

Drivers of recent energy consumption trends across sectors in EU28

Energy Consumption Trends Workshop Report

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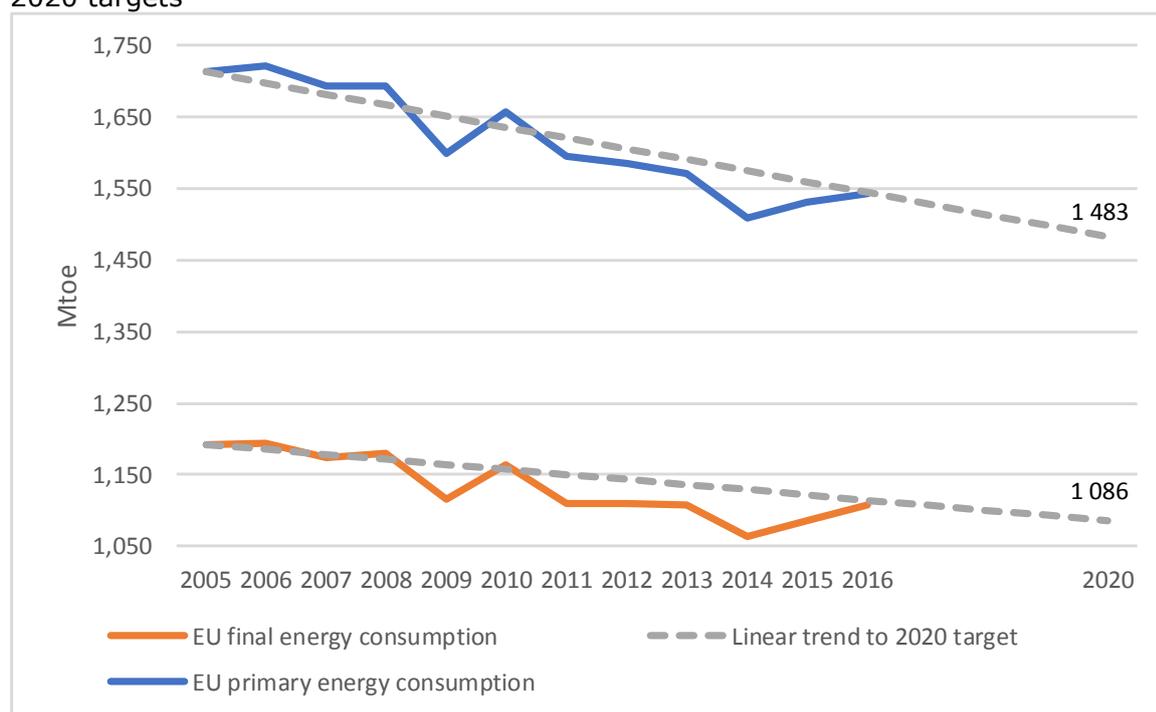
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EXECUTIVE SUMMARY

This report was commissioned by the European Commission, Directorate General for Energy, Energy Efficiency Unit, to provide an overview of the drivers of recent trends in final energy consumption and a first indication of the short-term future trends and efforts needed to reach the EU 2020 targets.

The report is based on material presented at an expert workshop on 25 May 2018 (see Annex), data analysis by the report author and wider literature. The views expressed in the report are the author's own unless specified.

Figure ES.1 EU primary and final energy consumption and linear trend from 2005 to 2020 targets



Source: Eurostat Energy Balance May 2018, <http://ec.europa.eu/eurostat/documents/38154/4956218/ENERGY-BALANCES-May-2018-edition.zip/310265d9-6adf-45aa-ba41-2dce8e5f78eb>

EU final and primary energy consumption¹ are the key performance indicators of the EU Energy Efficiency Directive² since the targets, to be met in 2020, are expressed using

¹ This report is focussed on trends in final energy consumption. Trends in primary energy consumption are heavily influenced by changes in final energy consumption as well as by changes in power sector consumption and other energy transformation. Since 2014, the increase in final energy consumption has been partly offset by reductions in power sector consumption associated with coal to gas switching and the increasing penetration of renewable sources.

² Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC Text with EEA relevance, <https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1399375464230&uri=CELEX:32012L0027>

the two indicators³. In 2016 both EU primary and final energy consumption were significantly lower than in 2005; a continuation of the average annual falls in consumption since 2005 would mean that both targets would be met. However, increases in energy consumption since 2014 suggest that this medium-term trend is at risk over the short run to 2020 (Figure ES.1).

Both EU primary and final energy consumption reached their lowest levels this century in 2014, with final energy consumption 2.1% below the target maximum level of energy consumption in 2020 set in the Energy Efficiency Directive⁴. However, between 2014 and 2016, final energy consumption rose by 4.2% and primary energy consumption rose by 2.3% bringing back both indicators to a level on the linear trend between consumption in 2005 and the target levels in 2020. Between 2016 and 2020, final energy consumption must fall by an average of 0.5% per year and primary energy consumption by 1.0% per year to meet the energy consumption targets. However, preliminary data suggest that both primary and final energy consumption rose again in 2017.⁵

A number of key dimensions correlated to the trends in final energy consumption in recent years were identified by the European Commission at the beginning of the workshop based on prior analysis, and the workshop findings contributed to substantiate their impact and identify policy messages related to each of them, though for some a more targeted analysis would be necessary:

- i. *The weather.* The increase in energy consumption since 2014 is a response to the weather, with successively colder winters in 2015 and 2016 bringing consumption back to a position from where it should fall again, if future winters are similar to 2016. The weather factor had an impact predominantly on sectors where heating and cooling are more relevant such as residential and services, the latter to a lesser extent. To the extent that the medium-term trend is driven by policy, the policy consequence would be to maintain the current policy framework aimed at meeting the 2020 targets.
- ii. *The role of economic growth.* Increases in economic growth since 2014 have driven up energy consumption. Economic growth had more impact on services and transport sectors and, to a lesser extent, on industry sector. During earlier periods with lower rates of economic growth, energy efficiency gains were large enough to offset the upward pressure on energy consumption from increases in economic activity. To the extent that efficiency gains can be driven by policy, the policy consequence would be to make the policy framework more ambitious.
- iii. *The impact and effectiveness of energy efficiency policies.* The analysis presented at the workshop provided some elements to understand the role of policies which will be presented in the report, though it was recognised that a more targeted research and analysis would be needed in this area.

³ The 2020 target involves lowering the EU's final energy consumption to at most 1086 Mtoe, and its primary energy consumption to at most 1483 Mtoe.

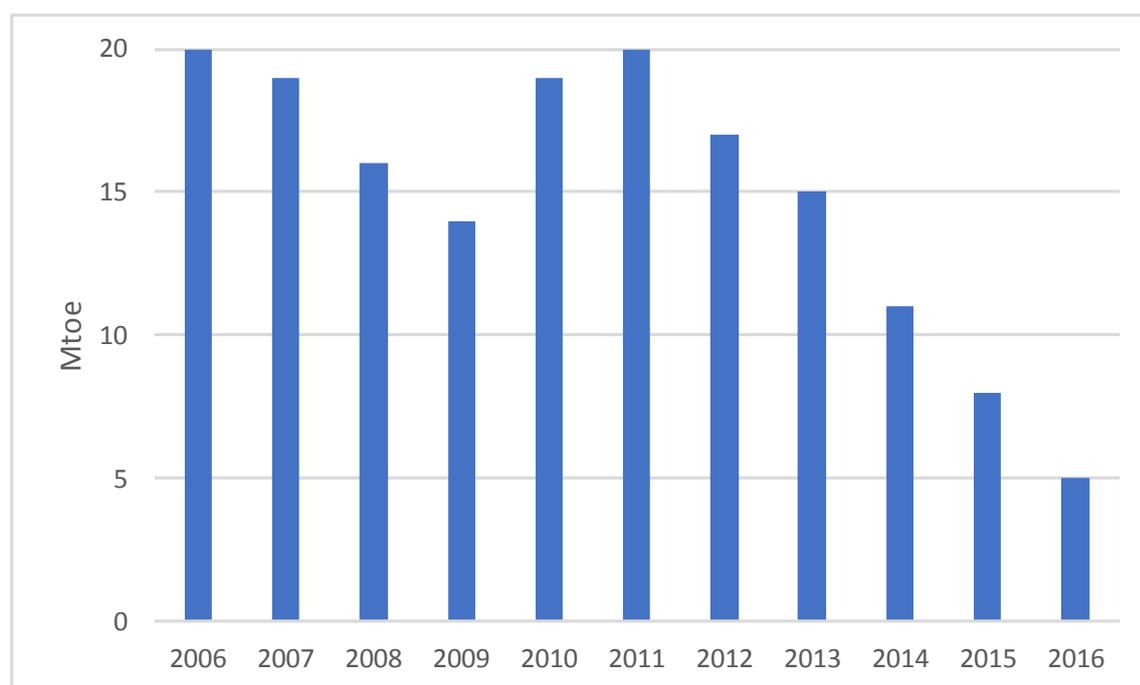
⁴ Directive 2012/27/EU

⁵ EC DG ENERGY estimates, based on ESTAT recent release of the EU28 early estimates of the energy balances indicate that the primary and final energy consumption will rise slowly in 2017 as compared to 2016. This is also confirmed by the estimates of the European Environment Agency. Eurostat early estimates of energy balances are available here: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Energy_balances_-_early_estimates

All three of these explanations are factors in recent trends. The return to more normal winter weather, following the exceptionally warm winter in 2014, has pushed up energy use in the residential and services sectors, where space heating accounted for 64% and 44% of final energy consumption respectively in 2016. With similar winter weather to that seen in 2016, space heating energy consumption in 2020 would be expected to be similar or to have declined a little over four years. However, the volatile impact of the weather, presents a risk to the achievement of the 2020 targets.

Stronger economic growth has clearly been a major factor in the growth in energy consumption in the EU since 2014. The EU economy continued to grow at above trend rates in 2017 and growth is projected to remain strong in 2018 and 2019. Increases in investment and consumer spending should lead to gains in efficiency in the medium-term, but in the short-run, the growth in economic activity looks set to put upwards pressure on energy consumption in the period to 2020 that would require a significant rate of efficiency gains to be offset.

Figure ES.2 EU energy savings from energy efficiency improvements



Note: Energy savings are generated using the online ODYSSEE decomposition tool to undertake one-year decomposition analyses, where the base year is the previous year (i.e. t-1). The sum of the energy savings presented in this chart is equal to the savings generated from undertaking an eleven-year decomposition analysis with base year 2005.

Source: ODYSSEE decomposition, <http://www.indicators.odyssee-mure.eu/decomposition.html>

The impact of energy efficiency improvements on energy consumption are difficult to isolate. Decomposition analysis allows the impact of changes in other factors, such as climate, activity (amount of production, travel, services sector output, building floor area) and industry structure to be accounted for, based on historical statistical relationships, enabling the underlying change in energy intensity to be identified at varying levels of disaggregation, depending upon the availability of data. At the workshop, analysis from the ODYSSEE project was presented; this approach to decomposition analysis generates estimates of energy savings from energy efficiency

progress based on these changes in energy intensity.⁶ Since 2011, the energy savings identified in the decomposition analysis have declined in every year to 2016 (Figure ES.2).

The extent to which efficiency gains have been driven by policy is difficult to ascertain and a more targeted analysis would be necessary. Evidence suggest that product, equipment and vehicle standards have had a strong impact on the efficiency of energy consuming goods on the market.⁷ The actions taken by the Commission to make tests procedures for vehicles fully effective are expected to make an impact in the coming years. The impact of standards on overall efficiency levels also depends upon consumer purchasing decisions. Lower levels of consumer spending during the first half of the current decade slowed down the uptake of the more efficient technologies brought to the market as a result of standards. Consumer spending has now picked up; however, energy prices have fallen, which is likely to have had a dampening effect on the impact of efficiency policy on consumers' purchasing decisions.

