC

3.3 Transport

Taking into account all transport modes, transport energy consumption[19] decreased by -5% in the period 2010-2021. Air transport (domestic) consumption alone fell by -32% over this period, followed by a drop in consumption of all other transport modes: inland waterways transport consumption fell by more than one third (−21%), rail transport consumption by −17% and road transport consumption decreased by -0.4%. At country level, 16 Member States recorded a drop in their transport energy consumption, while the consumption in all other Member State increased in 2010-2021. Countries with the most pronounced increase in their overall transport energy consumption included Poland (+35%), Lithuania (+34%), Slovakia (+29%) and Hungary (+25%). In contrast, transport consumption decline was more evident in Greece (-39%), the Netherlands (-29%) and Cyprus (-26%).

In relation to the EU passenger transport, the year-on-year results are shown in Figure 12. While the total effect has been on a declining trend from 2010 to 2013, this trend was completely reversed in 2014. In 2021, the passenger transport consumption increased by +0.1% since the lowest recorded consumption in 2013 and decreased by -4% compared to 2010. 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 2010-2012. Since 2013, the activity effect has had a strong positive drive on the overall energy consumption until 2019. In 2020, the COVID-19 crisis results in a drop of the activity effect without precedent. The lockdowns and teleworking rules established by the majority of the member states have almost zeroed the movement of people and goods. As seen from the results, both intensity and modal shift effects rose in 2020. The intensity effect has been mostly negative throughout the study period. In 2021, intensity and activity gains were responsible for a 5% drop in the overall consumption compared to 2010. The impact of the modal shift effect has been marginal for the entire period except for the year 2020. The latest change in EU passenger transport consumption is captured in Figure 13. In 2021 intensity and activity effects played a dominant role in driving up energy consumption, weakly compensated by modal shift changes, resulting into a +13 Mtoe increase of overall passenger transport consumption compared to 2020 levels.

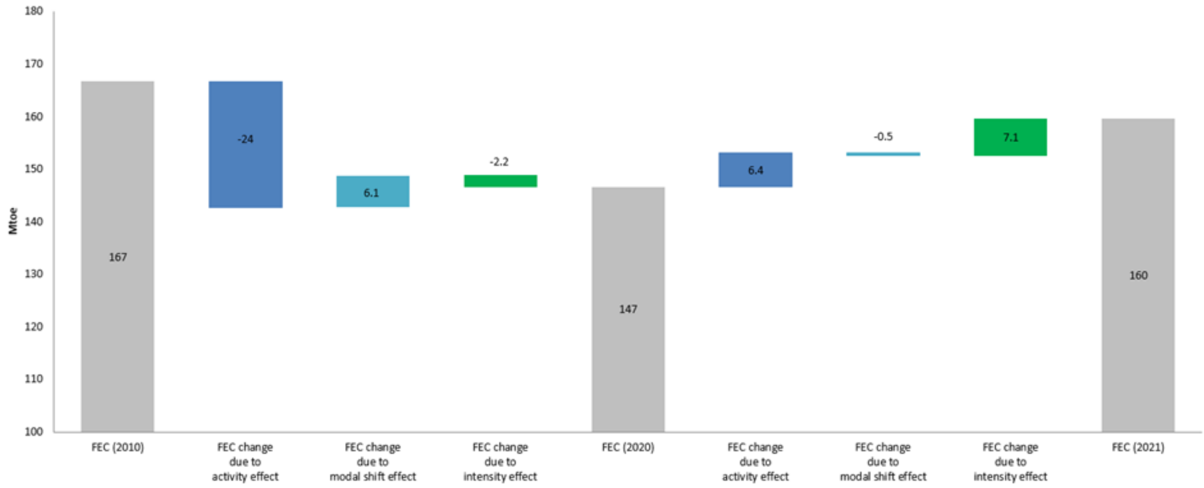
Figure 12. Yearly multiplicative LMDI decomposition results of passenger transport energy consumption changes at EU level in 2010-2021



Source: JRC

[19] Transport sector includes Road transport (ESTAT code: B_101920); Rail transport (ESTAT code: B_101910); Air transport (ESTAT code: B_101932); Water transport (ESTAT code: B_101940)

Figure 13. Decomposition of changes in EU passenger transport energy consumption (Mtoe) in 2010-2021 using the additive LMDI approach

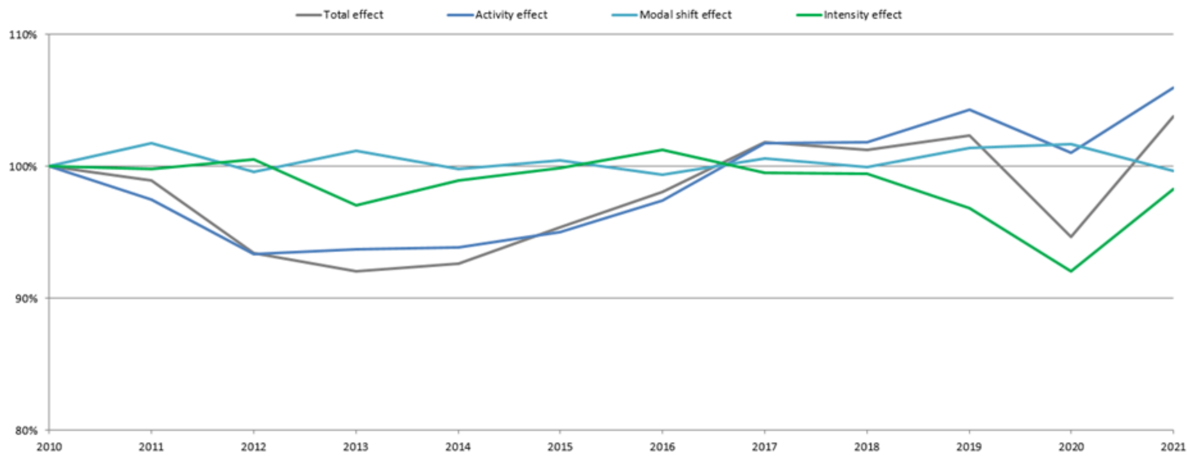


Source: JRC

At country level, half countries experienced growth, although restrained for most of them, in their passenger energy consumption in the period 2010-2021. Among those countries that registered a passenger energy consumption decrease, Greece (−39%), Netherlands (−29%), Cyprus (−26%), Belgium (−15%), Ireland (-13%), Finland (-13%), France (-8%), Luxembourg (-8%), Austria (-8%), Portugal (-8%), Spain (-4%), Slovenia (-4%), Malta (-3%), Denmark (−2%) and Germany (-1%) (Table 6). Poland, Slovakia, Lithuania, and Hungary, on the other hand, had a considerable increase in passenger transport. A shift to cleaner modes was noted only in Estonia (-3%), Lithuania (-3%), Luxembourg (-9%) and Slovenia (-1%). Improvements in efficiency were registered in Czechia, Denmark, Estonia, Ireland, Greece, France, Cyprus, Latvia, Luxembourg, Malta, Austria, Portugal, Romania, and Finland.

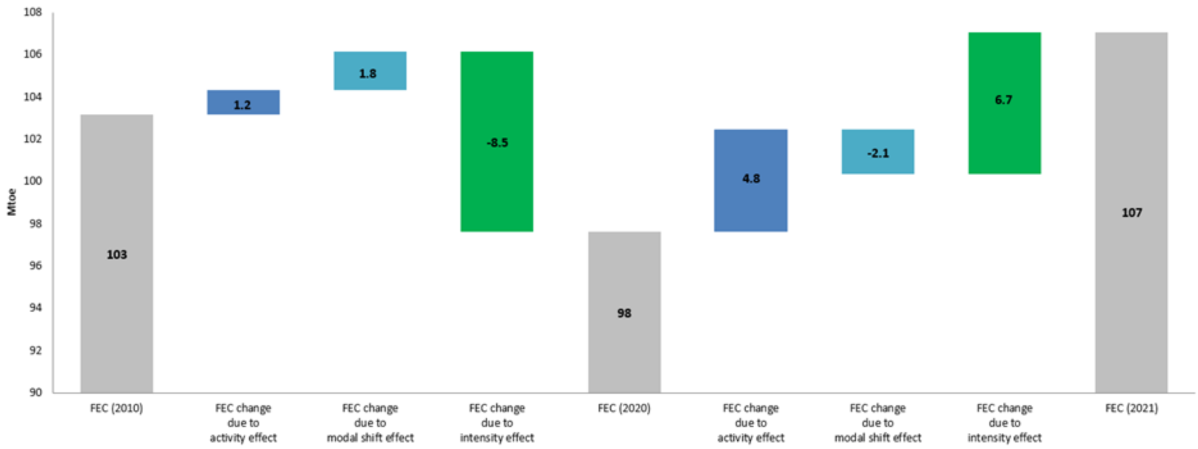
With regards to the EU freight transport, energy consumption (Figure 14) was on a recovering trajectory following a decline in 2010-2013 until 2019, then also in this transport sector in 2020 it has been registered a drop followed by a rebound effect of 3.8% in 2021 compared to 2010 levels. The activity and intensity effects showed an increase in 2021, while the modal shift effect declined in the same year. The intensity effect decreased by -2%, followed by the modal shift (-0.3%), while the activity effect (i.e. lower tonne kilometres) increased by 6% in the 2010-2021 period.

Figure 14. Yearly multiplicative LMDI decomposition results of freight transport energy consumption changes at EU level in 2010-2021



Source: JRC

Figure 15. Decomposition of changes in EU freight transport energy consumption (Mtoe) in 2010-2021 using the additive LMDI approach



Source: JRC

Table 6. Additive and multiplicative decomposition results of passenger transport energy consumption changes at Member State level in 2010-2021 and 2020-2021

		Additive results [ktoe]				Multiplicative results [%]			
	Period	Total effect	Activity effect	Modal shift effect	Intensity effect	Total effect	Activity effect	Modal shift effect	Intensity effect
BE	2010-2021	-814	-1120	217	89	85%	79%	105%	103%
	2020-2021	446	-59	16	489	111%	99%	100%	112%
BG	2010-2021	349	-132	71	410	119%	95%	104%	120%
	2020-2021	133	-3	-14	151	106%	100%	99%	107%
CZ	2010-2021	721	189	680	-148	118%	105%	117%	96%
	2020-2021	351	586	168	-403	108%	114%	104%	91%
DK	2010-2021	-51	78	116	-245	98%	103%	104%	92%
	2020-2021	48	-21	-2	71	102%	99%	100%	103%
DE	2010-2021	-320	-5348	1070	3958	99%	86%	103%	111%
	2020-2021	657	-226	-70	952	102%	99%	100%	103%
EE	2010-2021	27	86	-12	-47	106%	120%	97%	91%
	2020-2021	15	27	-28	17	103%	106%	94%	104%
IE	2010-2021	-298	153	40	-490	87%	104%	102%	82%
	2020-2021	229	12	-7	224	113%	101%	100%	112%
EL	2010-2021	-1519	-376	72	-1216	61%	86%	103%	69%
	2020-2021	143	-23	1	165	106%	99%	100%	107%
ES	2010-2021	-546	-3166	461	2159	96%	79%	103%	117%
	2020-2021	1765	-66	-38	1869	114%	100%	100%	115%
FR	2010-2021	-2294	309	590	-3193	92%	101%	102%	89%
	2020-2021	2525	3838	-286	-1027	111%	117%	99%	96%
HR	2010-2021	9	-194	17	186	101%	87%	101%	114%
	2020-2021	123	215	-33	-60	110%	118%	98%	96%
IT	2010-2021	-3291	-5608	431	1885	86%	73%	103%	114%
	2020-2021	4286	1618	2	2666	127%	110%	100%	116%
CY	2010-2021	-138	-5	8	-141	74%	97%	102%	75%
	2020-2021	26	-3	0	29	107%	99%	100%	108%
LV	2010-2021	10	55	11	-57	102%	111%	102%	89%
	2020-2021	11	21	-25	15	102%	103%	96%	102%
LT	2010-2021	309	-103	-35	447	134%	88%	97%	156%
	2020-2021	2	41	-51	12	100%	103%	96%	101%
LU	2010-2021	-118	239	-116	-241	92%	118%	91%	85%
	2020-2021	169	141	-140	168	115%	112%	89%	115%
HU	2010-2021	565	208	274	83	125%	110%	111%	103%
	2020-2021	276	124	14	137	111%	105%	101%	105%
MT	2010-2021	-4	3	1	-8	97%	101%	101%	94%
	2020-2021	4	-1	0	5	103%	99%	100%	104%
NL	2010-2021	-2179	-1999	8	-187	71%	71%	100%	100%
	2020-2021	7	66	-95	36	100%	101%	98%	101%
AT	2010-2021	-504	-615	347	-235	91%	87%	107%	96%
	2020-2021	76	-329	260	145	102%	93%	106%	103%
PL	2010-2021	3173	563	1128	1482	135%	107%	111%	114%
	2020-2021	953	504	-52	502	108%	104%	100%	104%
PT	2010-2021	-302	-23	45	-323	92%	99%	101%	92%
	2020-2021	270	-1	-23	294	109%	100%	99%	109%
RO	2010-2021	239	466	69	-296	109%	121%	103%	87%
	2020-2021	164	-13	-7	184	106%	100%	100%	107%
SI	2010-2021	-47	-57	-12	23	96%	94%	99%	103%
	2020-2021	134	49	-56	142	114%	105%	95%	114%
SK	2010-2021	277	-126	5	398	129%	91%	100%	142%
	2020-2021	70	15	-23	78	106%	101%	98%	107%
FI	2010-2021	-315	-91	14	-238	87%	96%	101%	90%
	2020-2021	-6	-23	-14	32	100%	99%	99%	101%
SE	2010-2021	-6	-914	87	822	100%	82%	102%	119%
	2020-2021	141	-56	32	165	103%	99%	101%	104%
EU27	2010-2021	-7066	-17528	5588	4875	96%	89%	104%	103%
	2020-2021	13018	6430	-471	7059	109%	104%	100%	105%