Overall, when considering the implications for the short-run to 2020, the second explanation appears to be the most important factor i.e. that the impacts of strong economic conditions are driving up energy consumption by more than efficiency gains (policy driven or not) are offsetting. Economic growth is projected to remain strong until at least 2019, suggesting that energy consumption is likely to continue to rise. The weather clearly played an important role in driving up energy consumption between 2014, with its exceptionally warm winter, and 2016, with its more average winter conditions; the risk of another cold winter in 2020 presents a further uncertainty to the level of consumption in the coming years. In the medium-term, lower levels of economic growth than those expected in the period 2020, would be expected to exert less upward pressure on energy consumption; the weather will continue to present a risk to targets designed to be met in one particular year; and policy will need to be more effective in driving progress during periods of lower economic growth beyond that implied by a linear pathway to meeting targets.

Given the specific energy-related characteristics of each sector, it is necessary to go beyond an assessment of trends at the aggregate level and to examine each sector in turn and consider a "what if" case for the period to 2020. For this reason, the workshop followed a sectoral perspective which enabled the identification of more specific explanatory factors linked to the macroeconomic environment, technologies, behaviour and to societal trends. Such a level of detail is key to understand drivers of energy consumption trends.

In the transport sector, which accounts for 1/3 of EU final energy consumption, energy use rose by 4.2% between 2014 and 2016. About 82% of the final energy consumption in transport is on road transport and oil products (gasoline and diesel) are by far the most important energy carriers used in this sector. In the medium-term, the introduction of freight standards, the tightening up of test procedures for passenger vehicles and supportive local and national policy environments for electric vehicle penetration are likely to drive down energy consumption. However, in the short-run, the strong

⁶ Energy savings in the ODYSSEE decomposition are derived from ODEX, an indicator derived from movements in the energy intensity effect, that measures the energy efficiency progress by main sector and for the whole economy (all final consumers). Energy savings correspond to technical savings, i.e. to gross savings corrected of negative savings due to inefficient operation of facilities or behaviours. <http://www.indicators.odyssee-mure.eu/decomposition.html>

⁷ See for example, IEA Energy Efficiency Market Report 2016, https://www.iea.org/eemr16/files/medium-term-energy-efficiency-2016_WEB.PDF

economic conditions are likely to continue driving up both passenger travel and freight transport putting upwards pressure on energy consumption. Meanwhile, new passenger vehicle efficiency improvements may well continue to be offset by further growth in the market share of larger sports utility vehicles (SUVs)⁸. An increase of 1.5% per annum in transport sector energy consumption over the four years to 2020 would add around 2.0% to 2016 EU final energy consumption.

In the industry sector, which accounts for ¼ of EU final energy consumption, energy use rose by 0.3% between 2014 and 2016, driven by strong economic growth. In the medium-term, a return to trend growth rates, allied with the greater uptake of energy management practices and projections of higher EU Emissions Trading System prices⁹, suggests a relatively benign environment for energy consumption in the sector. However, in the short-run, the continuation of relatively strong economic growth suggests that sector consumption is likely to rise. At the same time, the composition of industry output growth indicates that any increases are likely to be small. An increase of 0.2% per annum in industry sector energy consumption over the four years to 2020 would add around 0.2% to 2016 EU final energy consumption.

In the residential sector, which accounts for a further ¼ of EU final energy consumption, energy use rose by 7.4% between 2014 and 2016. However, this increase was largely a result of colder winter weather, following the exceptionally warm winter of 2014, given that space heating energy consumption accounts for around 2/3 of residential energy consumption. Weather-corrected heating energy consumption has been relatively flat since 2010, following a decade of reductions. In the medium-term, concerted policy action to drive up building renovation rates and decarbonise heating systems would be expected, given the need for action in the sector to meet energy and climate targets. However, in the short-run, a continuation of current trends seems reasonably likely since the renovation and new construction rates are not sufficiently high to have a visible impact over a short period of time. The remaining 1/3 of residential energy consumption also rose between 2014 and 2016, by 3.0% per annum, following a period of energy consumption reductions between 2010 and 2014. The recent uptick in non-heating energy consumption has occurred despite increases in the efficiency of large appliances such as refrigerators and televisions. For example, the total amount of energy consumption by televisions and monitors has decreased despite a huge increase in screen area. More attention is needed to analyse other electricity end-uses which appear to be driving up energy consumption. Questions around the extent to which these trends are related to lifestyle changes, such as the increasing penetration of smaller appliances and ICT in EU households could be addressed in future research. The implications for short-term residential energy consumption growth are unclear. An increase of 0.5% per annum in residential sector energy consumption over the four years to 2020 would add around 0.5% per annum to 2016 EU final energy consumption.

In the services sector, which accounts for around 1/6 of EU final energy consumption, energy use rose by 6.4% between 2014 and 2016. In the medium-term, concerted policy action to drive up building renovation rates and decarbonise heating systems would be expected also in this sector. However, in the short-run, the continuation of

⁸ Increases in the average weight of vehicles has the effect of increasing the amount of energy associated with the achievement of the targets set under Regulation (EC) No 443/2009 of the European Parliament and of the Council of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO₂ emissions from light-duty vehicles,
https://ec.europa.eu/clima/policies/transport/vehicles/cars_en#tab-0-1

⁹ See for example, <https://www.carbontracker.org/eu-carbon-prices-could-double-by-2021-and-quadruple-by-2030/>

relatively strong economic growth would be expected to drive further increases in consumption, although data limitations make meaningful analysis difficult. An increase of 0.3% per annum in services sector energy consumption over the four years to 2020 would add around 0.2% to 2016 EU final energy consumption.

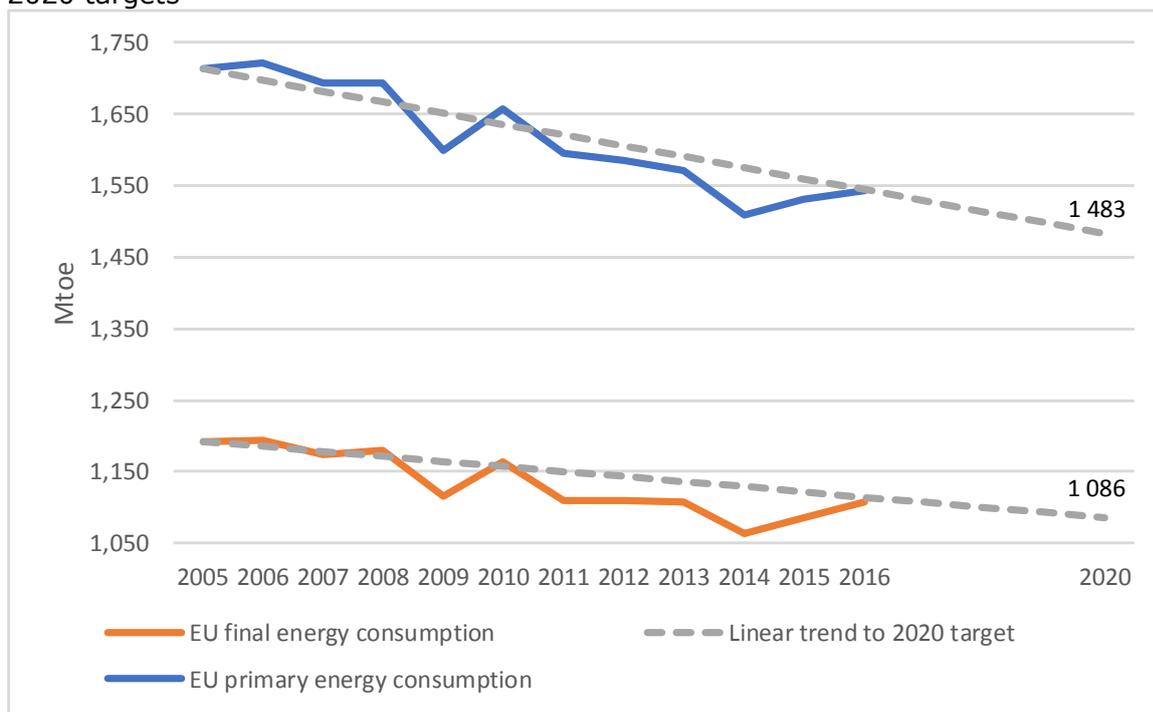
Year-to-year variations in energy consumption in the residential sector and, to a lesser extent, in the services sectors are seriously influenced by winter temperatures. If 2020 has similar weather conditions to 2016, which was a fairly average year for winter temperatures, the combination of the impacts set out above would be to increase EU final energy consumption by almost 3% over 2016 levels. A warm winter, similar to that experienced in 2014, would see consumption rise by closer to 1%. A cold winter, such as in 2012, could see consumption more than 7.5% higher than in 2016.

The analysis in this report could be improved if more data were available at a more disaggregated level, particularly at sub-sectoral and end-use level. Services sector data in particular are very poor, with very few surveys undertaken and none that are both regular and frequent. The roll-out of smart meters and the digitalisation of the energy sector provide opportunities to analyse data on a much more disaggregated basis and enable the effects of policy interventions to be more easily tracked. More generally, if short-term demand forecasting is a priority for the European Commission, setting up a modelling team to focus on this issue would be a good first step. This team could draw from both the expertise already residing in-house to produce quarterly gas and electricity market reports and whole-economy economic forecasts. These exercises examine both recent trends and the potential short-term evolution and interaction of many of the indicators that affect energy demand, and which are not picked up in decomposition analyses. Such a team could provide a useful focal point for the design of future research projects aimed at improving data and understanding better the relationships between existing data series.

1. INTRODUCTION

The EU-wide energy efficiency targets are set in final and primary energy consumption terms for 2020 in the EU Energy Efficiency Directive¹⁰. Targets are set in absolute terms and the EU was broadly on target to meeting those targets in 2016 when plotted on a linear trend from 2005. However, a continuation of the recent increases in energy consumption, seen since 2014, would mean that meeting those targets could be at risk. (Figure 1.1). Preliminary data suggest that both final and primary energy consumption increased again in 2017.¹¹

Figure 1.1 EU primary and final energy consumption and linear trend from 2005 to 2020 targets



Source: Eurostat Energy Balance May 2018, <http://ec.europa.eu/eurostat/documents/38154/4956218/ENERGY-BALANCES-May-2018-edition.zip/310265d9-6adf-45aa-ba41-2dce8e5f78eb>

The Energy Efficiency Unit regularly monitors progress towards the final and primary energy consumption targets and publishes an annual Energy Efficiency Progress

¹⁰ Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC Text with EEA relevance, <https://eur-lex.europa.eu/legal-content/EN/TXT/?qid=1399375464230&uri=CELEX:32012L0027>

¹¹ Increases in the average weight of vehicles has the effect of increasing the amount of energy associated with the achievement of the targets set under Regulation (EC) No 443/2009 of the European Parliament and of the Council of 23 April 2009 setting emission performance standards for new passenger cars as part of the Community's integrated approach to reduce CO₂ emissions from light-duty vehicles, https://ec.europa.eu/clima/policies/transport/vehicles/cars_en#tab-0-1

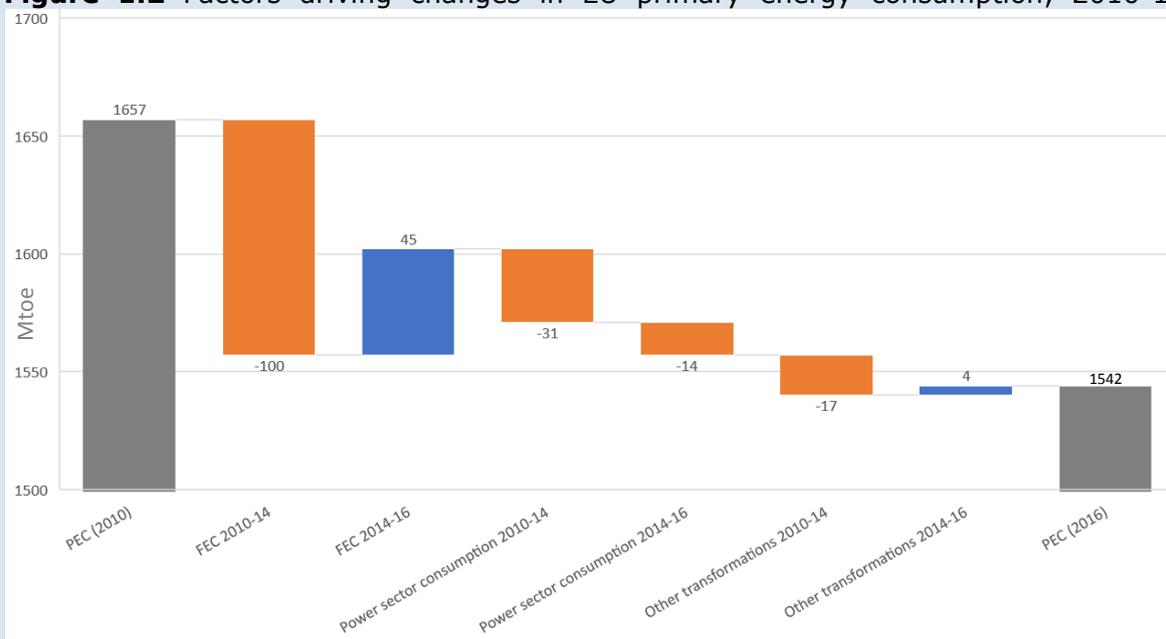
Report¹². Recently this analysis has been supported by a decomposition analysis performed by the Joint Research Centre (JRC).¹³

The focus of the workshop and this report is on final energy consumption in the end-use sectors of transport, industry, residential and services. Sections 2 to 5 of the report focus on these sectors in turn. It examines recent trends and presents a “what-if” scenario for the short-term evolution of EU final energy consumption to 2020. The increase in final energy consumption since 2014 has been the biggest driver in the increase in primary energy consumption over the same period (see Box 1)¹⁴. From the position in 2016, an annual reduction of 0.5% per annum would be required to meet the 2020 final energy consumption target.

Box 1: Relationship between primary and final energy consumption

The increase in final energy consumption (FEC) since 2014 has been the main driver behind the increase in primary energy consumption (PEC) (Figure 1.2).

Figure 1.2 Factors driving changes in EU primary energy consumption, 2010-16



Source: ODYSSEE decomposition (2018), <http://www.indicators.odyssee-mure.eu/decomposition.html>

¹² The most recent annual report is COM(2017) 687 final, https://ec.europa.eu/energy/sites/ener/files/documents/report_energy_efficiency_final_2017_en.pdf

¹³ Economidou M, (2017) *Assessing the progress towards the EU energy efficiency targets using index decomposition analysis*, EUR 28710 EN, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-71299-9, doi:10.2760/675791, JRC106782. [http://publications.jrc.ec.europa.eu/repository/bitstream/JRC106782/jrc_decomposition_report_final\(1\).pdf](http://publications.jrc.ec.europa.eu/repository/bitstream/JRC106782/jrc_decomposition_report_final(1).pdf)

¹⁴ Analysis of factors driving changes in primary energy consumption from ODYSSEE decomposition (2018), <http://www.indicators.odyssee-mure.eu/decomposition.html>

Box 1: Relationship between primary and final energy consumption (cont.)

Between 2010 and 2014, the large fall in FEC was supported by reductions in power sector consumption (the difference between energy inputs and energy outputs in the electricity sector and the cogeneration of electricity and heat) and other transformations (mostly in the refineries sector). Since 2014, power sector consumption has continued to fall at a similar rate, while final energy consumption has risen.

The reduction in power sector consumption has occurred in spite of the increase in electricity production to satisfy demand from end-uses. The main factor behind this trend has been the increase in the efficiency of thermal production since 2014; at the workshop, Willem Braat (IEA) explained that falls in gas prices and increases in coal prices had led to an increase in gas-powered electricity generation over the 2014-16 period. In addition, changes in the power mix (between thermal, renewable and nuclear energy), driven by increases in renewable electricity production, have continued to exert downward pressure on the sector's consumption, although not at the rate observed between 2010 and 2014. In 2017, Willem Braat explained that dry conditions in southern Europe had led to a further increase in gas-powered generation (see Figure 4.10), this time at the expense of renewable generation.

2. TRANSPORT SECTOR

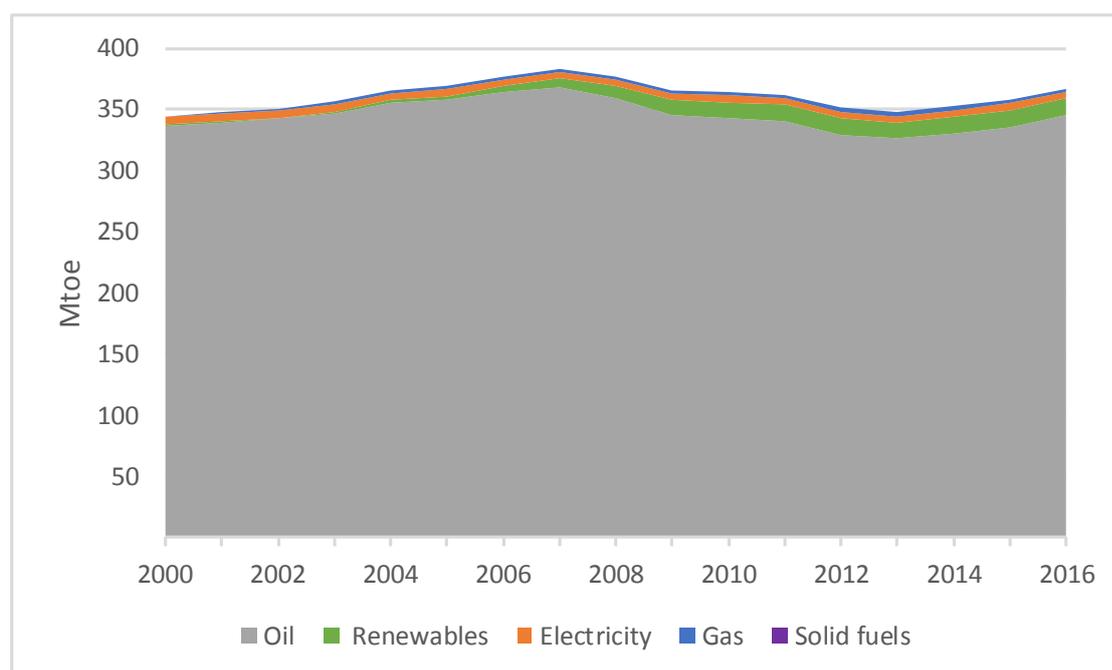
This section discusses recent trends affecting energy consumption in the transport sector and short-term future prospects. At the workshop, presentations from the private sector (Jean Cadu, Shell), the international sector (Jacob Teter, IEA) and a national agency (Maria Lelli, ENEA, Italy) provided different perspectives supplementing the European Commission's analysis of recent trends. Discussion covered both recent developments and likely potential future changes in the transport sector.

The transport sector accounts for around 1/3 of EU final energy consumption, making it the largest end-use sector in this analysis. Consumption in the sector grew by 4.2% between 2014 and 2016 and a continuation of this trend would make it very difficult to meet the EU's overall energy efficiency targets.

2.1. Background

EU final energy consumption in the transport sector increased steadily at around 1.5% per annum over the period 2000-2007, before falling at an annual rate of 1.6% during the period 2007-2013. Since 2013, transport energy consumption has been rising again at an annual average of 1.9% per year, accelerating to 2.6% in 2016. Oil products dominate the EU fuel mix, making up 94% of all final energy consumption in the sector in 2016. Biofuels consumption has increased over the last decade to represent 4% of the fuel mix in 2016, with electricity, coal and natural gas consumption comprising the remainder (Figure 2.1).

Figure 2.1: EU 28 transport sector final energy consumption by fuel type

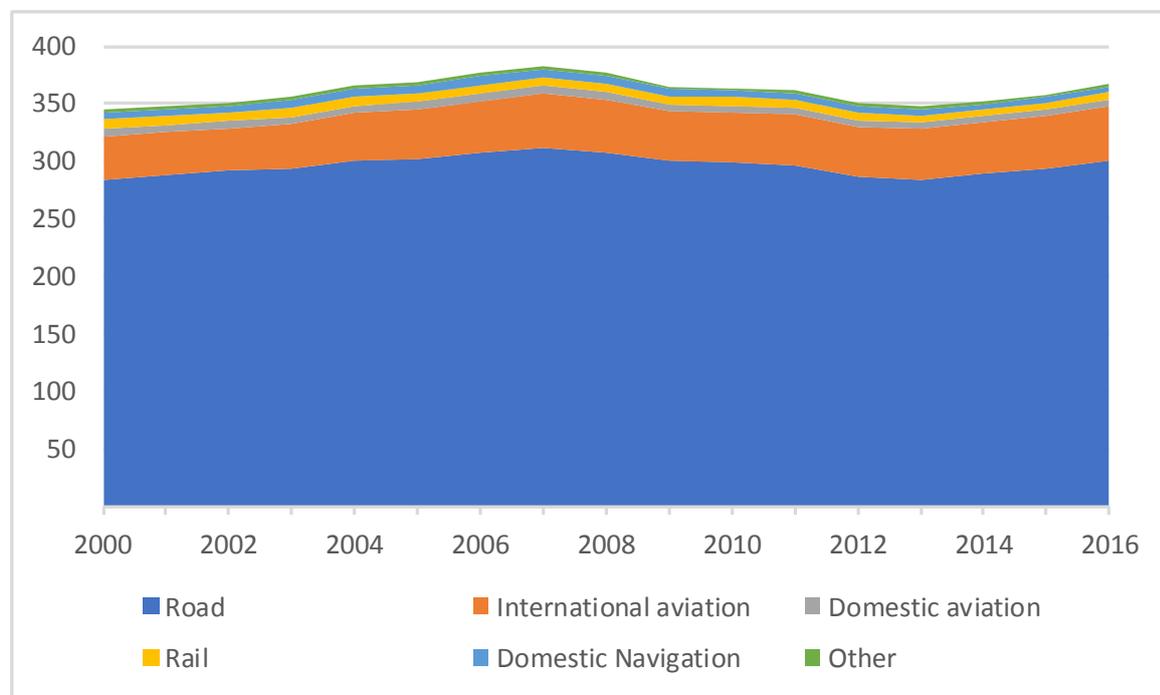


Source: Eurostat Energy Balance May 2018, <http://ec.europa.eu/eurostat/documents/38154/4956218/ENERGY-BALANCES-May-2018-edition.zip/310265d9-6adf-45aa-ba41-2dce8e5f78eb>

Since 2013, the increase in EU transport sector final energy consumption can be seen across all transport modes. Amongst the modes, two important trends should be noted. Firstly, and most importantly, road transport continues to be the most important mode to analyse when looking at overall trends in the transport sector. Between 2000 and 2016, the share of EU final energy consumption in the transport sector that can be attributed to road transport has remained at around 82%. Secondly, aviation is taking a

growing share of overall transport energy consumption. Since 2007, when transport final energy consumption peaked, only international aviation has seen an increase in its energy consumption. Between 2014 and 2016, domestic aviation grew faster than any other mode, albeit from a low base (Figure 2.2).

Figure 2.2: EU 28 transport sector final energy consumption by mode



Source: Eurostat Energy Balance May 2018, <http://ec.europa.eu/eurostat/documents/38154/4956218/ENERGY-BALANCES-May-2018-edition.zip/310265d9-6adf-45aa-ba41-2dce8e5f78eb>

2.2. Factors influencing transport energy consumption

Transport energy consumption is influenced by three major factors: transport activity levels (the amount of transportation); the modes of transport used; and the efficiency of those modes.