Source: JRC

The results at country level are shown in Table 7. Freight transport energy consumption dropped in 10 countries in 2010-2021. The largest drops were registered in Luxembourg (-40%), Portugal (-26%), Spain (-17%), Denmark (-17%) and the Netherlands (-14%). On the opposite side, freight transport consumption increased considerably in Bulgaria (+73%), Romania (+57%), Lithuania (+46%) and Poland (+40%). The activity effect was a main driver of freight transport consumption in Croatia, Poland, Lithuania, Bulgaria, and Romania. On the opposite side, Estonia, Greece, the Netherlands, Cyprus, Luxembourg, and Slovenia experienced strong negative activity effects. A shift to cleaner transport modes is noted in 6 Member States, while improvements in energy intensity are observed in 16 of them.

Table 7. Additive and multiplicative decomposition results of freight transport energy consumption changes at Member State level in 2010-2021 and 2020-2021

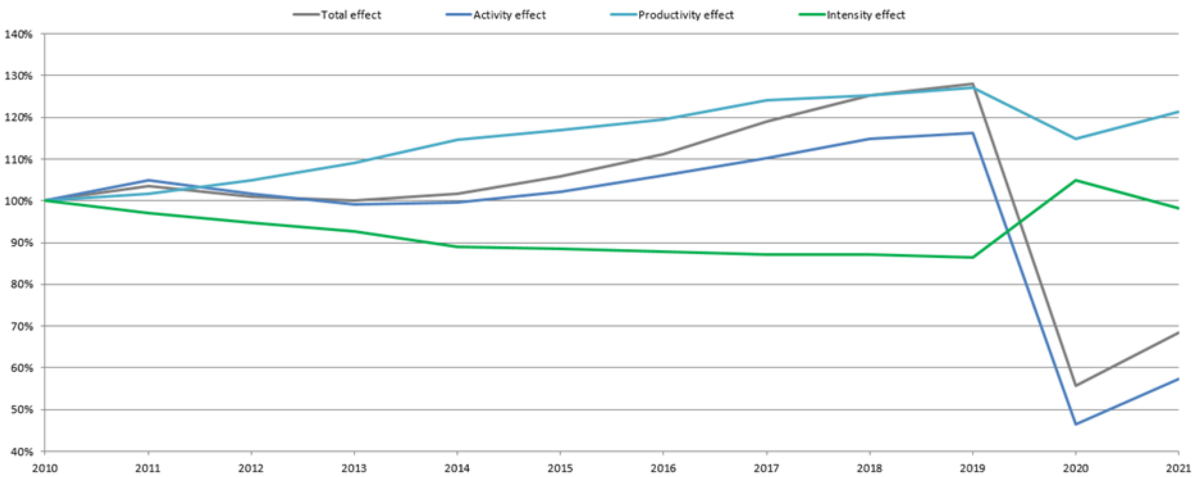
		Additive results [ktoe]				Multiplicative results [%]			
	Period	Total effect	Activity effect	Modal shift effect	Intensity effect	Total effect	Activity effect	Modal shift effect	Intensity effect
BE	2010-2021	404	14	142	249	112%	100%	104%	107%
	2020-2021	369	243	3	123	110%	107%	100%	103%
BG	2010-2021	488	425	60	3	173%	163%	110%	97%
	2020-2021	70	80	4	-14	106%	107%	100%	99%
CZ	2010-2021	298	393	-2	-93	115%	122%	100%	95%
	2020-2021	162	247	18	-103	108%	112%	101%	95%
DK	2010-2021	-261	96	10	-368	83%	106%	100%	78%
	2020-2021	31	84	0	-54	102%	107%	100%	96%
DE	2010-2021	1459	-158	-53	1670	110%	99%	100%	111%
	2020-2021	1092	602	-358	848	107%	104%	98%	105%
EE	2010-2021	-3	-139	95	40	99%	60%	141%	116%
	2020-2021	22	57	-1	-34	108%	123%	100%	89%
IE	2010-2021	56	173	7	-123	105%	114%	101%	91%
	2020-2021	105	106	6	-8	109%	109%	101%	99%
EL	2010-2021	-326	-1043	363	354	90%	71%	112%	113%
	2020-2021	193	-494	127	559	107%	84%	105%	122%
ES	2010-2021	-2850	3443	95	-6388	83%	128%	100%	65%
	2020-2021	1757	1460	-59	356	114%	112%	100%	103%
FR	2010-2021	789	-692	-470	1951	105%	95%	97%	114%
	2020-2021	1859	214	-274	1919	114%	101%	98%	114%
HR	2010-2021	163	251	18	-106	128%	144%	104%	85%
	2020-2021	62	58	15	-11	109%	108%	102%	98%
IT	2010-2021	-131	-2020	-468	2357	99%	87%	97%	118%
	2020-2021	1653	1248	-122	527	113%	110%	99%	104%
CY	2010-2021	11	-73	0	84	105%	70%	100%	151%
	2020-2021	16	15	0	1	107%	107%	100%	100%
LV	2010-2021	-13	-90	186	-109	97%	81%	153%	78%
	2020-2021	21	16	21	-17	105%	104%	105%	96%
LT	2010-2021	292	610	95	-413	146%	220%	111%	60%
	2020-2021	13	15	18	-20	101%	102%	102%	98%
LU	2010-2021	-306	-190	11	-126	60%	75%	102%	79%
	2020-2021	-50	32	0	-82	90%	107%	100%	84%
HU	2010-2021	241	169	-34	106	114%	113%	98%	103%
	2020-2021	189	191	65	-67	110%	110%	103%	97%
MT	2010-2021	4	4	2	-2	106%	107%	103%	96%
	2020-2021	5	4	1	0	108%	107%	102%	99%
NL	2010-2021	-578	-882	-769	1073	86%	77%	80%	138%
	2020-2021	65	-586	-633	1284	102%	84%	83%	146%
AT	2010-2021	339	-444	-506	1290	113%	85%	83%	162%
	2020-2021	219	-303	-423	945	108%	90%	86%	141%
PL	2010-2021	3115	5168	587	-2640	140%	185%	107%	70%
	2020-2021	850	1413	81	-643	108%	114%	101%	94%
PT	2010-2021	-681	-187	11	-504	74%	92%	100%	80%
	2020-2021	162	505	0	-343	109%	131%	100%	83%
RO	2010-2021	1247	1278	636	-667	157%	164%	130%	73%
	2020-2021	210	215	6	-11	107%	107%	100%	100%
SI	2010-2021	110	-610	-523	1243	119%	38%	44%	711%
	2020-2021	81	-833	-526	1440	114%	27%	44%	961%
SK	2010-2021	53	34	9	10	104%	107%	102%	96%
	2020-2021	74	7	-59	126	106%	101%	95%	111%
FI	2010-2021	89	42	49	-2	105%	103%	103%	99%
	2020-2021	148	25	-20	143	109%	101%	99%	108%
SE	2010-2021	-90	409	196	-694	97%	118%	108%	75%
	2020-2021	68	200	25	-157	103%	108%	101%	94%
EU27	2010-2021	3921	5981	-254	-1806	104%	106%	100%	98%
	2020-2021	9442	4820	-2084	6707	110%	105%	98%	107%

Source: JRC

3.3.1 Air transport

In the period 2010-2021, energy consumption of the EU air transport dropped by -12 Mtoe, corresponding to a -32% decrease compared to 2010 levels (Figure 16). Air transport represents the most affected sector by COVID-19 restrictions in 2020. Many reasons are behind the fall of the activity (-23.6 Mtoe in 2010-2020 and +5 Mtoe in 2020-2021) and the productivity (expressed as tonnes/flights) (+7.6 Mtoe in 2010-2020 and +1.3 Mtoe in 2020-2021) effects: generalised lockdowns among member states have resulted in people being unable to travel. In addition, most Member States have closed their borders in order to contain the spread of the virus. Finally, the uncertainty arising from countries' health situations has caused an inevitable slowdown in both people and goods flows. All the three effects have shown an inverse trend in 2021 compared to 2020. Activity and productivity effects started increasing again in 2021, offsetting the drop of the intensity effect. Therefore, the energy consumption of the air transport sector experienced a rebound effect in 2021, even if the consumption level is still quite far from the level reached in 2019, before the pandemic crisis.

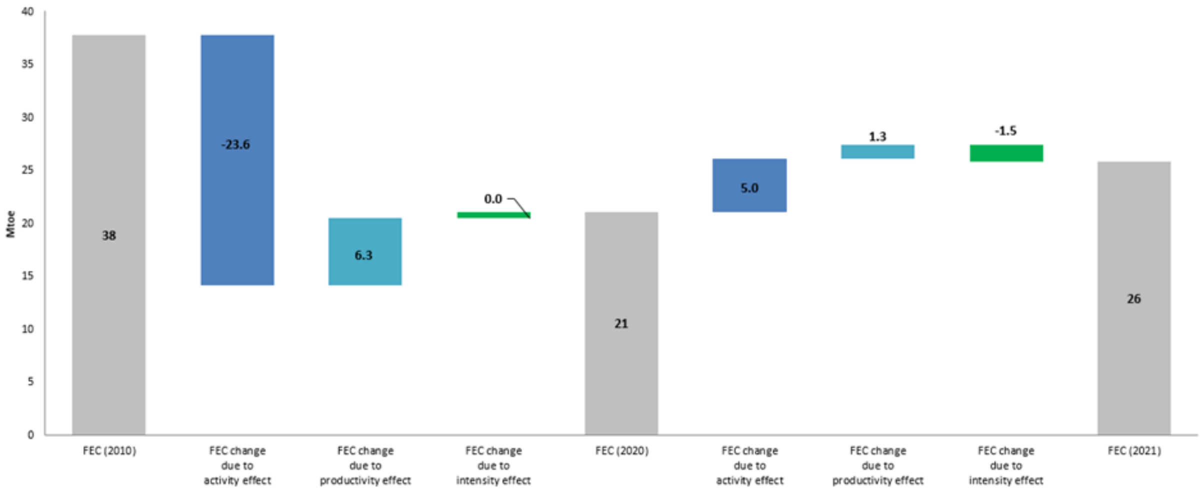
Figure 16. Yearly multiplicative LMDI decomposition results of air transport energy consumption changes at EU level in 2010-2021



Source: JRC

The energy consumption at EU level decreased by -12 Mtoe in 2021, corresponding to a -32% decrease compared to 2010 levels. The reason of the decreasing trend in consumption is directly consequence of the pandemic crisis occurred in 2020. Before this peculiar year, the energy consumption of the air transport was showing a constant increasing trend since 2013. The productivity effect (expressed as tonnes/flights) increased over time (with the exception of year 2020), which was another major driving force of the air transport consumption. These were mostly counterbalanced by improvements in energy intensity until 2019, then it registered a strong increase in 2020 hold back by a new decrease dynamic in 2021 (+7.6 Mtoe over the 2010-2021 period). This effect has been consistently an inhibitor force of the air transport consumption since the beginning of the examined period.

Figure 17. Decomposition of changes in EU air transport energy consumption (Mtoe) in 2010-2021 using the additive LMDI approach



Source: JRC

At Member States level, air transport consumption decreased in 22 countries, except for Belgium, Estonia, Lithuania, Luxembourg, and Poland. Countries with the most pronounced decrease in air transport energy consumption included Czechia (-49%), Denmark (-48%), Ireland (-42%), Italy (-46%), Cyprus (-44%), Hungary (-46%), Austria (-40%), Romania (-54%), Slovenia (-62%), Slovakia (-45%), Finland (-51%) and Sweden (-51%). The activity effect contributed to an increase in consumption only in Greece (+1%) while for all the other countries the activity effect played a key role in decreasing the energy consumption. Productivity in terms of goods/passengers transferred per flight has increased in 22 countries, with the exception of Slovakia, Malta, Spain, Greece and Ireland. This had most dominant impact in Belgium, Czechia, Germany, Estonia, Lithuania, Luxembourg, Hungary, Austria, Poland, Romania, and Slovenia. Finally, intensity improvements caused a drop in energy consumption in 14 countries, with the most notable results in France, Italy, Cyprus, Romania, and Hungary.

Table 8. Additive and multiplicative decomposition results of air transport energy consumption changes at Member States level in 2010-2021 and 2020-2021

		Additive results [ktoe]				Multiplicative results [%]			
	Period	Total effect	Activity effect	Productivity effect	Intensity effect	Total effect	Activity effect	Productivity effect	Intensity effect
BE	2010-2021	135	-758	932	-40	110%	60%	191%	96%
	2020-2021	314	244	147	-78	126%	120%	111%	94%
BG	2010-2021	-14	-59	31	14	92%	72%	116%	110%
	2020-2021	27	37	7	-16	119%	127%	104%	90%
CZ	2010-2021	-170	-331	128	33	51%	33%	141%	110%
	2020-2021	19	23	15	-19	112%	115%	109%	89%
DK	2010-2021	-408	-519	200	-90	52%	45%	127%	91%
	2020-2021	96	45	60	-9	127%	112%	116%	98%
DE	2010-2021	-2463	-5233	2364	406	72%	49%	134%	109%
	2020-2021	1420	802	278	340	129%	116%	105%	106%
EE	2010-2021	10	-17	16	12	130%	68%	136%	140%
	2020-2021	20	4	9	7	178%	113%	129%	122%
IE	2010-2021	-322	-482	-24	184	58%	46%	99%	128%
	2020-2021	48	-8	50	6	112%	98%	113%	101%
EL	2010-2021	-71	-8	12	-75	92%	101%	99%	92%
	2020-2021	402	308	73	21	190%	164%	112%	103%
ES	2010-2021	-2024	-2117	83	10	63%	65%	98%	100%
	2020-2021	976	1084	237	-345	138%	144%	108%	89%
FR	2010-2021	-2392	-3671	1868	-589	62%	54%	130%	89%
	2020-2021	263	866	1	-603	107%	126%	100%	85%
HR	2010-2021	-3	-29	2	24	97%	87%	110%	102%
	2020-2021	46	42	23	-18	178%	169%	133%	79%
IT	2010-2021	-1778	-1865	273	-185	54%	58%	105%	89%
	2020-2021	265	580	141	-456	114%	134%	107%	79%
CY	2010-2021	-125	-74	17	-68	56%	72%	102%	77%
	2020-2021	63	66	27	-30	165%	169%	124%	79%
LV	2010-2021	-39	-67	23	5	67%	49%	116%	118%
	2020-2021	20	10	2	8	135%	116%	103%	112%
LT	2010-2021	14	-19	21	12	129%	83%	139%	112%
	2020-2021	8	9	6	-7	114%	116%	111%	89%
LU	2010-2021	192	-102	308	-13	145%	88%	173%	95%
	2020-2021	77	93	24	-41	114%	117%	104%	93%
HU	2010-2021	-106	-130	80	-55	54%	45%	158%	77%
	2020-2021	22	6	18	-2	121%	105%	117%	98%
MT	2010-2021	-24	-5	-17	-2	77%	92%	86%	98%
	2020-2021	18	20	4	-6	130%	135%	106%	91%
NL	2010-2021	-978	-1060	408	-327	71%	69%	111%	93%
	2020-2021	222	370	28	-176	110%	117%	101%	93%
AT	2010-2021	-283	-539	202	54	60%	41%	132%	111%
	2020-2021	85	37	31	17	125%	110%	108%	105%
PL	2010-2021	81	-208	174	116	116%	80%	136%	107%
	2020-2021	118	103	60	-45	125%	121%	112%	92%
PT	2010-2021	-234	-112	59	-182	77%	89%	101%	86%
	2020-2021	170	185	21	-36	128%	131%	103%	95%
RO	2010-2021	-148	-72	197	-273	46%	55%	216%	39%
	2020-2021	43	40	5	-2	150%	145%	105%	98%
SI	2010-2021	-18	-28	11	-1	38%	27%	146%	99%
	2020-2021	1	2	1	-2	107%	120%	111%	81%
SK	2010-2021	-19	-6	-23	11	55%	83%	52%	128%
	2020-2021	-6	6	-4	-8	79%	126%	86%	73%
FI	2010-2021	-315	-550	173	62	49%	35%	120%	115%
	2020-2021	-9	-15	-3	9	97%	95%	99%	103%
SE	2010-2021	-444	-575	68	62	49%	43%	103%	111%
	2020-2021	24	38	24	-39	106%	110%	106%	91%
EU27	2010-2021	-11946	-18635	7587	-898	68%	57%	121%	98%
	2020-2021	4750	4997	1284	-1531	123%	124%	106%	94%

Source: JRC

3.4 Residential

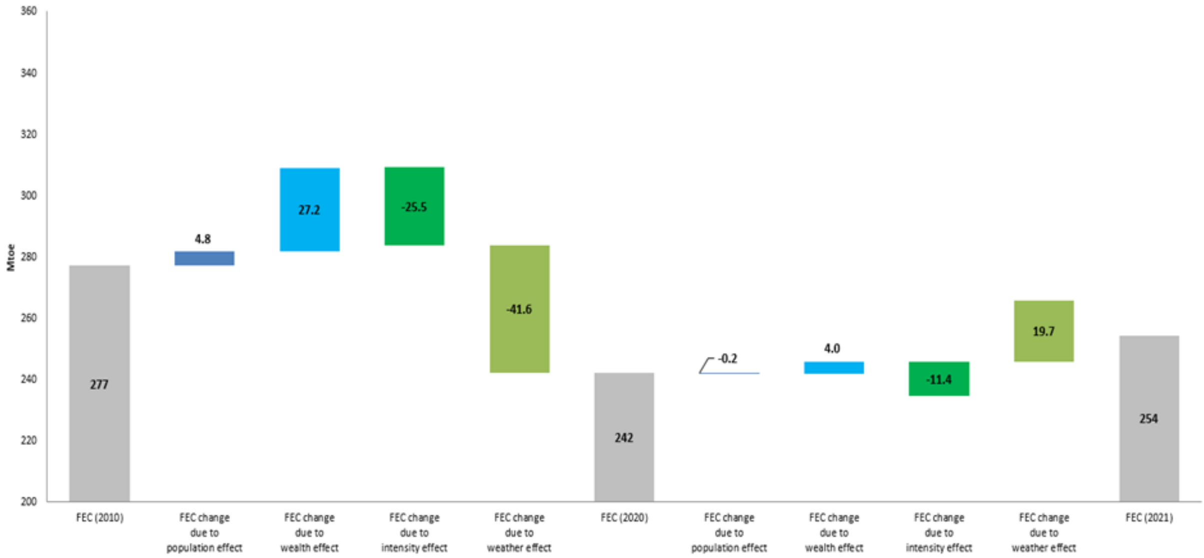
In the period 2010-2021, energy consumption[20] of the EU27 residential sector decreased by -23 Mtoe, corresponding to a drop of −8% compared to 2010 levels (Figure 18). Improvements in energy intensity contributed to a reduction of −36.8 Mtoe in this sector. Warmer winters over this period resulted in an energy consumption drop of −22 Mtoe in 2021 compared to 2010. Both effects more than offset the driving forces behind residential consumption, namely the population and wealth effects that together accounted for an increase of +36 Mtoe in the same period. At Member States level, residential consumption dropped in all but 9 countries. Member States with the most pronounced decline in residential energy consumption included Spain (-29% compared to 2010 levels), Latvia (−25%), Slovenia (-28%), Croatia (-23%) and Netherlands (−27%). In contrast, residential consumption increased in Malta (+152%), Romania (+16%), Bulgaria (+15%), Poland (+6%), Slovakia (+74%), Czechia (+17%), Austria (+13%), Lithuania (+9%) and Cyprus (+9%).

In 2020-2021, a consumption increase (+12 Mtoe) has been recorded at EU level. Based on the decomposition results, the effects that contributed to this trend are a more important increase in weather effect (+19.7 Mtoe), an increase in the wealth effect (+4 Mtoe), a very minor decrease driven by the population (-0.2 Mtoe) and a drop in the intensity effect (-11.4 Mtoe). Indeed, residential consumption increased in most countries in 2020 compared to 2019 except for Ireland, Cyprus, Luxembourg, and Portugal.

The yearly results (Figure 19) 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 wealth and population effects have been on constant rise in the period 2010-2020, while in 2021 the latter registered a small drop compared to 2020. The intensity effect shows a trend inversion in 2020, it was declining after a breakdown since 2018 and it started to rise again in 2020 given the COVID-19 crisis that had the effect of reversing the intensity trend. In 2021, the intensity effect started dropping again.