2.2.1 Changes in transport sector activity levels

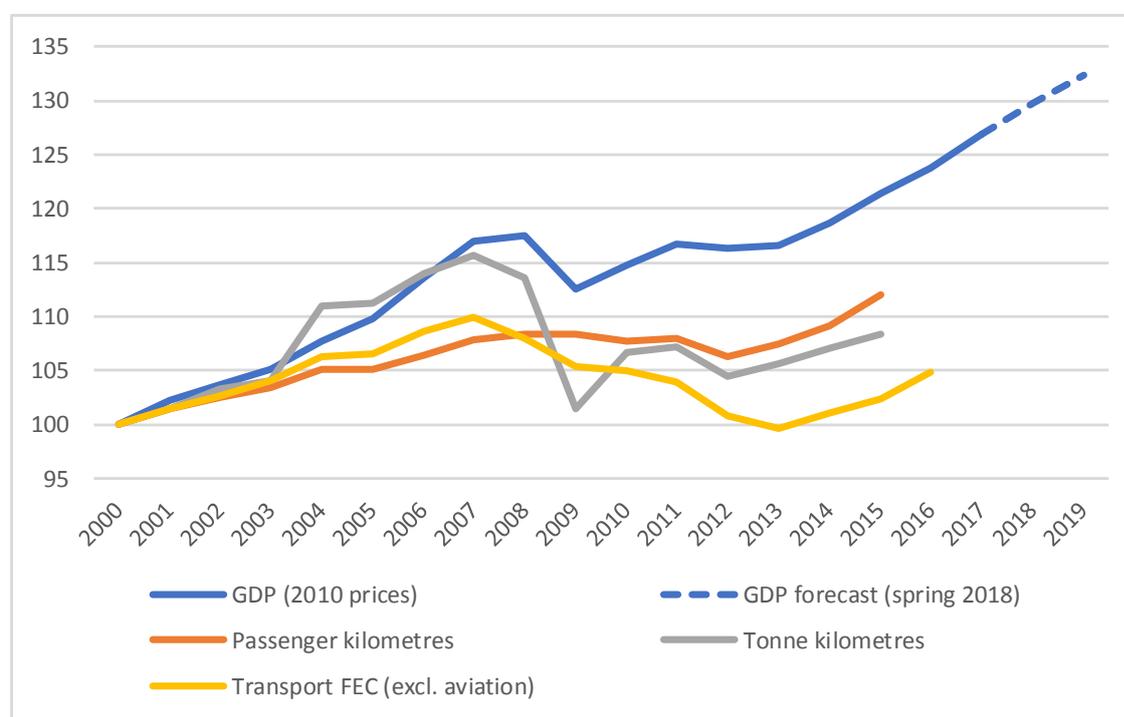
The amount of passenger travel increased by 5% between 2012 and 2015, following three years of decline. The increase of 2.6% in 2015 was the fastest growth rate in at least the last 20 years, and the 4.7 trillion passenger kilometres recorded in 2015 was a new high. The amount of freight transportation has also increased since 2012, rising by 4% over the three years to 2015. Despite this upward trend, the amount of tonne kilometres transported remained 6% lower than its peak level in 2007.

Jean Cadu noted the strong correlation between economic growth and commercial road freight transport demand in the EU and at global level. The one significant departure from this relationship occurred between 2007 and 2009, when EU freight tonne-kilometres fell by 12%, a much bigger fall than GDP, which was 4% lower in 2009 than in 2007. While the recovery in freight transport activity since 2009 has been broadly in line with economic growth, the depth of the fall in activity during the economic downturn has not been retrieved. With continued economic growth, freight tonne kilometres would be expected to rise, all other things being equal.

Jean Cadu explained that on the other hand the relationship between GDP growth and passenger transport is more complicated as it is affected by a multiplicity of factors. Passenger kilometres did not fall until 2010 and then only began to pick up again in 2013, suggesting that there may be a lagged response associated with the economic cycle. For example, consumers' willingness to undertake discretionary travel may be related to their confidence in the economy, or to the state of household balance sheets.

GDP is forecast to continue to grow, at 2.3% in 2018 and 2.0% in 2019.¹⁵ With this level of relatively high sustained growth, passenger activity levels would be expected to grow along with freight transportation. Rising transport activity levels have tended to be associated with increases in transport sector energy consumption; in only one year since 2000 (in 2013), did energy consumption fall while activity levels rose across both freight and passenger transport (Figure 2.3).

Figure 2.3 Indices of GDP, activity and transport sector energy consumption, 2000=100



Sources: Eurostat GDP and main components, http://ec.europa.eu/eurostat/estat-navtree-portlet-prod/BulkDownloadListing?file=data/nama_10_gdp.tsv.gz; European Commission, European Economic Forecast Spring 2018, https://ec.europa.eu/info/sites/info/files/economy-finance/ip077_en.pdf; European Commission Statistical Pocketbook 2017, https://ec.europa.eu/transport/facts-fundings/statistics/pocketbook-2017_en; and Eurostat Energy Balance May 2018, <http://ec.europa.eu/eurostat/documents/38154/4956218/ENERGY-BALANCES-May-2018-edition.zip/310265d9-6adf-45aa-ba41-2dce8e5f78eb>.

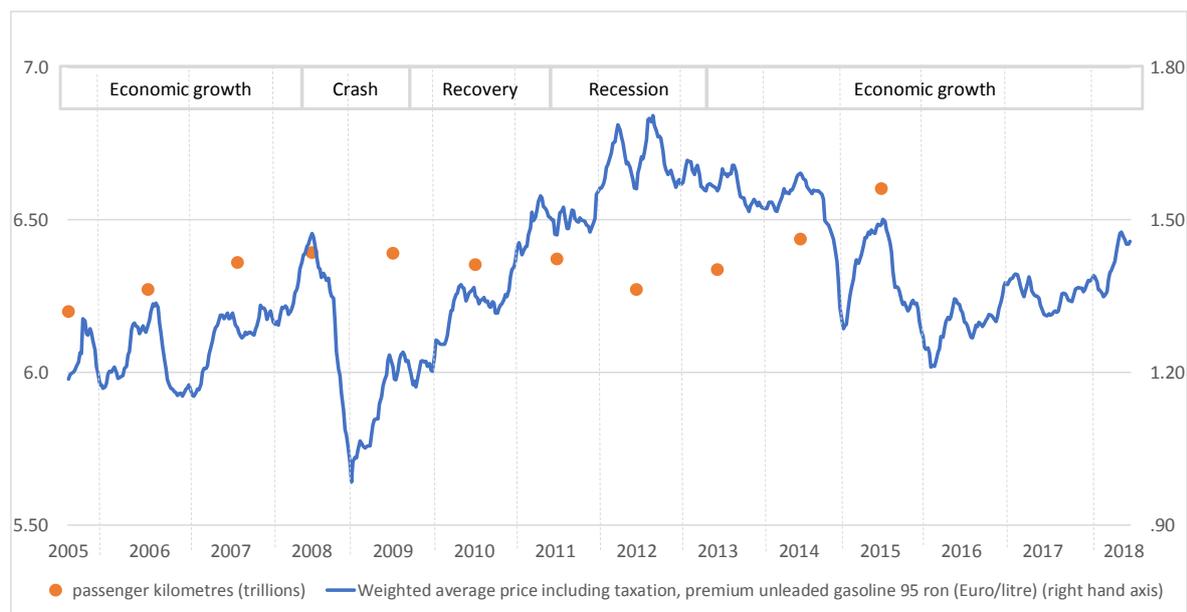
Jacob Teter noted the many estimates of responsiveness of the demand for transport to fuel prices, with empirical estimates of the elasticity of fuel demand with respect to fuel prices of between 0 and -0.4 in the short-run (as consumers adapt the amount of discretionary travel to changes in the cost of travel), and between -0.1 and -0.7 in the long-run (as consumers purchase more or less fuel-efficient vehicles). While all

¹⁵ European Economic Forecast, Spring 2018, European Union (2018), https://ec.europa.eu/info/publications/economic-and-financial-affairs-publications_en

estimates are specific to the particular time, place and demand segment of focus, they do suggest that a fall in fuel prices will put upwards pressure on transport fuel demand.

The relationship between fuel prices and the demand for transportation in the EU is complicated by the changing macroeconomic environment over the period since 2000. However, some effects of the changes in fuel prices seen over the same period can be seen in the passenger transport segment, where a proportion of travel is discretionary. During the period of steady economic growth prior to 2008, rising fuel prices were accompanied by rising passenger kilometres. During the economic crash of 2008-09, fuel prices fell suddenly and passenger kilometres were broadly flat. During the economic recovery of 2009-11, fuel prices rose sharply and passenger kilometres remained fairly flat, falling slightly. The recession of 2011-2012 saw a continuation of rising fuel prices and passenger kilometres fell, particularly in 2012, when fuel prices reached their peak. The current period of economic growth, beginning in 2013, was accompanied by further sharp falls in fuel prices, particularly in 2014 and 2015, and passenger kilometres rose quickly. Beyond 2015, passenger kilometre data do not yet exist, however, continued economic growth and gently rising fuel prices suggest an environment similar to the 2005-2007 period, during which passenger transport demand grew at a rate of 1.0-1.5% per annum (Figure 2.4).

Figure 2.4 EU average unleaded gasoline prices and passenger kilometres



Sources: European Commission Weekly Oil Bulletin, http://ec.europa.eu/energy/observatory/reports/Oil_Bulletin_Prices_History.xls; and European Commission Statistical Pocketbook 2017, <https://ec.europa.eu/transport/sites/transport/files/pb2017-section23.xls>

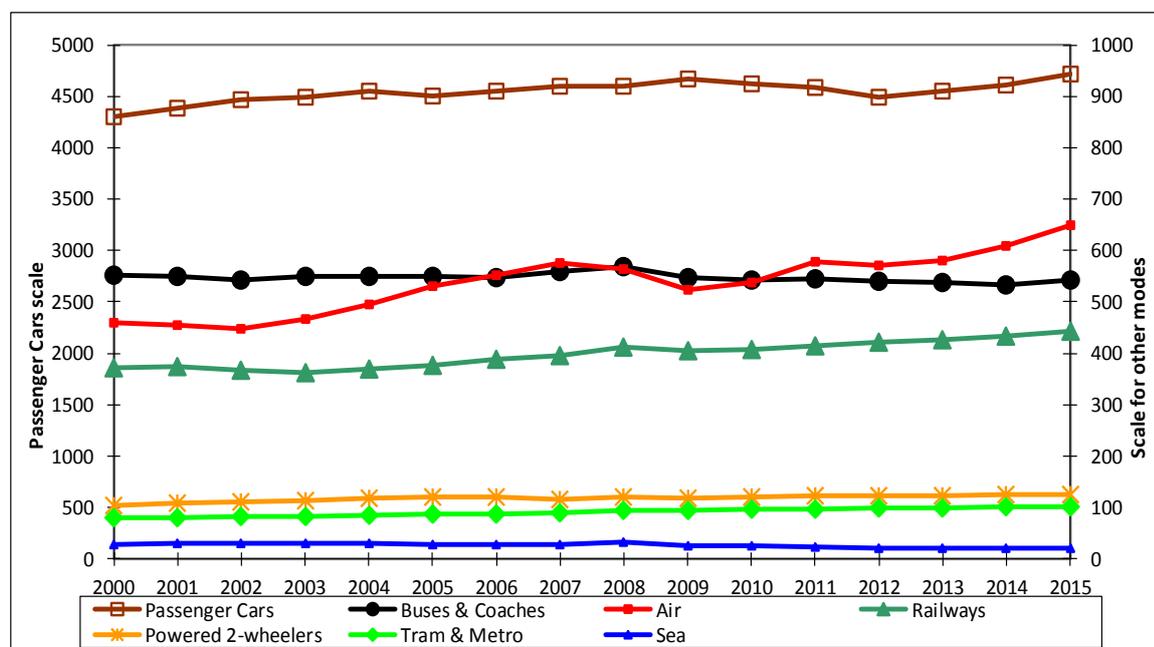
2.2.2 Transport modes

Cars are the predominant form of passenger transport across the EU, comprising 71% of kilometres travelled in 2015. The share of car kilometres in all passenger travel has remained fairly constant over time, falling by 1.5 percentage points between 2009 and 2012, but remaining flat since then. Amongst the other transport modes, air travel has been growing at the fastest rate, notably since 2013, and comprised 10% of passenger kilometres in 2015 (Figure 2.5).

The rise in the share of air travel will have put some upwards pressure on energy consumption, given that, on average, planes use more fuel per passenger kilometre than

any other transport mode. High-speed rail is seven times more efficient on an energy per passenger kilometre basis on routes which are likely to have comparable travel times (i.e. < 1 000 kilometres).¹⁶ When considering the options available to passengers outside of urban areas, Maria Lelli explained that in Italy, aviation used around 40 toe per million passenger kilometres in 2015, compared with around 10 toe for rail and less than 30 toe for passenger cars.

Figure 2.5 EU 28 passenger activity by mode (billion kilometres)



Source: European Commission (DG MOVE) Statistical Pocketbook 2017, <https://ec.europa.eu/transport/sites/transport/files/pb2017-section23.xls>

While the share of collective land transport in all passenger land transport has changed relatively little over the last decade, there have been some significant changes in individual EU Member States, with the spread between countries narrowing. The countries with the highest share of collective land transport in 2000 have seen their share decline; these countries are mostly located in the EU’s newer member states (EU 13). In other countries with relatively low levels of collective passenger transport penetration, mostly located in the EU’s older member states (EU 15), the share has slightly increased (Figure 2.6).

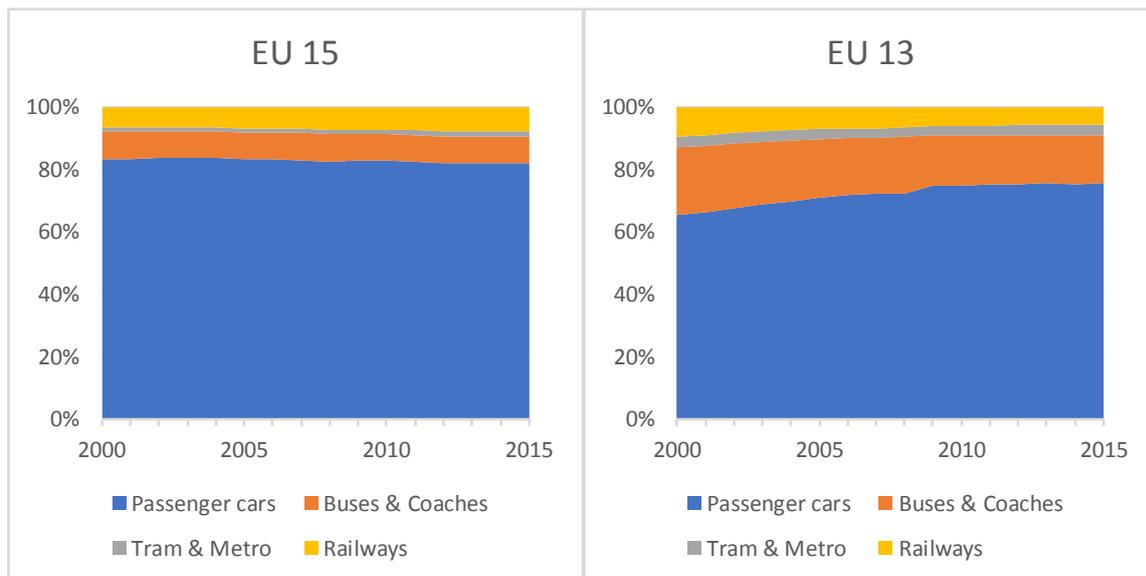
Maria Lelli noted the dominance of passenger cars in Italy, with Italians owning more cars per person (0.63 in 2016) than any other EU Member State except Luxembourg. In Italy, the share of collective land transport in all passenger transport has remained fairly constant over the last decade, while overall levels of passenger travel have declined.

Overall, at EU level, shifts in the shares of the different passenger transport modes do not appear to be having a major impact on energy consumption, however the continued increase in air travel is exerting some upward pressure. The number of European passenger journeys is projected to rise at a compound annual growth rate of 2.5% between 2015 and 2035, adding 570 million passengers per year.¹⁷

¹⁶ IEA Mobility Model, <https://www.iea.org/topics/transport/mobilitymodelpartnership/>

¹⁷ International Air Transport Association (2018), <https://www.iata.org/pressroom/pr/Pages/2016-10-18-02.aspx>

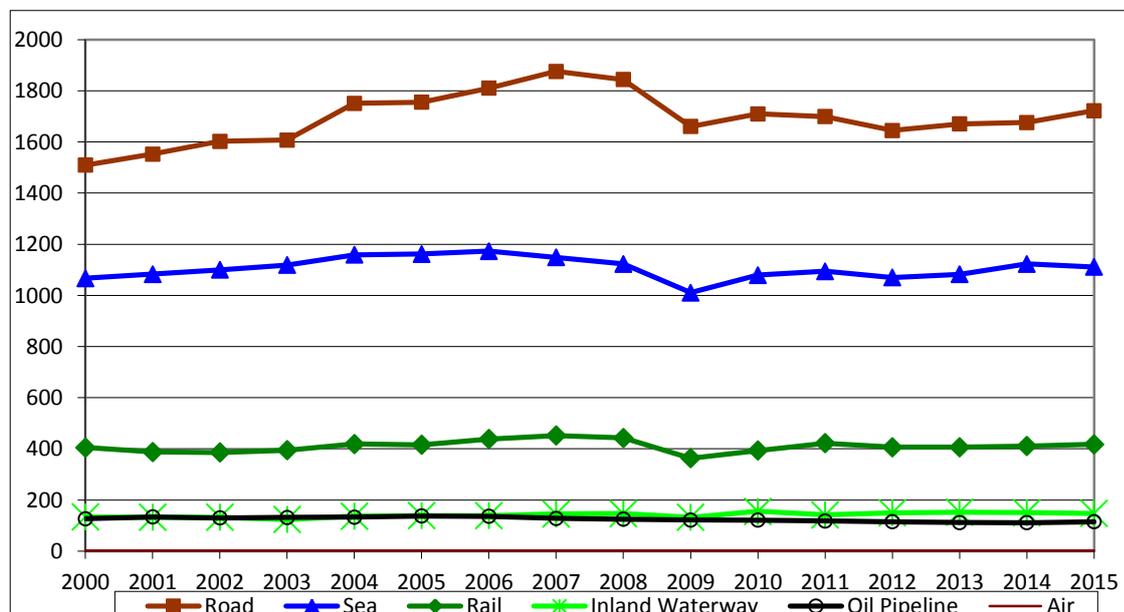
Figure 2.6: Share of land transport passenger kilometres by mode



Source: European Commission (DG MOVE) Statistical Pocketbook 2017, <https://ec.europa.eu/transport/sites/transport/files/pb2017-section23.xls>

In the freight sub-sector, the shares of each mode have remained broadly constant over time, with road transport comprising around half of all tonne kilometres and sea transport around one third. Overall, changes in the shares of the different freight transport modes do not appear to be having a significant impact on energy consumption (Figure 2.7).

Figure 2.7 EU 28 freight activity by mode (billion tonne kilometres)



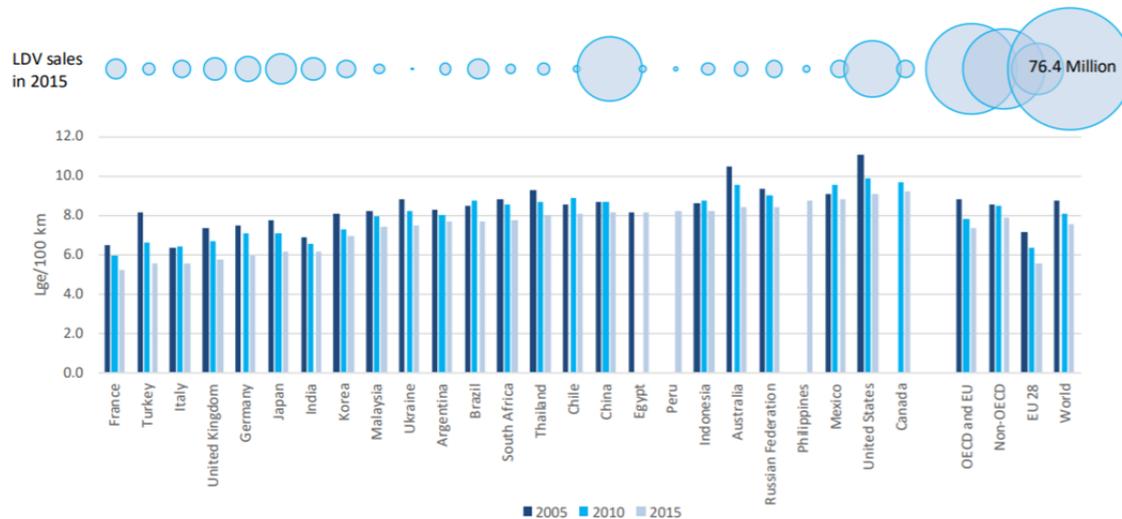
Source: European Commission (DG MOVE) Statistical Pocketbook 2017, <https://ec.europa.eu/transport/sites/transport/files/pb2017-section22.xls>

2.2.3 Transport sector efficiency

Jacob Teter explained that the efficiency of the light passenger vehicle segment has been improving over time, driven in part by EU mandatory emissions reduction targets for

new vehicles. As new, more efficient vehicles enter the passenger vehicle fleet, the average amount of energy used per passenger kilometre decreases, putting downward pressure on energy consumption. The average fuel economy of new light duty vehicles (LDVs) in the EU was better than in any other large vehicle market in 2015 except Turkey (Figure 2.8).

Figure 2.8 Average new LDV fuel economy by country, normalised to the WLTC



Notes: Lge/100 km = litres of gasoline equivalent per 100 kilometres; OECD and EU = member states of the European Union and specified member countries of the Organisation for Economic Co-operation and Development (Australia, Canada, Chile, Japan, Korea, Mexico, Turkey and United States); Non-OECD = specified non-OECD countries (Argentina, Brazil, China, Egypt, India, Indonesia, Malaysia, Peru, Philippines, Russian Federation, South Africa, Thailand and Ukraine); **WLTC** = Worldwide harmonised Light Vehicle Test Cycle.