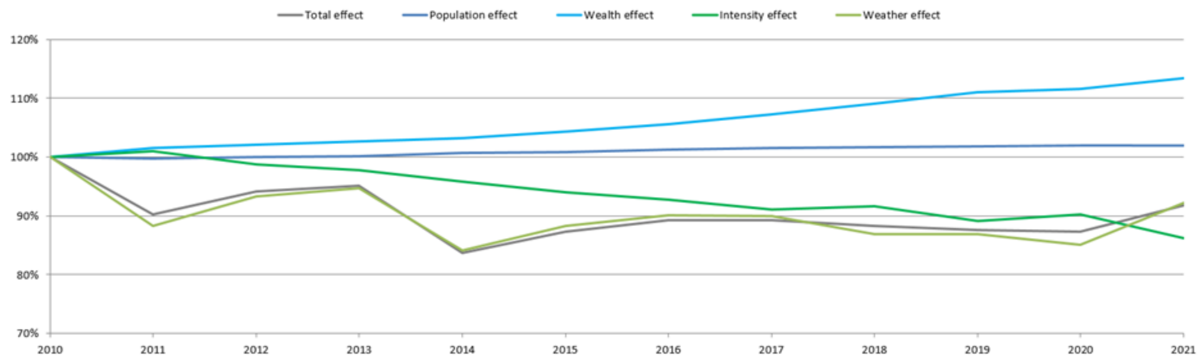
[20] ESTAT code: FC_OTH_HH_E

Figure 18. Decomposition of changes in EU residential energy consumption (Mtoe) in 2010-2021 using the additive LMDI approach



Source: JRC

Figure 19. Yearly multiplicative LMDI decomposition results of residential energy consumption changes at EU level in 2010-2021



Source: JRC

At countries level, the decomposition results show that intensity and weather effects were the two main inhibitor factors restricting energy consumption growth in the residential sector in most countries. Intensity acted as a limiting factor in 24 Member States, except for Greece, Portugal, and Slovakia. Weather effect contributes to restrict energy consumption in all countries, except for Greece, Cyprus, and Malta. The largest drop in residential energy consumption due to warmer winters in 2010-2021 was noted in Belgium, Denmark, Germany, Ireland, Spain, Netherlands, Portugal, and Sweden. In relative terms (% change compared to 2010 consumption levels), the largest impact energy intensity improvements had on the residential sector can be seen in Belgium, Estonia, Ireland, Spain, Croatia, Cyprus, Latvia, Lithuania, Luxembourg, Hungary, Netherlands, Romania, Slovenia, Finland, and Sweden (greater than 30% compared to 2010 consumption levels). On the opposite side, the population and wealth effects were the main determinants of growth in residential energy consumption in many Member States in 2010-2021. The population effect was positive in all countries except Bulgaria, Greece, Croatia, Lithuania, Latvia, Hungary, Poland, Portugal, and Romania.

The wealth effect was a driver in all countries except Greece where a reduction equivalent to -10% was found.

Table 9. Additive and multiplicative decomposition results of residential energy consumption changes at Member State level in 2010-2021 and 2020-2021

		Additive results [ktoe]					Multiplicative results [%]				
	Period	Total effect	Population effect	Wealth effect	Intensity effect	Weather effect	Total effect	Population effect	Wealth effect	Intensity effect	Weather effect
BE	2010-2021	-1173	529	668	-1358	-1013	87%	114%	129%	69%	87%
	2020-2021	661	23	119	-470	989	125%	101%	104%	101%	118%
BG	2010-2021	159	-160	686	-367	0	115%	87%	184%	72%	99%
	2020-2021	20	-12	117	-221	137	102%	99%	111%	84%	111%
CZ	2010-2021	246	14	1550	-800	-519	117%	101%	172%	75%	90%
	2020-2021	687	-137	434	-175	565	126%	96%	116%	100%	112%
DK	2010-2021	-663	232	471	-567	-799	96%	111%	138%	76%	82%
	2020-2021	193	12	49	-242	374	124%	101%	103%	107%	112%
DE	2010-2021	-5989	843	6850	-7161	-6522	90%	103%	138%	73%	86%
	2020-2021	647	-8	767	-5138	5026	107%	100%	103%	91%	114%
EE	2010-2021	-62	-2	275	-237	-97	95%	100%	231%	47%	88%
	2020-2021	21	1	28	-134	126	110%	100%	109%	83%	121%
IE	2010-2021	-606	283	454	-942	-400	81%	121%	140%	57%	83%
	2020-2021	-141	26	78	-176	-69	91%	102%	106%	87%	96%
EL	2010-2021	-487	-173	-405	-273	364	85%	92%	80%	104%	110%
	2020-2021	-15	-16	-124	50	75	101%	99%	97%	101%	103%
ES	2010-2021	-2405	288	1338	-2948	-1083	71%	104%	119%	68%	85%
	2020-2021	170	20	237	-473	386	101%	100%	103%	92%	107%
FR	2010-2021	-5235	1801	3230	-6059	-4206	86%	109%	123%	73%	88%
	2020-2021	2866	187	631	-2182	4230	110%	101%	104%	88%	118%
HR	2010-2021	-330	-152	504	-562	-120	77%	88%	161%	58%	94%
	2020-2021	163	-13	104	-91	163	113%	99%	113%	91%	111%
IT	2010-2021	-3462	52	1678	-3192	-2000	89%	100%	113%	85%	92%
	2020-2021	1370	-213	565	-802	1819	112%	99%	105%	99%	109%
CY	2010-2021	7	32	27	-72	19	109%	120%	119%	62%	122%
	2020-2021	-9	3	9	-18	-3	93%	102%	105%	90%	97%
LV	2010-2021	-186	-142	505	-436	-113	75%	80%	263%	40%	89%
	2020-2021	87	-9	50	-106	152	112%	98%	113%	83%	122%
LT	2010-2021	-22	-173	614	-349	-113	109%	79%	269%	56%	91%
	2020-2021	166	1	35	-61	191	129%	100%	106%	100%	121%
LU	2010-2021	-38	116	37	-167	-24	96%	160%	133%	48%	95%
	2020-2021	-19	7	1	-110	83	94%	103%	101%	73%	124%
HU	2010-2021	-247	-178	1120	-913	-276	97%	94%	173%	63%	95%
	2020-2021	433	-25	174	-133	417	121%	99%	111%	100%	110%
MT	2010-2021	40	19	24	-4	1	252%	155%	161%	87%	116%
	2020-2021	11	0	7	1	2	139%	101%	110%	109%	116%
NL	2010-2021	-2538	518	1116	-2480	-1692	73%	111%	136%	59%	82%
	2020-2021	985	37	195	-66	820	128%	101%	106%	105%	114%
AT	2010-2021	407	444	852	-621	-268	113%	114%	132%	80%	93%
	2020-2021	674	25	204	95	351	120%	101%	106%	103%	109%
PL	2010-2021	-164	-98	3901	-2152	-1814	106%	99%	160%	76%	89%
	2020-2021	976	-66	-439	-600	2081	109%	99%	97%	98%	116%
PT	2010-2021	-216	-69	326	-363	-111	91%	95%	110%	106%	82%
	2020-2021	-5	1	73	-111	33	97%	100%	103%	89%	106%
RO	2010-2021	663	-431	3219	-2110	-15	116%	90%	236%	56%	98%
	2020-2021	757	-55	381	-115	547	122%	99%	111%	99%	112%
SI	2010-2021	-254	33	155	-378	-64	72%	106%	144%	50%	95%
	2020-2021	60	7	28	-45	70	108%	101%	107%	90%	111%
SK	2010-2021	603	28	222	360	-6	174%	103%	139%	126%	97%
	2020-2021	208	1	-104	137	174	118%	100%	95%	111%	111%
FI	2010-2021	-481	175	772	-1055	-372	92%	107%	141%	68%	91%
	2020-2021	545	8	64	20	454	121%	100%	103%	101%	115%
SE	2010-2021	-404	799	1065	-1634	-634	91%	123%	134%	63%	87%
	2020-2021	697	38	343	-195	511	121%	101%	110%	96%	113%
EU27	2010-2021	-22837	4627	31253	-36840	-21877	92%	102%	113%	86%	92%
	2020-2021	12210	-158	4028	-11359	19700	105%	100%	102%	96%	108%

Source: JRC

4 COVID-19 impact on energy consumption

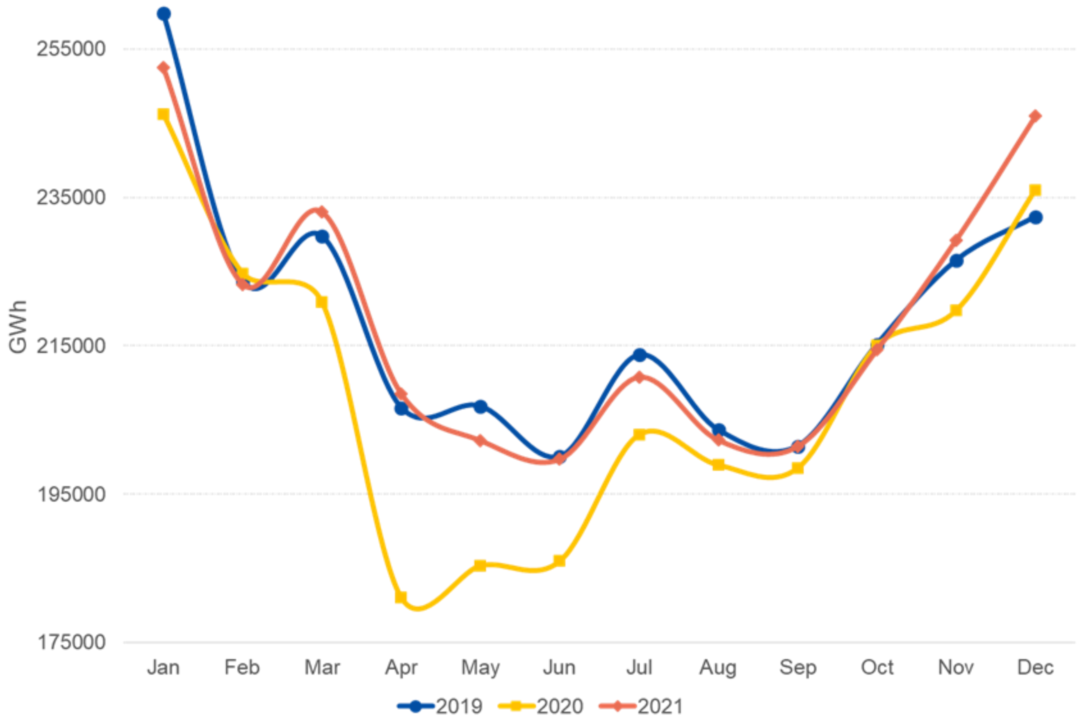
The COVID-19 global pandemic that started at the beginning of 2020 has heavily affected the health, society, and economy of the Member States. Generalised lockdowns, mobility restrictions both at public and private level, the growth of teleworking from home and the shutdown of the majority of economic activities have certainly affected the energy consumption in 2020. The following analysis attempts to assess the impact of COVID-19 crisis at European, Member States and sectoral level (industry, services, transport and residential). Given the peculiar nature of the health crisis, the government responses to COVID-19 evolution were adjusted from time to time on a monthly if not weekly basis; hence, the analysis is focused on the electricity consumption where both weekly and monthly data are available at Member State level.

4.1 Electricity consumption and COVID-19 at European and Member States level

On a European scale Figure 20 shows the monthly comparison among three years (2019, 2020 and 2021) of the electricity consumption weather adjusted. The evolution trends through the same year are similar, with the middle months of the year characterised by lower electricity consumption with respect to the autumn and winter months. However, the drop magnitude in 2020 is extremely higher then both 2019 and 2021 (-3.9% and -5.2% respectively). From the figure is possible to set at the end of February 2020 the starting point of the health emergency, with each Member State establishing containment measures ranging from closure of production activities, gatherings restrictions and travel both domestically and internationally, culminating in lockdowns of varying lengths in terms of days/weeks. Indeed, the electricity consumption in February 2020 shows an almost flat curve instead of an increasing one, as it is observed in 2019 and 2021. Only at the end of the month the intensity of COVID-19 restrictions started to heavily affect the consumption. This exceptional decrease in the consumption lasted until April, where the Member States on the basis of the national epidemiological situation started to soften the restrictions put in place across the end February and the beginning of March. During the summer months, the 2020 consumption trend shows a pattern similar to the other two year considered here, reaching the 2019 level in October, before the so-called second wave of the pandemic occurred in several Member States[21].

[21] The first wave occurred between February/March 2020 until June 2020. The second one started from September/October 2020.