Source: GFEI Working Paper 15, International comparison of light-duty vehicle fuel economy 2005-2015: ten years of fuel economy benchmarking, <https://www.globalfueleconomy.org/data-and-research/publications/gfei-working-paper-15>

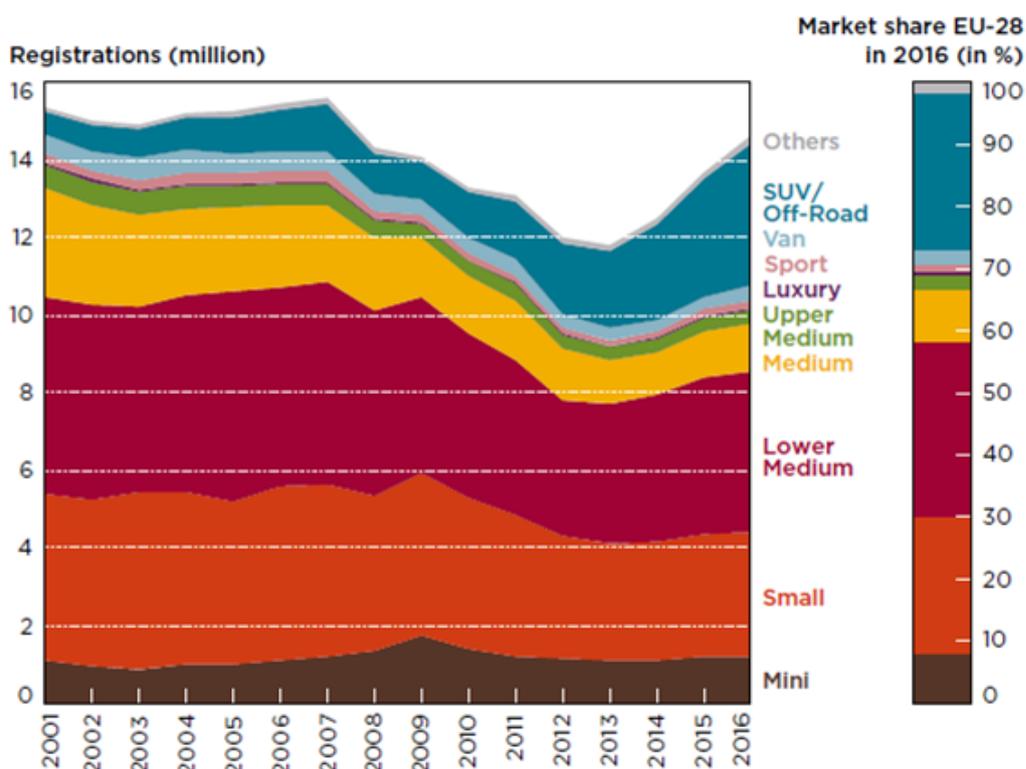
The extent to which new vehicle fuel economy improvements affect final energy consumption depends on both the number and types of new vehicles purchased. Jacob Teter showed that new light duty vehicle registrations had declined for six successive years between 2007 and 2013 as household expenditure fell following the economic crisis in 2008. Since 2013, however, annual new registrations have picked up, rising by more than 20% to 2016. A rising number of registrations helps to improve the fuel economy of the whole fleet more quickly. On the other hand, the rise in registrations has been concentrated largely in the sports utility vehicle (SUV) and off-road segment, which contains vehicles which, on average, consume more fuel per passenger kilometre than those in other segments. Between 2013 and 2016, the annual number of SUV registrations almost doubled (Figure 2.9).

These two trends have continued since 2016. In 2017, new passenger vehicle registrations rose by 3.4% across the EU, with demand particularly strong in the EU's new member states, where registrations grew by 12.8%. Over the first half of 2018, registrations were 2.9% higher than in the same period in 2017, with new member states continuing to post the biggest increases.¹⁸ Meanwhile, SUVs accounted for 26% of

¹⁸ European Automobile Manufacturers Association (2018), <https://www.acea.be/statistics/tag/category/passenger-cars-registrations>

all new vehicle sales in 2016 and are forecast to reach a share of 34% by 2020, putting upwards pressure on transport sector final energy consumption.¹⁹

Figure 2.9: New EU passenger vehicle registrations by segment



Source: Source: International Council for Clean Transportation, European Vehicle Market Statistics Pocketbook 2017/2018, <https://www.theicct.org/publications/european-vehicle-market-statistics-20172018>

The impact of the increase in SUVs on energy consumption has been reinforced by the move away from diesel towards petrol engines elsewhere in the passenger vehicle fleet. For the same vehicle model, the petrol version will consume more energy per kilometre and emit more CO₂ emissions. Jacob Teter explained that, following the publicity surrounding “Dieselgate” in 2015, the percentage of registrations has fallen in many major European markets. This trend picked up in 2017 (Figure 2.10).

Provisional data for the whole of 2017 suggest that, for the first year since monitoring began, petrol cars comprised more than half of all vehicles sold (53%). These data suggest that, on average, the petrol cars sold in the EU in 2017 were 3% less fuel efficient (in g CO₂/km terms) than the diesel cars sold. Meanwhile, while the average fuel efficiency of petrol cars remained constant when compared to 2016, the average fuel efficiency of diesel cars worsened, by 1%, reflecting the shift towards SUVs, which tend to be diesel-powered.²⁰ The combination of these factors had led to a slowdown in

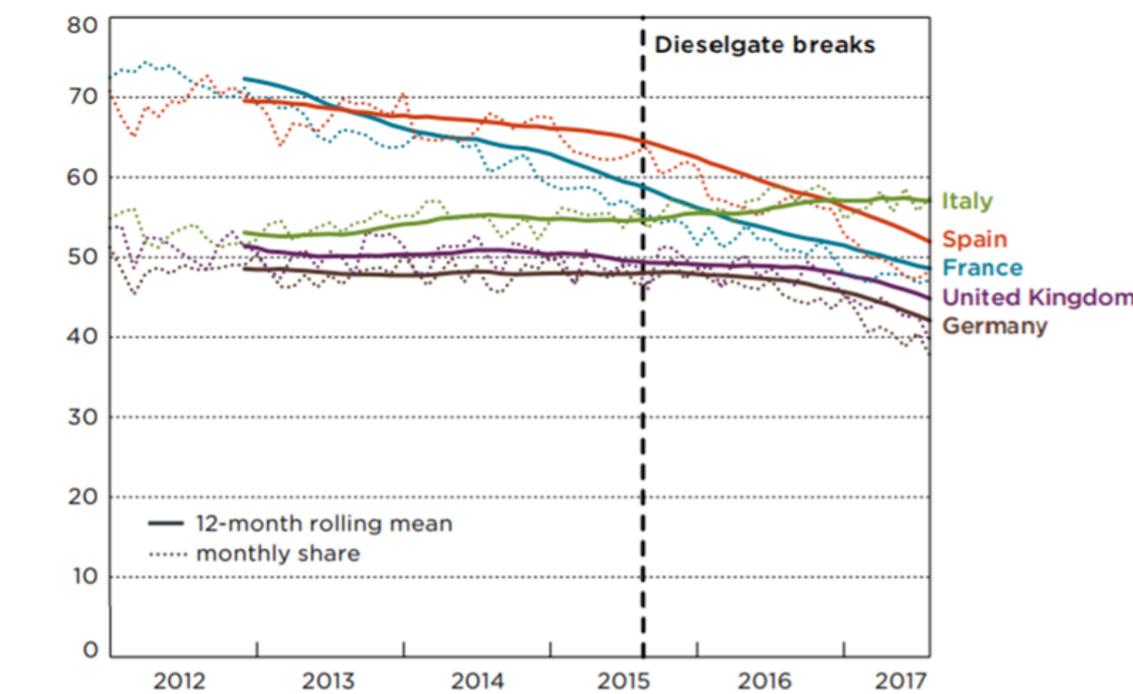
¹⁹ Crain Communications, Inc. (2017), <http://europe.autonews.com/article/20170811/ANE/170739935/suvs-will-continue-to-dominate-in-europe>

²⁰ European Environment Agency (2018), <https://www.eea.europa.eu/highlights/no-improvements-on-average-co2>

the rate of new passenger vehicle efficiency progress during 2015 and 2016; in 2017, provisional data suggest that new vehicle efficiency worsened by 0.3%.

The interaction between these factors deserves further attention, however both factors are likely to moderate in the medium-term. The acceleration in the rate of new registrations is likely to soften as consumers complete the purchases that had been put-off when weaker economic conditions were weaker and the pressure on manufacturers to meet emissions targets in 2021 should lead to greater efforts to persuade consumers to purchase more efficient vehicles. A continuation of anti-diesel sentiment would mean a greater emphasis would need to be placed on the development of the electric vehicles fleet.

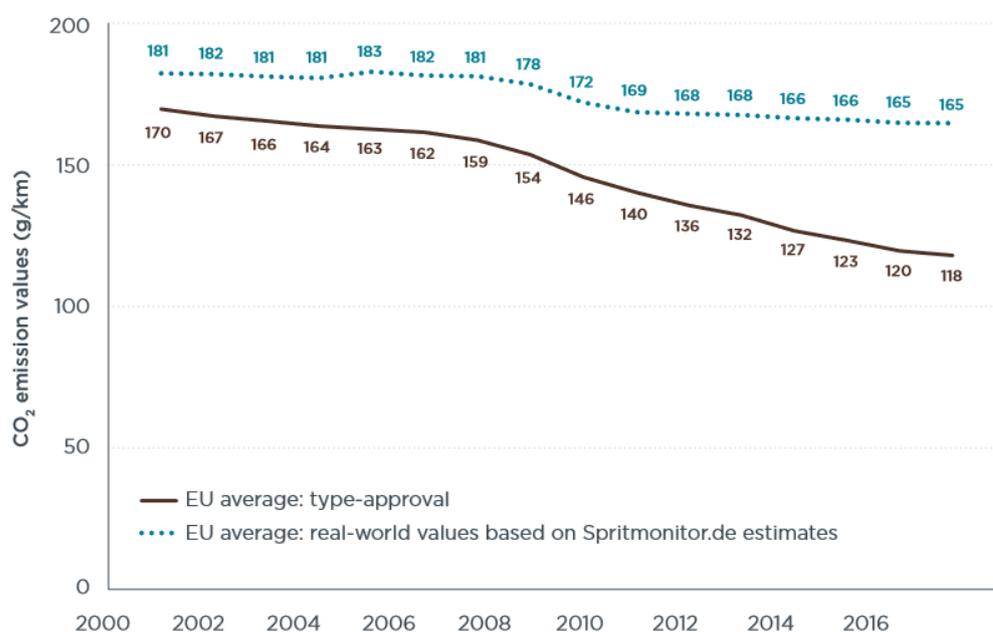
Figure 2.10 Diesel share of new car registrations



Source: Source: International Council for Clean Transportation, European Vehicle Market Statistics Pocketbook 2017/2018, <https://www.theicct.org/publications/european-vehicle-market-statistics-20172018>

While the emissions targets on manufacturers have helped to drive down emissions in the past, and should continue to do so in the future, their impact on energy consumption has also been affected by the divergence between test results used to comply with regulations and the real-world performance of vehicles on the road (Figure 2.11).

Figure 2.11: Real-world vs type-approval CO₂ emission values of new EU passenger cars



Source: ICCT White Paper, From Laboratory to Road (2017), https://www.theicct.org/sites/default/files/publications/Lab-to-road-2017_ICCT-white%20paper_06112017_vF.pdf drawing upon Spritmonitor.de real world estimates and European Environment Agency type-approval data.

The Commission has taken action to address this issue. The more stringent target of 95 g/km set at EU level for CO₂ emissions from passenger cars (95% of each manufacturer's new cars will have to comply with the limit value curve in 2020, increasing to 100% in 2021) will reduce consumption and emissions of the new fleet. In addition, the transition to a new regulatory test procedure for measuring CO₂ emissions and fuel consumption from light duty vehicles, the World Harmonised Light Vehicles Test Procedure (WLTP), since 1 September 2017 for new types of passenger cars and since 1 September 2018 for all new passengers should further put downward pressure on EU passenger transport energy consumption in the coming years.