Figure 20. EU monthly electricity consumption comparison over years 2019, 2020 and 2021



Source: JRC elaboration on Entso-e, 2023

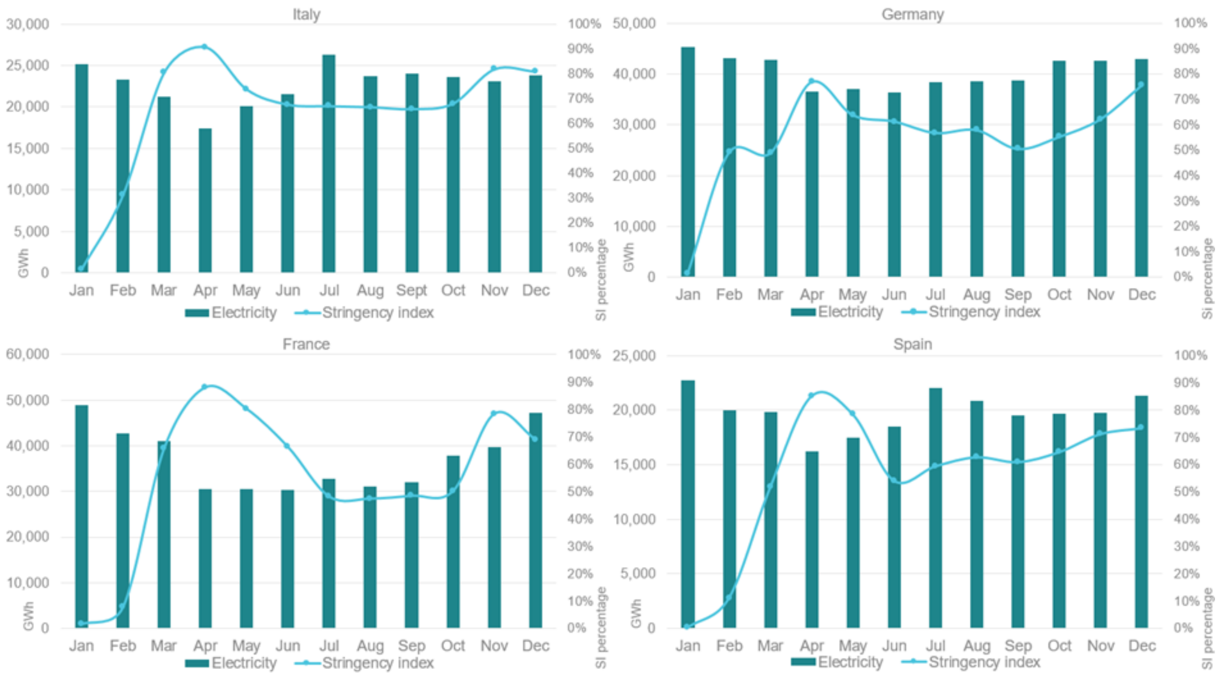
To better understand the effects of Member States' measures to counteract the virus spreading, Figure 21 compares the electricity consumption in four selected Member States (Italy, Germany, France, and Spain) with the stringency index elaborated by the Oxford COVID-19 Government Response Tracker[22]. This indicator detects the response of the government to the evolution of the virus spreading measuring and gathering the containment closure, and health system policies. In particular, the stringency index is calculated as the mean value of a set of sub-indexes encompassing different government response to the virus spreading[23]. Looking at Italy, the first country forced to introduce such measures, it is possible to observe how from February 2020 the increase in the stringency index was matched by a sharp decrease in electricity consumption, with an irregular increase of the consumption from April, when the index (and so the counteract measures) started to decrease. Almost the same trend, in the same months, has been registered by the other Member States here analysed. Based on the speed at which the stringency indicator increases, the electricity consumption of the Member States decreases accordingly. Among the countries considered, France, together with Italy, has registered a sudden increase of the index, reaching in March 2020 a value of 70% (Italy almost 80%). This strong increase led to a higher decrease in consumption compared to those countries where the stringency index reached levels higher than 50% more gradually; this has been the case for Spain and Germany. For the latter the stringency index even decreases between

[22] Thomas Hale, Noam Angrist, Rafael Goldszmidt, Beatriz Kira, Anna Petherick, Toby Phillips, Samuel Webster, Emily Cameron-Blake, Laura Hallas, Saptarshi Majumdar, and Helen Tatlow. (2021). "A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker)." Nature Human Behaviour. https://doi.org/10.1038/s41562-021-01079-8

[23] Sub-indexes considered: school closure, workplace closing, cancel public events, restrictions on gatherings, public transportation, stay at home order, restrictions on internal movement, international travel control and public information campaign.

February and March and it possible to observe that also the electricity consumption did not decrease between these two months.

Figure 21. Electricity consumption and stringency index, monthly values for 2020, Italy, Germany, France, and Spain



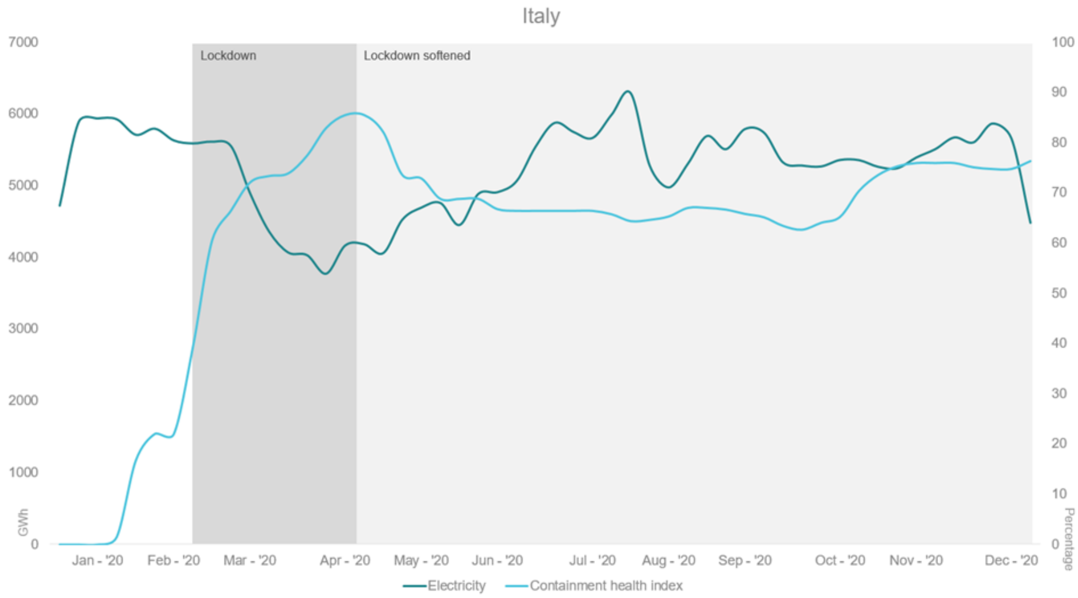
Source: JRC elaboration on Entso-e and OxCGRT, 2023

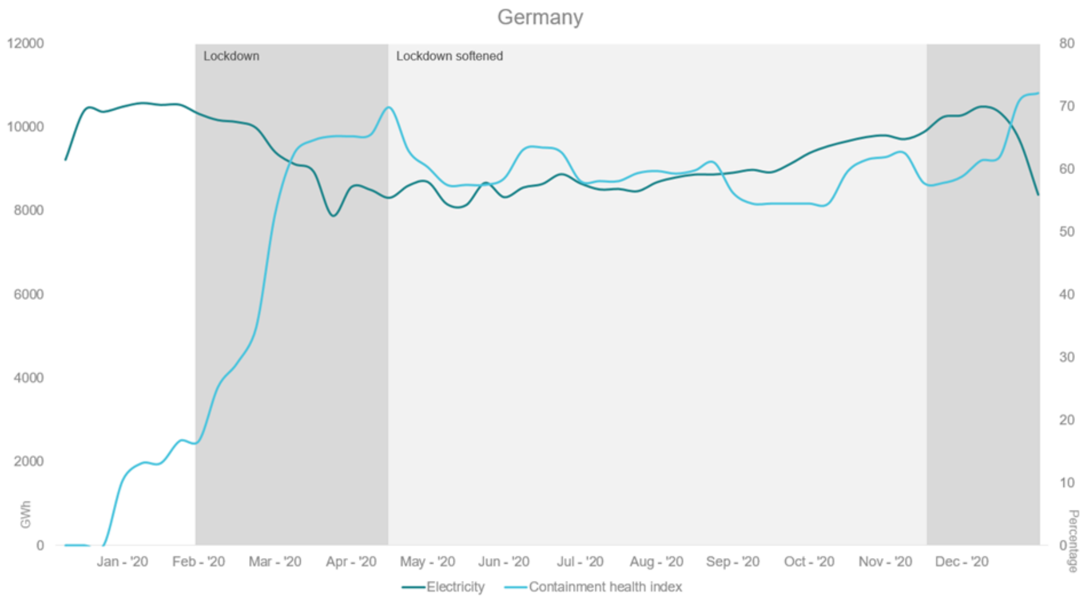
Considering the containment health index (Figure 22), it is possible to capture the trend of the lockdowns that have affected the Member States in every aspect of the daily life. Economic activities have been shut down, citizens have been forced to stay at home with limited exceptions, with severe consequences on mobility and transport in general. Since each Member State has set its own containment measures in different time (days or weeks in this case) with also different stringency intensity, an average containment stringency at European level would not be representative of the specific situations occurred within the countries. Hence, Figure 22 analyses the lockdown effect on electricity consumption on a weekly basis in four selected countries, i.e., Italy, Germany, France, and Spain.

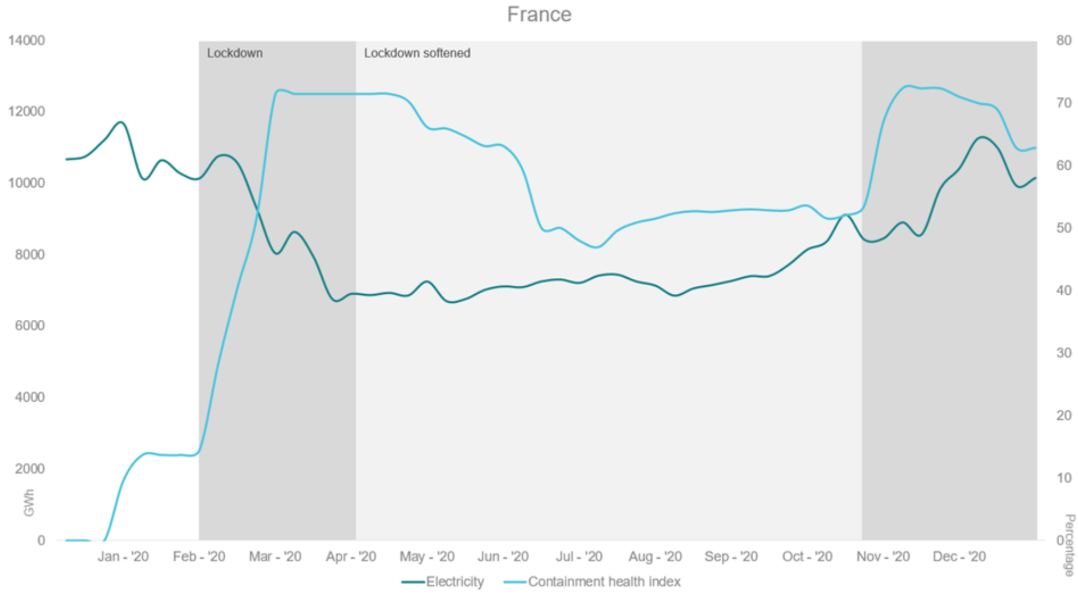
For all the four Member States the weekly electricity consumption has been affected by the introduction of containment measures. In the case of Italy, the electricity consumption generally fell until the lockdown was in place and it started to show an overall increasing trend once the containment measures have been softened. This has been observed especially at the time of the first COVID-19 spreading wave, while in the second one (from autumn 2020) the electricity consumption shows less sensibility to the new increase in the intensity of the containment index. The same dynamic has been observed for Germany, despite the drop in the electricity consumption has been more contained. Furthermore, its mobility stringency shows a constant and frequent change in the intensity of the measures established, resulting in an electricity consumption trend that is less linked to the containment measures. France shows a similar trend of Italy for the first weeks of lockdown, with the difference that the electricity consumption stopped decreasing already when the containment measures were still at their peak (first half of April) and it continued in a slightly upward trend. Moreover, this increasing trend withstood the second wave of the COVID-19 pandemic, where the containment index reached again its highest level since March 2020. Finally, the Spanish electricity consumption decreased at the beginning of March until mid-April, while for the rest of the year it shows a trend that seems affected more from other factors then the containment measures.

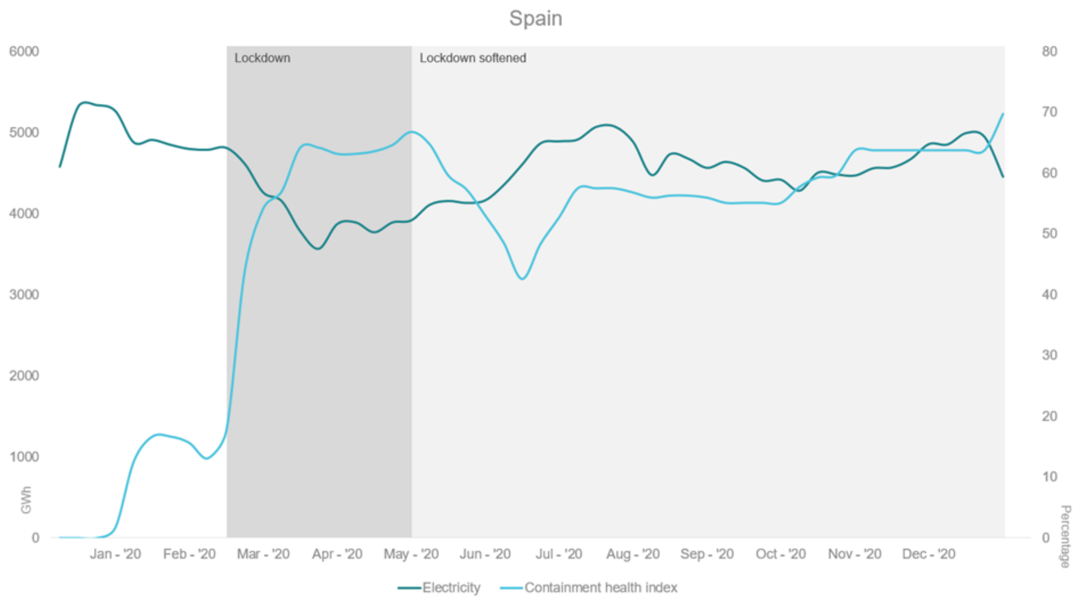
It is important to highlight that several other factors usually affect the electricity consumption, such has the energy efficiency, the energy mix of a country, the economic growth cycle, and other sectoral aspects. A more comprehensive COVID-19 would have to consider also these factors; however, since to analyse the pandemic effect on energy consumption is necessary to refer to a time scale lower than the yearly one (monthly, weekly and daily basis), the lack of the above-mentioned data related to the other factors affecting the consumption, results in an analysis that cannot considers a complete scenario.

Figure 22. Electricity consumption and containment health index, weekly values for 2020, Italy, Germany, France, and Spain





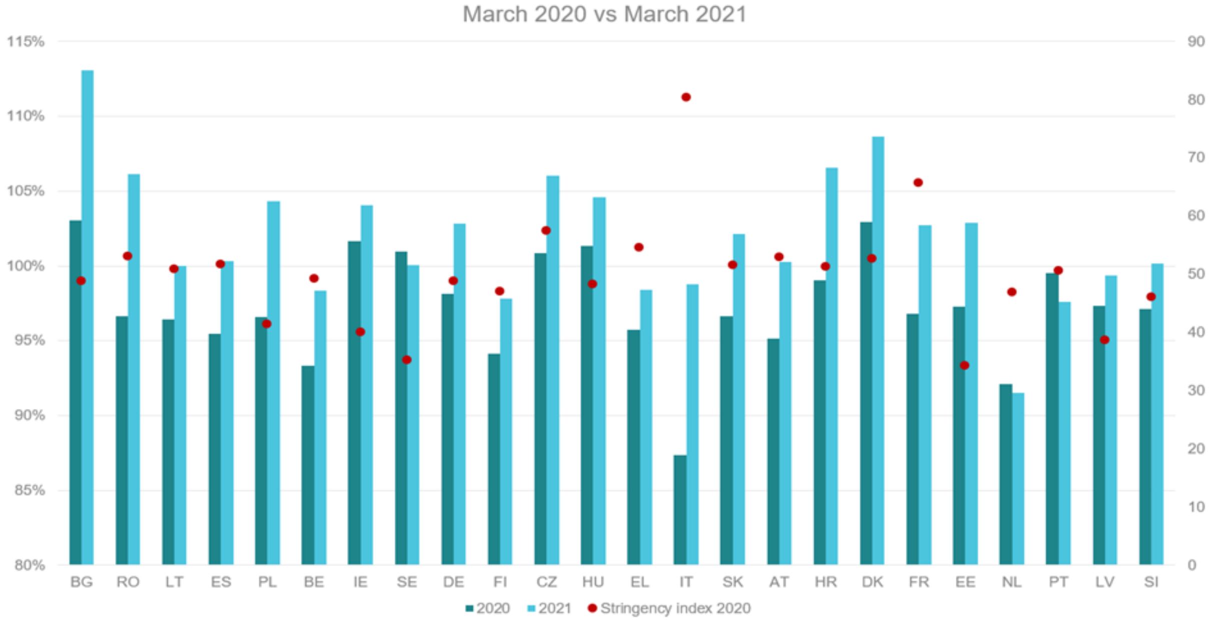




Source: JRC elaboration on Entso-e and OxCGRT, 2023

Figure 23 shows the comparison by Member States of the electricity consumtpion in March 2020 and 2021, the month where the containment policies were in place in all the European countries. Also the red dots represent the stringency index of each country in March 2020. At that time, the only two Member States reporting a level of stringency below 40% were Estonia and Sweden, while the highest level has been registered in Italy (more than 80%). Most of the countries with a stringency index higher than 40% experienced a electricity consumption reduction in March 2020 compared to the same month of the previous year (2019), this is clearly visible looking at Italy, France, Austria, Slovakia, Greece, Germany, Spain, Lithuania, and Romania. Other Member States, despite the high stringency level, reports higher 2020 electricity consumption compared to 2019 (Bulgaria, Ireland, Sweden, Czechia, Hungary and Denmark). Another trend observed is the rebound effect occurred between the same month in 2020 and 2021. One year later, only Sweden, the Netherlands and Portugal registered higher electricity consumption in 2020 than 2021. Largest rebound effects are observed for Italy, Bulgaria, Poland, Croatia, France, and Estonia.

Figure 23. Electricity consumption comparison between March 2020 and March 2021 and reported stringency index by Member State



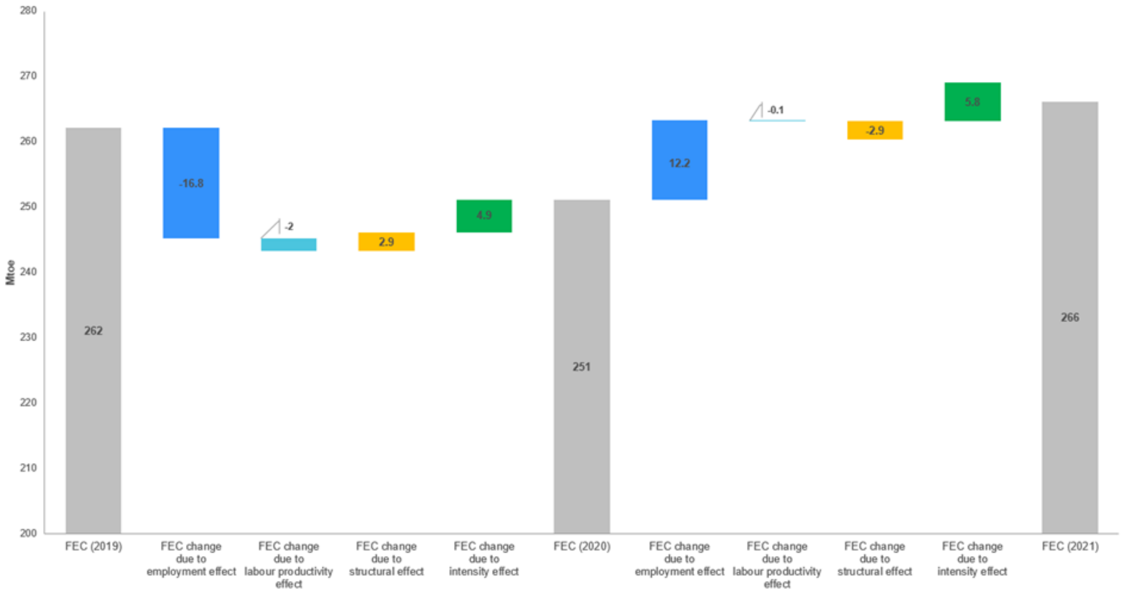
Source: JRC elaboration on Entso-e and OxCGRT, 2023

4.2 Energy consumption and COVID-19 at sectoral level

At sectoral level the COVID-19 had different impact on the energy consumption, with some sectors being more affected than others. To investigate these impacts, a combination of monthly and yearly data has been used, since data of sectoral energy consumption are not available on a more detailed scale of a yearly one. In this case, the Logarithmic Mean Divisia Index approach is useful to understand which effect, and which factor into which the final energy consumption is decomposed, have been affected by the COVID-19 crisis and the related counteract policies.

Looking at the industry sector, Figure 24 shows that the employment and the labour productivity effects have driven down the FEC between 2019 and 2020, only partially offset by the structural and intensity effects. Despite both values composing the intensity effect (i.e., final energy consumption and gross value added) strongly decreased between 2019 and 2020 (-4.3% for FEC and -7.6% for GVA), the worsening of the economic situation contributed in offsetting the positive FEC reduction. Hence, by observing the activity effect (employment + labour productivity effects), the drop in GVA and the production index trend (Figure 26), it is possible to attribute these dynamics to the closure and containment measures adopted by the Member States during the health emergency. In particular, during the months characterised by the strict lockdown (February-April), the monthly production index for manufacturing and construction reported in Figure 26 decreased up to -20% for manufacturing and -16% for construction, with a strong rebound in May after the progressively slackening of the containment measures by Member States.

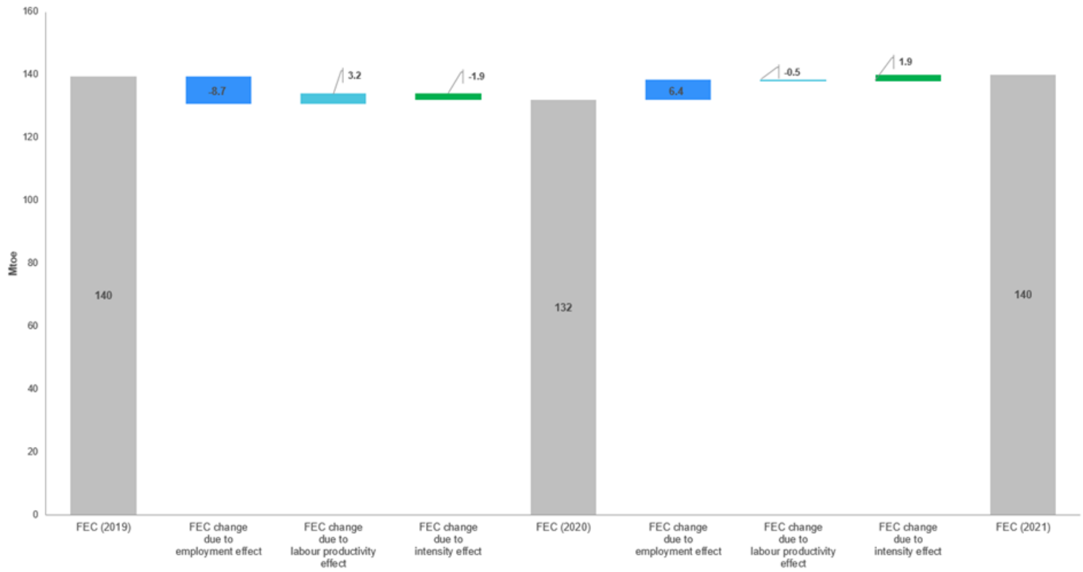
Figure 24. Decomposition of changes in final energy consumption (Mtoe) of industry in 2019-2021 using the additive Logarithmic Mean Divisia Index approach (LMDI)



Source: JRC

A similar trend has been observed for the service sector, where the employment effect drove down the FEC in 2020 (-8.7 Mtoe compared to 2019), while the labour productivity has partially compensated the negative employment effect. The establishment of closure policies have an impact on the service's production (up to -9% in April 2020) (Figure 26) and, as a consequence of that, several companies had to take measures that had serious repercussions on employment levels in the sector. Moreover, unlike the industry sector, the intensity effect decreased of -1.9 Mtoe in 2020 compared to the 2019.