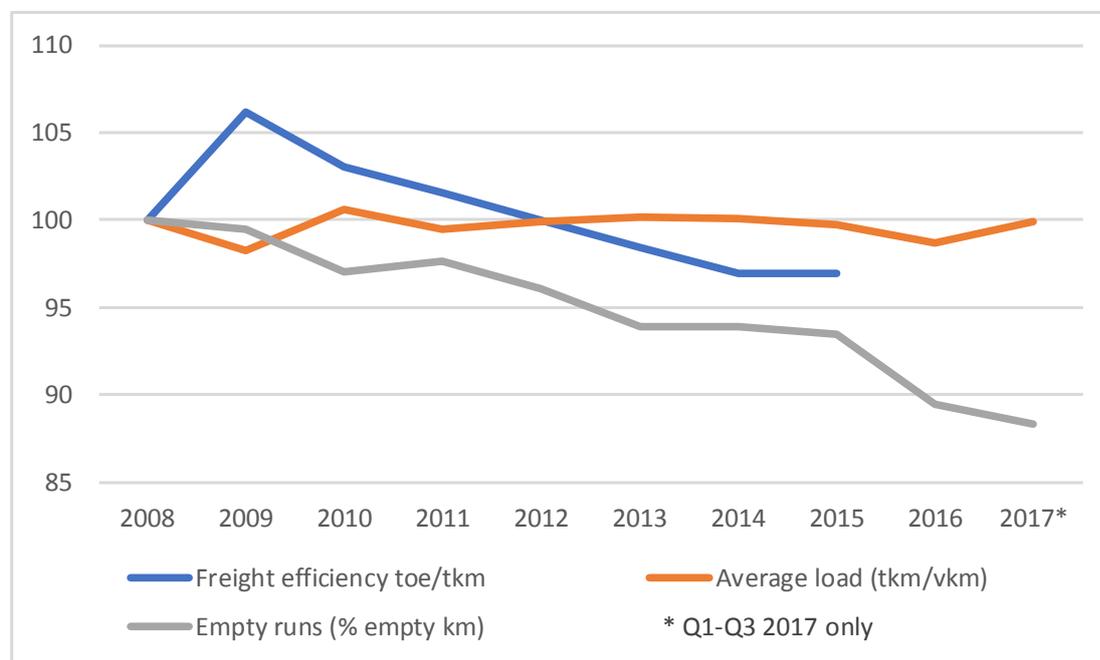
The efficiency of the freight sector, while subject to emissions targets in the light duty segment, is only expected to see emissions targets for the period 2019-2025 for large lorries and for smaller goods vehicles from 2022.²¹ Partly as a result, freight efficiency has improved relatively little over time, with 3% less energy used per tonne kilometre in 2015 compared with 2008.²² The efficiency of the freight sector is affected by the economic cycle and logistics, which both impact upon the average load (higher is more efficient) and the amount of empty freight runs (lower is more efficient). In 2009, the economic crisis led to sharp decline in efficiency (increase in energy per tonne kilometre) as the average load also declined. Since then, average loads have recovered and remained fairly constant, while the proportion of empty freight runs has declined at roughly the same rate as the increase in efficiency. 2016 saw a relatively large fall in average load, which will have exacerbated the impact of the increase in tonne kilometres on energy consumption. However, average load levels appear to have recovered in 2017. Overall, these indicators suggest that the efficiency of freight operations may have

²¹ European Commission (2018), https://ec.europa.eu/clima/policies/transport/vehicles/heavy_en

²² ODYSSEE-MURE (2018), <http://www.indicators.odyssee-mure.eu/energy-indicators/specific-road-transport-consumption-goods.html>

put a little less downward pressure on energy consumption in 2016 than in previous years, but there is nothing in the trend data to suggest that this will continue (Figure 2.12).

Figure 2.12 EU indices of freight efficiency, average load and empty runs, 2008=100



Sources: Odyssey Mure (2018), <http://www.indicators.odyssee-mure.eu/energy-indicators/specific-road-transport-consumption-goods.html>; and Eurostat (2018), <http://appsso.eurostat.ec.europa.eu/nui/setupDownloads.do?p=749c0e30-ab0b-4217-a681-188e70f9326a-1531913268882>

2.2.4 Other factors

Additional discussion at the workshop revolved around a number of trends that are emerging but have not yet had a major impact on energy consumption. The electrification of passenger transport was seen as necessary in the medium-term if climate targets are to be met but facing significant barriers to uptake in the short-term. In the short to medium-term, the efficiency of passenger transport is most likely to continue to be dominated by the rate of improvement demanded by emissions targets, with electric vehicles playing a smaller or larger role depending on consumer preferences for SUVs and petrol and diesel vehicles. Jacob Teter explained that, in Europe, battery electric vehicles were projected to become cost-competitive (with average mileage over 3.5 years of use) by 2030 according to the IEA’s “2°c degree scenario”.²³ However, some commentators believe that the electric vehicle market may take-off more quickly than emissions targets require²⁴, driven in part by new urban regulations aimed at cutting local air pollution. Electric vehicles produce fewer local pollutants and are three-to-four times more efficient in final energy terms than the equivalent vehicles powered

²³ International Energy Agency (2018), <https://www.iea.org/etp/>

²⁴ See for example ING (2017), <https://www.ing.com/Newsroom/All-news/Electric-cars-will-take-over-threatening-European-car-industry.htm>

by internal combustion engines²⁵, meaning that, if electrification does proceed more quickly than expected, transport sector final energy consumption would also fall more quickly in the medium term.

Developments in shared ownership, ride-hailing services and self-driving vehicles were also discussed. These developments were generally expected to increase mobility (passenger kilometres) and the efficiency with which people and goods travel, with better use of the capital stock, logistics and travel routes. These two effects are likely to have opposing impacts on energy consumption in the transport sector, and it is too early to tell which effect is most likely to dominate. In the short-term, impacts on energy consumption were expected to be small.

In the medium-term, however, increases in ride-hailing would be expected to speed up the penetration of electric vehicles in the stock, given the increasing cost-competitiveness of electric vehicles as the number of kilometres driven increases. Discussion in the room also highlighted uncertainties around the modes of transport that these changes might displace, with some suggesting that mass transportation might lose out to ride-hailing services, leading to increases in energy consumption, given the relative energy efficiency of rail, buses, trams and other mass transportation modes.

2.3. *Prospects for transport sector energy consumption*

In the short-term, to 2020, a continuation of the current uptick in energy consumption is likely. Strong investment in the new car fleet, along with the transition to a more stringent test regime, may well drive up efficiency levels, offsetting the expected growth in SUV sales. However, the relatively strong economic growth seen in 2017 and predicted for 2018 and 2019 is likely to continue to put upward pressure on passenger and tonne kilometres, driving up the sector's energy consumption. An increase of 1.5% per annum in transport sector energy consumption would add around 2.0% to 2016 EU final energy consumption by 2020.

In the medium-term, beyond 2020, EU actions taken for stricter passenger vehicle standards and test procedures, and the impact of regulations on freight emissions should act to improve the efficiency of road transport significantly, driving down the sector's energy consumption.

²⁵ International Energy Agency Mobility Model, <https://www.iea.org/topics/transport/mobilitymodelpartnership/>

3. INDUSTRY SECTOR

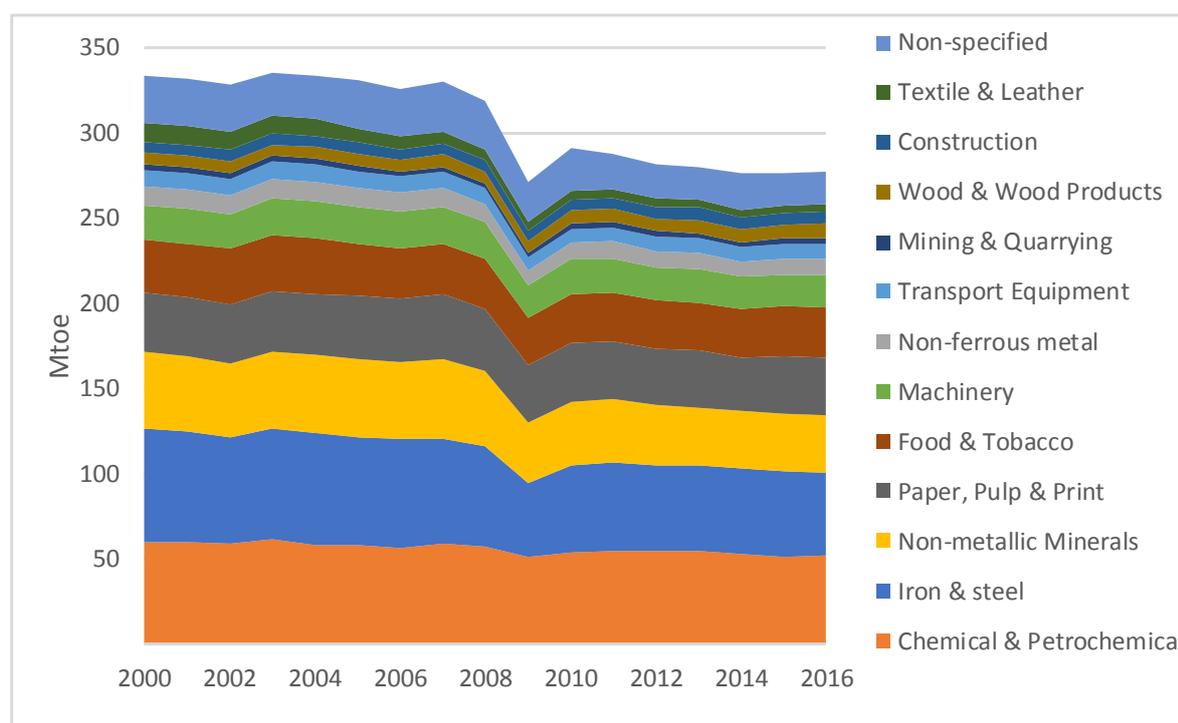
This section discusses recent trends affecting energy consumption in the industry sector and short-term future prospects. At the workshop, presentations from the public sector (Didier Bosseboeuf (Adème, France) and academia (Patrik Thollander, Linköping University, Sweden), supplementing the European Commission's presentation of recent trends. Discussion covered both recent developments and the extent to which policy has driven them.

The industry sector accounts for around 1/4 of EU final energy consumption. Consumption in the sector rose by 0.3% between 2014 and 2016, the first increases seen since the economic recovery of 2010.

3.1. Background

The industry sector has seen the biggest falls in energy consumption over the period since 2007. The average annual reduction of 2.5% per annum over the 2007-2014 period can be split into three distinct periods: a dramatic fall of 17.9% between 2007 and 2009; a limited recovery of 7.4% in 2010; and a more gradual reduction of 5.1% between 2010 and 2014. The small increases in consumption in 2015 (0.1%) and 2016 (0.2%) left EU industry sector final energy consumption 16.1% lower than in 2007, with the energy intensive iron and steel, non-ferrous metals, chemical and petrochemical, and non-metallic minerals sub-sectors seeing reductions of between 12% and 27%. Since 2007, only the mining and quarrying, wood and wood products and construction sectors have seen an increase in energy consumption (Figure 3.1).

Figure 3.1: EU industry sector area final energy consumption by sub-sector

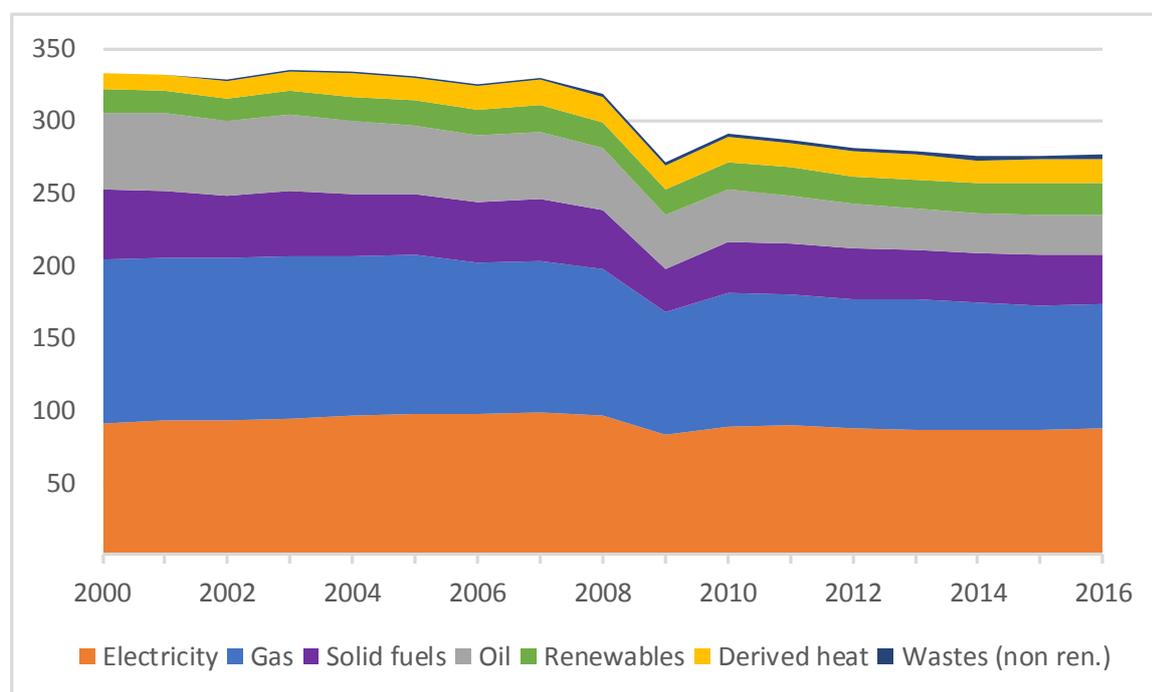


Source: Eurostat Energy Balance May 2018, <http://ec.europa.eu/eurostat/documents/38154/4956218/ENERGY-BALANCES-May-2018-edition.zip/310265d9-6adf-45aa-ba41-2dce8e5f78eb>

Across the industry sector, electricity and gas are the most commonly used fuels, both accounting for 31% of the sector's final energy consumption in 2016. Oil has seen the

biggest declines since 2007 and accounts for 10% of consumption, less than solid fuels (12%) but more than renewables (8%) (Figure 3.2).