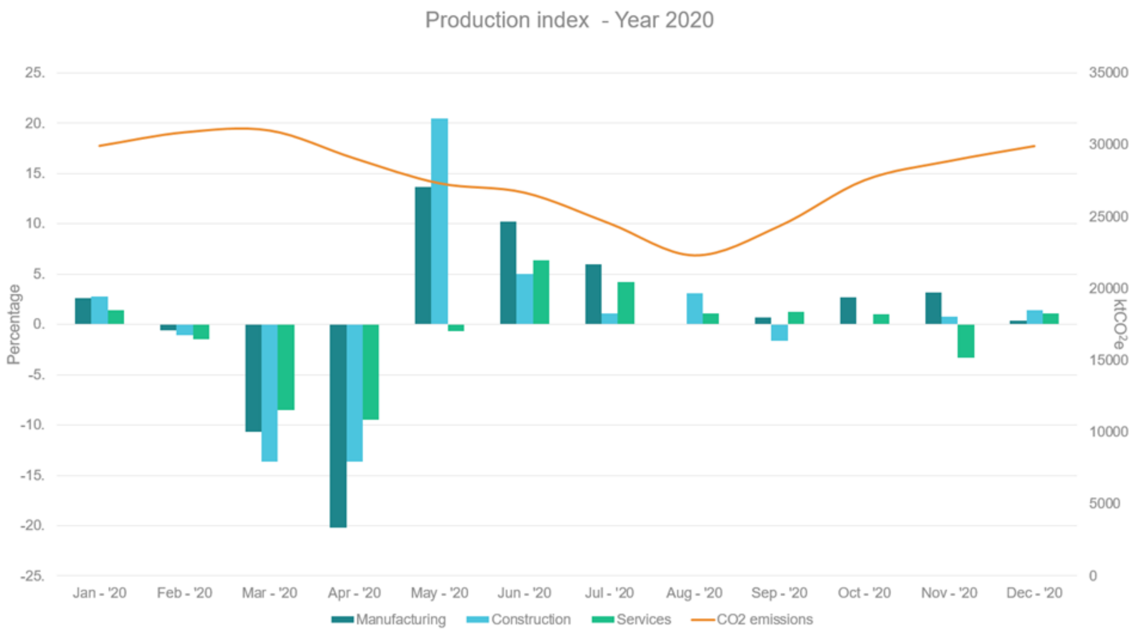
Figure 25. Decomposition of changes in final energy consumption (Mtoe) of service sector in 2019-2021 using the additive Logarithmic Mean Divisia Index approach (LMDI)



Source: JRC

Both industry and service sector show a rebound effect in 2021, mainly driven by the increase of the employment effect. The slackening of the containment measures, together with the Member States economic support to productive sectors, resulted in a +15 Mtoe (compared to 2020) and +4 Mtoe (compared to 2019) of FEC for industry, while the service sector FEC returned at the 2019 level (with a +8 Mtoe compared to 2020).

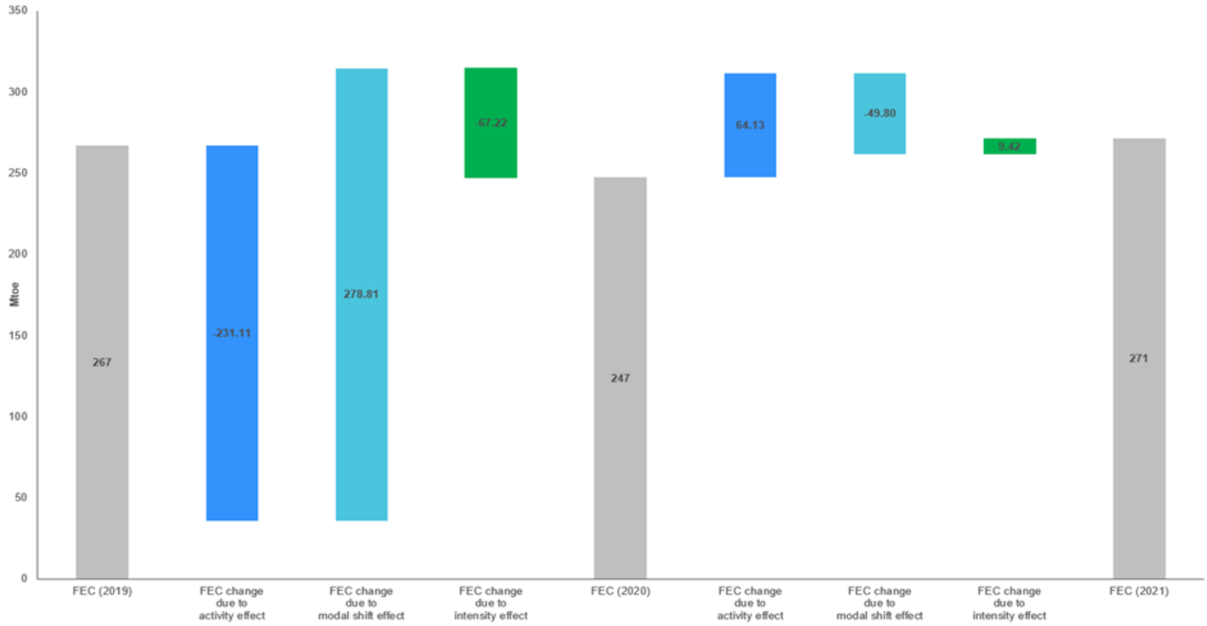
Figure 26. Monthly production index and CO2 emissions of EU manufacturing, construction and services, year 2020



Source: JRC elaboration on ESTAT and IPCC, 2023

The transport sector has been heavily affected by the COVID-19 containment measures. All the effects in which the FEC is usually decomposed show in 2020 a reverse trend compared to what is expected, furthermore, their magnitude is higher than a business-as-usual (BAU) situation (Figure 27). The intensity effect drops of -67.2 Mtoe from 2019-2020. Both activity and modal shift effects are based on either the number of passengers per kilometres or the tonnes per kilometres, two values almost zeroed by the mobility restrictions established during the 2020. With only the availability of yearly data for road and rail transports, the number of passengers decreased of -16.7% for cars and -39.8% for buses and coaches, while the rail passengers decreased by -46%.

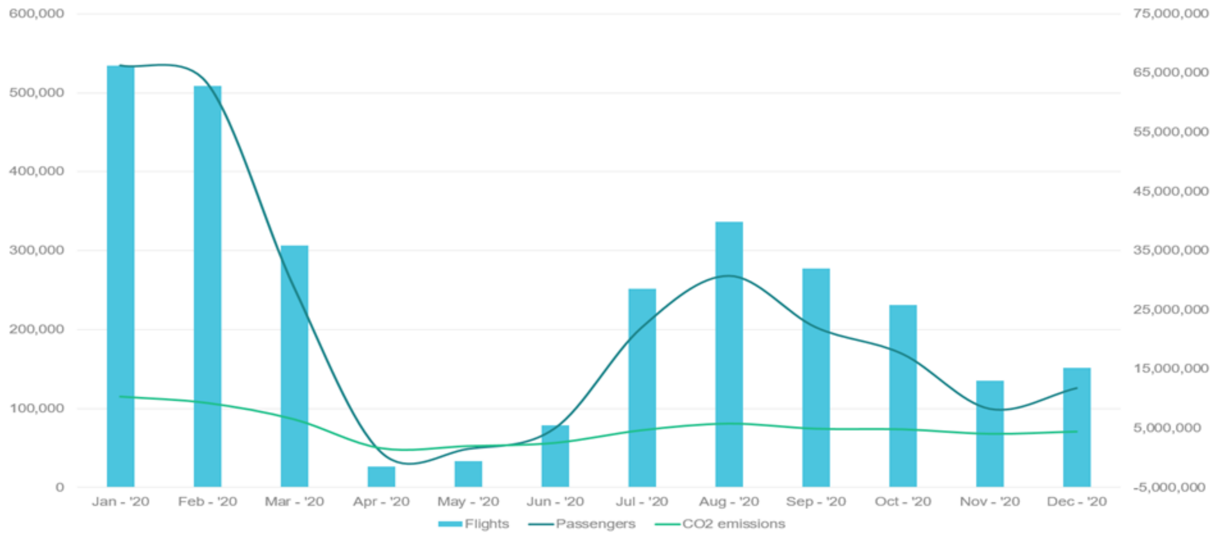
Figure 27. Decomposition of changes in final energy consumption (Mtoe) of transport sector in 2019-2021 using the additive Logarithmic Mean Divisia Index approach (LMDI)



Source: JRC

The sector that suffered the most the effects of the counteract Member States measures is certainly the air transport. Thanks to the monthly data availability of number of flights and passengers, it is possible to see how great the impact of the mobility restriction measures has been (Figure 28). In March the flights decreased by 39.7%, taking into account that each Member State have adopted its containment measures with different timing. In April the pandemic crisis contributed in a reduction of the number of flights by -91.4% that is the entire air sector came close to a complete stop. This phenomenon is also identifiable looking at the number of passengers of air transport, where at its lowest point it reached a value of less than one million compared to a value of ten million one year ago. Certainly, this almost complete stop of the flights due to severe mobility restrictions had heavily affected the FEC of the entire sector in 2020. Finally, from Figure 28 is also possible to observe the starting point of the so-called second wave of the pandemic, where from September 2020 the epidemiological situation started again to worsen after the summer period.

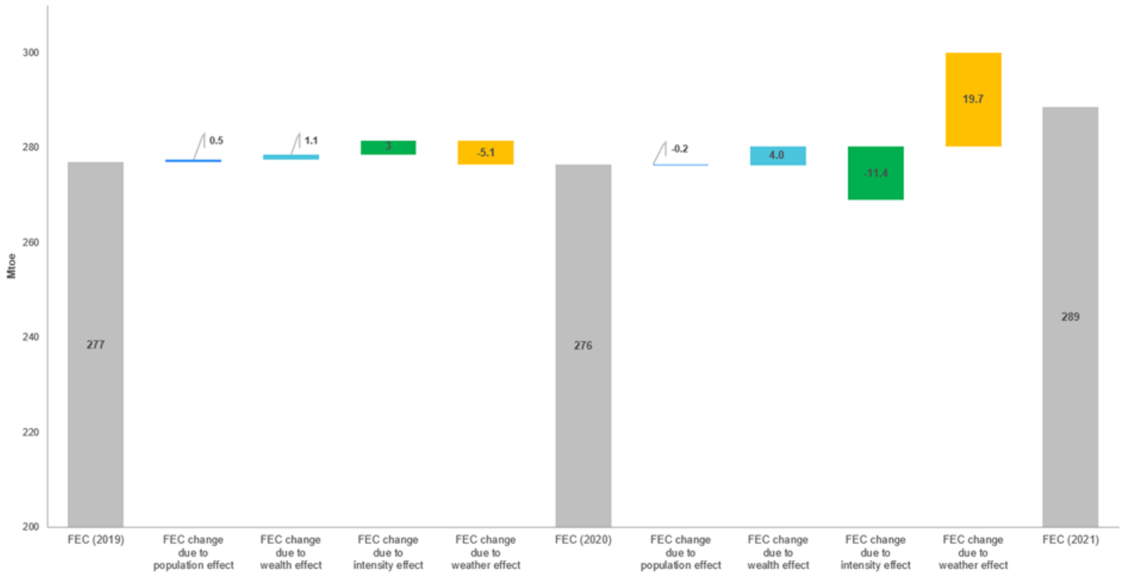
Figure 28. Monthly number of flights, passengers and CO2 emission of air transport, year 2020



Source: JRC elaboration on ESTAT and IPCC, 2023

On a yearly basis, despite people were forced to stay home during the most critical time of the pandemic, the FEC of the residential sector slightly decreased from 2019 to 2020 (-0.6 Mtoe), driven down from the weather effect (-5.1 Mtoe). The intensity effect increased by +3 Mtoe and then fell sharply in 2021 (-11.4 Mtoe) (Figure 29). In general, it is difficult to observe a specific COVID-19 effect since the energy consumption of the residential sector rely on the number of dwellings and the total floor area, that are factors that have not been affected by the containment measures established to contrast the virus spreading. Moreover, the lack of daily/monthly data contributes is hiding the COVID-19 counteract measures behind other factors, e.g., the weather effect. Another element that may have compensated for the possible FEC increase is the fact that the COVID-19 crisis started at the end of the winter period. This favourable timing might averted any increase of the energy consumption for heating purposes. However, the analysis of the yearly trend of teleworking (Figure 30) can be useful to partially understand the effect of the heath crisis in this sector.

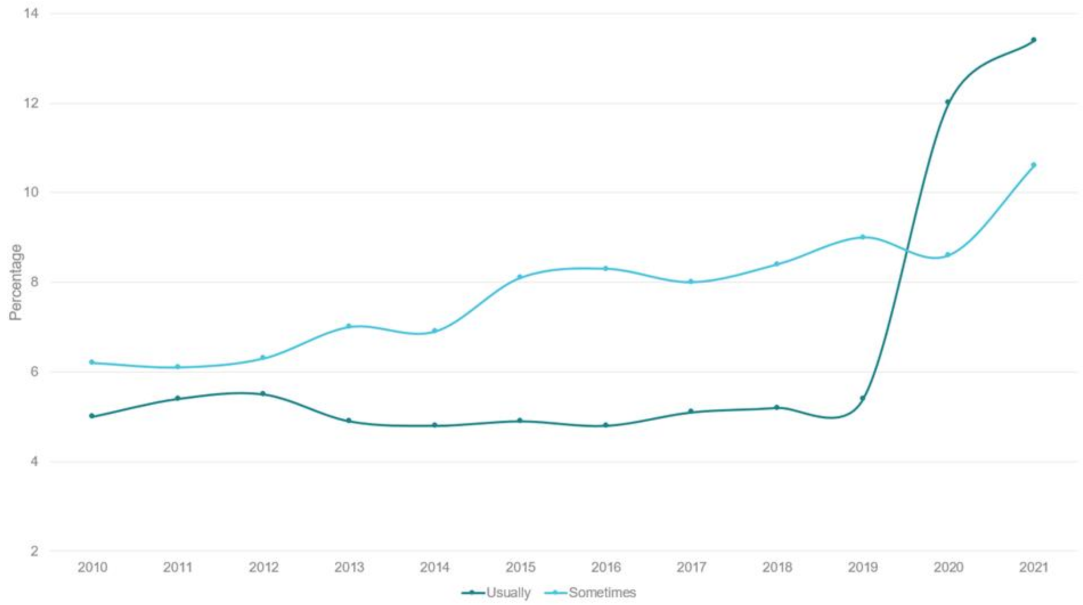
Figure 29. Decomposition of changes in final energy consumption (Mtoe) of residential sector in 2019-2021 using the additive Logarithmic Mean Divisia Index approach (LMDI)



Source: JRC

Before year 2020 the percentage of employees working from home (as a percentage of the total employment) was substantially stable around 5%. This is true for those employees that used to usually work from home. At the same period, the percentage of employees occasionally working from home varied from around 6% to 9%. In 2020, the more systematic teleworking increased up to 12% followed by a concomitant decrease of the occasional teleworking. As a consequence of the containment measures established by the Member States, several employees were forced to switch their working habits. Despite this, also due to the limited time of the restriction measures, the FEC of residential sector was not significantly affected.

Figure 30. Persons working from home as a percentage of the total employment, EU27



Source: JRC elaboration on ESTAT, 2023

5 Conclusions

This study applied the logarithmic-mean Divisia index method to study both aggregated and sectoral energy consumption changes at both EU and Member State levels over the period 2010-2021. The LMDI-I decomposition analysis has enabled to determine the influence of different effects on energy consumption changes registered in these years.

The decomposition of primary energy consumption changes in this period showed that the reduction in the final energy demand was the most decisive explanatory factor behind the decrease in primary energy consumption. In terms of the productive sectors of the economy (industry, services, and agriculture), intensity had the biggest inhibiting effect among the different factors followed by structural changes which were attributed to the increasing importance of services as a whole across the EU economies. Together with the negative intensity effect, these two effects offset the positive activity effect in 2010-2021, resulting to an overall drop in consumption. These findings are similar to the results from the decomposition analysis applied by the JRC in 2022, focusing on the period up to 2020. However, focusing only on the last year (2020-2021), the rebound effect occurred in 2021 as a consequence of the COVID-19 pandemic of 2020 had the opposite effect compared to the last 10 years. Both intensity and activity effects increased, with especially the latter driving up the energy consumption, while the decrease of the structural effect is negligible. In terms of activity, employment was the major driver in energy consumption in all productive sectors of the economy, with the highest relative impact in services, followed by industry and then agriculture. Concerning industry, the comparison between using production-based and monetary-based results showed that the use of gross value added generally overestimated efficiency improvements.

The decomposition of transport showed some interesting findings. Similar to the previous decomposition analysis, the activity effect was the main driver in driving up the consumption of all the transport subsectors (passenger, freight, and air). The intensity effect contributes to the increase of the consumption in both passenger and freight transport, while air transport showed a reverse trend with respect to 2020.

For the residential sector the results showed the decisive impact of weather fluctuations[24] and wealth effect on the overall energy consumption of this sector, which have exhibited as main drivers for the increase in energy consumption. Finally, the biggest inhibitor was found to be the intensity effect, while the population effect showed substantially a neutral effect on the consumption.

The analysis raised some conclusions that could be useful for the decision-makers. Even if the 2020 Energy Efficiency targets were achieved, the 2021 results showed a rebound effect compared. The European Energy Efficiency Directive of 2023, in the context of the European Green Deal, has set more ambitious targets for energy consumption reduction for the year 2030. Consequently, the EU member states should increase and strengthen their energy efficiency policy efforts in the forthcoming period. Some examples of sectoral policies contributing to this could be the implementation of more ambitious legislation (i.e. buildings standards and other measures under the 2024 recast EPBD) as well as financial and fiscal incentives for deep renovation of existing buildings. Furthermore, the development of energy efficiency technologies, the electrification of vehicles, and a

[24] These fluctuations are associated with changes in wintertime temperatures only. In the future, the analysis may consider the effect of summertime temperature variations on electricity and specifically cooling-related consumption.

modal shift to public transport could also be important in an attempt to ensure the achievement of the targets.

While the overall results of the decomposition analysis offered valuable insights into the factors behind recent consumption trends at both EU and Member State 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 data quality issues. Sectors with significant challenges include the transport sector as not a 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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List of abbreviations and definitions

AR	Activity revaluation
BAU	Business-as-usual
EC	European Commission
EED	Energy Efficiency Directive
ENTSO-E	European Network of Transmission System Operators for Electricity
ESTAT	European Statistical Office
EU	European Union
FEC	Final energy consumption
GVA	Gross value added
HDD	Heating degree days
IDA	Index Decomposition Analysis
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPI	Industrial production index
JRC	Joint Research Centre
Ktoe	Kilotonne of oil equivalent
LMDI	Logarithmic Mean Divisia
MS	Member state
Mtoe	megaton of oil equivalent
OxCGRT	Oxford Covid-19 Government Response Tracker
PEC	Primary energy consumption

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Table 10. Input datasets

Indicator	Source	ESTAT dataset	ESTAT code	Available time period	Unit
Primary Energy Consumption (PEC)	ESTAT	FINAL-ENERGY-CONSUMPTION-OLD-METHODOLOGY	PEC2020-2030	2010-2021	Mtoe
Final Energy Consumption (FEC)	ESTAT				
Total		FINAL-ENERGY-CONSUMPTION-OLD-METHODOLOGY	B_101700	2010-2021	Mtoe
Food & Tobacco			B_101830	2010-2021	
Textile & Leather			B_101835	2010-2021	
Wood, paper, etc.			B_101851+ B_101840	2010-2021	
Chemical & Petrochemical			B_101815	2010-2021	
Metals/Machinery			B_101847+ B_101805+ B_101810	2010-2021	
Non-metallic minerals etc.			B_101820+ B_101853	2010-2021	
Transport equipment			B_101846	2010-2021	
Construction			B_101852	2010-2021	
Services			B_102035	2010-2021	
Agriculture etc.			B_102020+ B_102030	2010-2021	
Road transport	ESTAT Odyssee[25]	FINAL-ENERGY-CONSUMPTION-OLD-METHODOLOGY	B_101920	2010-2021	Mtoe
Rail transport			B_101910	2010-2021	
Air transport			B_101932	2010-2021	
Water transport			B_101940	2010-2021	

[25] Odyssee database has been used to calculate car, bus, truck & light vehicles, motorcycles, rail passenger and rail freight shares.

Residential	ESTAT	nrg_d_hhq	FC_OTH_HH_E	2010-2021	Mtoe
Gross Value Added (GVA)	ESTAT				
Total		nama_10_a64	B1G	2010-2021	Chain linked volumes (2010), million EUR
Food & Tobacco				2010-2021	
Textile & Leather				2010-2021	
Wood, paper, etc.				2010-2021	
Chemical & Petrochemical				2010-2021	
Metals/Machinery				2010-2021	
Non-metallic minerals etc.				2010-2021	
Transport equipment				2010-2021	
Construction				2010-2021	
Services				2010-2021	
Agriculture etc.				2010-2021	
Thousands hours worked	ESTAT				
Food & Tobacco		nama_10_a64e	C10-C12	2010-2021	Thousands hours worked
Textile & Leather			C13-C15	2010-2021	
Wood, paper, etc.			C16-C18	2010-2021	
Chemical & Petrochemical			C19-C20	2010-2021	
Metals/Machinery			C24_C25+C28	2010-2021	
Non-metallic minerals etc.			C23	2010-2021	
Transport equipment			C30	2010-2021	
Construction			F	2010-2021	
Services			G-I+J+K+L+M_N+O-Q+R-U+C33+E+T+H49+H50+H51	2010-2021	
Agriculture etc.			A	2010-2021	
Volume Index Production					
Manufacturing	ESTAT	sts_inpr_a	C	2010-2021	-
Construction			-	2010-2021	-

Passenger kilometres	DG MOVE OECD Library[26]				
Road		-	-	2010-2021	Billion pkm
Rail		-	-	2010-2021	
Air		-	-	2010-2021	
Tonne kilometres					
Road		-	-	2010-2021	Billion tkm
Rail		-	-	2010-2021	
Water		-	-	2010-2021	
Total floor area	Odyssee	-	-	2010-2021	m2
Gross Disposable Income per capita (GDI)	ESTAT	nasa_10_nf_tr	B6G	2010-2021	Million EUR
Population	ESTAT	demo_pjan	-	2010-2021	Number
Climatic correction factor	JRC	-	-	2010-2021	-

[26] OECD Library database has been used to calculate passengers and freight transport (road and rail) for year 2021.

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