Figure 3.2 EU industry final energy consumption by fuel



Source: Eurostat Energy Balance May 2018, <http://ec.europa.eu/eurostat/documents/38154/4956218/ENERGY-BALANCES-May-2018-edition.zip/310265d9-6adf-45aa-ba41-2dce8e5f78eb>

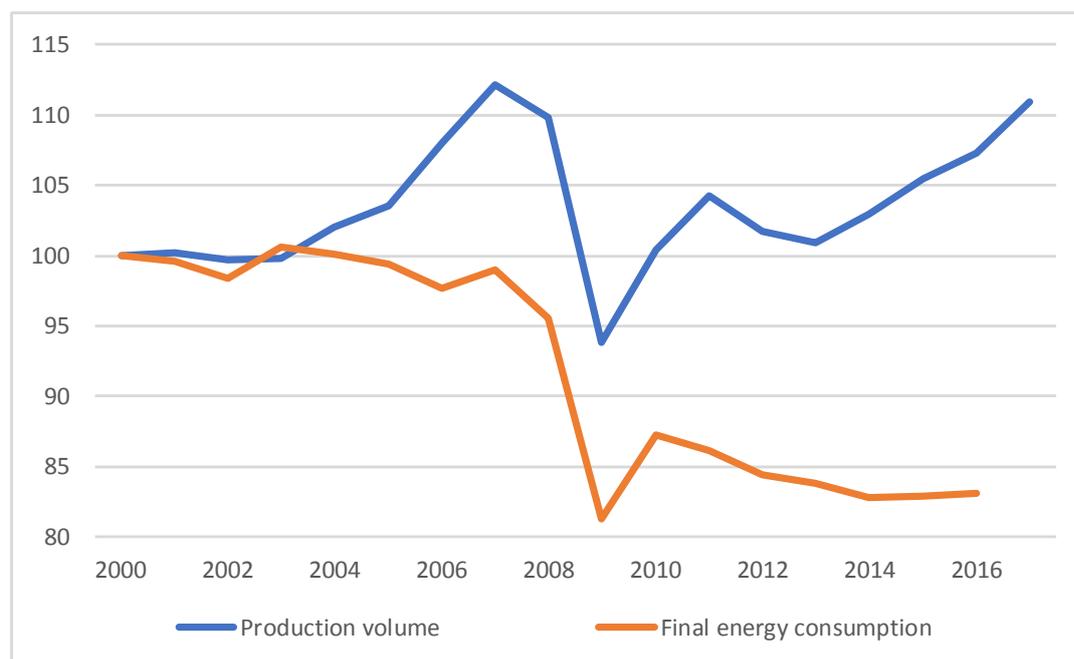
3.2. Factors influencing industry sector energy consumption

Industry sector energy consumption is influenced by activity levels (output growth); industrial structure (shifts in production between and within industry sub-sectors); and the efficiency with which energy is used.

3.2.1 Changes in industry sector activity levels

The volume of industrial production rose at an annual rate of 1.4% between 2013 and 2016, following two years of decline (2011-2013). In 2017 the increase in the volume of production accelerated to 3.4%, the highest rate since 2010. All other things being equal, an increase in industrial production across all sub-sectors will drive up energy consumption, suggesting that 2017 may have seen further increases in industry sector energy consumption. This was the case in 2010, during the recovery from the crisis of 2008-09, and the uptick in production in 2015 and 2016 was also accompanied by a small rise in energy consumption. However, in other periods, increases in industrial output have not been accompanied by rises in energy consumption, including the 2003-06 period (Figure 3.3).

Figure 3.3 Indices of EU industrial production volumes and final energy consumption, 2000=100



Note: Production volumes for NACE codes B and C: mining & quarrying and manufacturing.

Source: Eurostat Production in Industry, <http://appsso.eurostat.ec.europa.eu/nui/setupDownloads.do?p=6d425b62-a7cf-4471-8415-da35339f2f87-1532191555478>; and Eurostat Energy Balance May 2018, <http://ec.europa.eu/eurostat/documents/38154/4956218/ENERGY-BALANCES-May-2018-edition.zip/310265d9-6adf-45aa-ba41-2dce8e5f78eb>

To examine the impacts of recent trends in industry sector production on energy consumption a more detailed look at the most important sub-sectors is required.

3.2.2 Changes in industry structure

Didier Bosseboeuf highlighted the different periods since 2000 during which the impact of structural change had impacted upon energy consumption in France. During the period prior to the economic crisis, structural changes towards less energy-intensive sectors had put downward pressure on energy consumption, although the effect was quite small. Between 2007 and 2009, the economic crisis had a very large structural effect, again putting downward pressure on energy consumption, but since 2013, structural changes had put upward pressure on energy consumption, although this effect was more than offset by other factors.

At the EU level, between 2000 and 2007, iron & steel and paper, pulp & print production moved broadly in line with the sector average, while non-metallic mineral production (including cement) expanded at a slightly slower rate than overall production. Non-ferrous metals production (including aluminium) declined, as did the petrochemical sector (from 2004), while the chemicals sub-sector expanded rapidly along with the less energy intense equipment manufacturing sectors. Overall, this represented a fairly benign structural change for energy consumption.

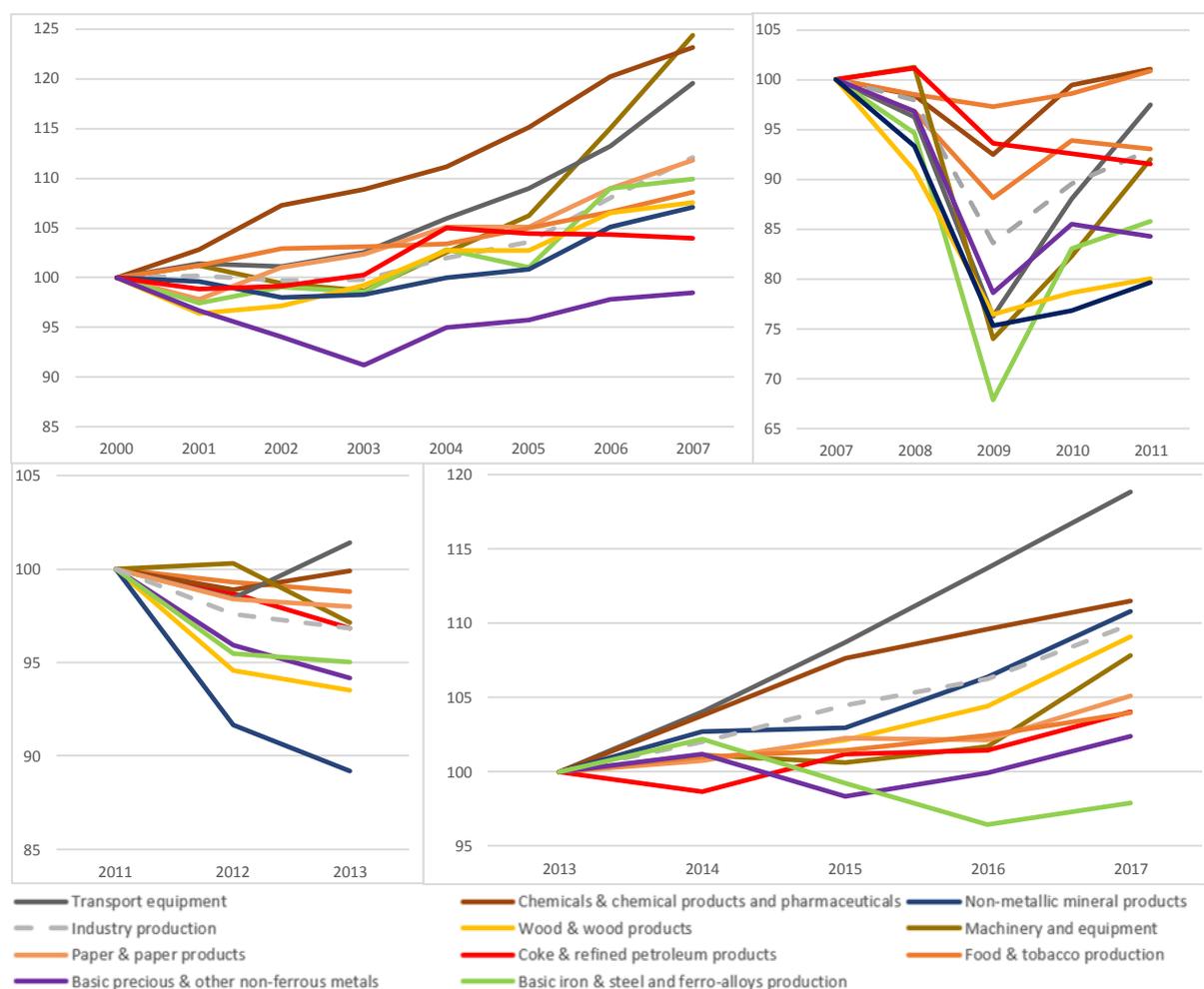
The economic crisis and partial recovery between 2007 and 2011 led to structural change that pushed energy consumption downwards, reinforcing the impact of the overall reduction in economic activity. While all sectors experienced falls in production,

non-metallic minerals, non-ferrous metals and iron & steel saw significantly larger reductions than the sector average. Amongst the most energy intensive sub-sectors, only the chemicals industry did recover production levels relatively quickly, with production in 2010 higher than in 2008.

The recession of 2011 to 2013 saw a further deep decline in the non-metallic minerals sector, and greater than average reductions in both iron & steel and non-ferrous metals output. While the chemicals sector again maintained output levels, overall this period saw structural change that should have put downward pressure on energy consumption.

The period of economic growth since 2013 has been led by the relatively less energy-intensive transport equipment sub-sector. Amongst the most energy-intensive sub-sectors, chemicals have again outperformed the rest, although non-metallic minerals have grown significantly more quickly since 2015. Iron & steel and non-ferrous metals, however, have continued to underperform, although both sectors did grow in 2017. Again, the structural implications of industry sector growth look to be softening the impact on energy consumption of the overall increase in activity. In 2017, while industrial production grew by 3.4%, the fastest growing sub-sectors were machinery & equipment (6.0%), wood & wood products (4.5%) and transport equipment (4.5%), although non-metallic minerals did grow quickly too (4.2%) (Figure 3.4).

Figure 3.4 Indices of EU industrial production, 2000=100, 2007=100, 2010=100 and 2013=100

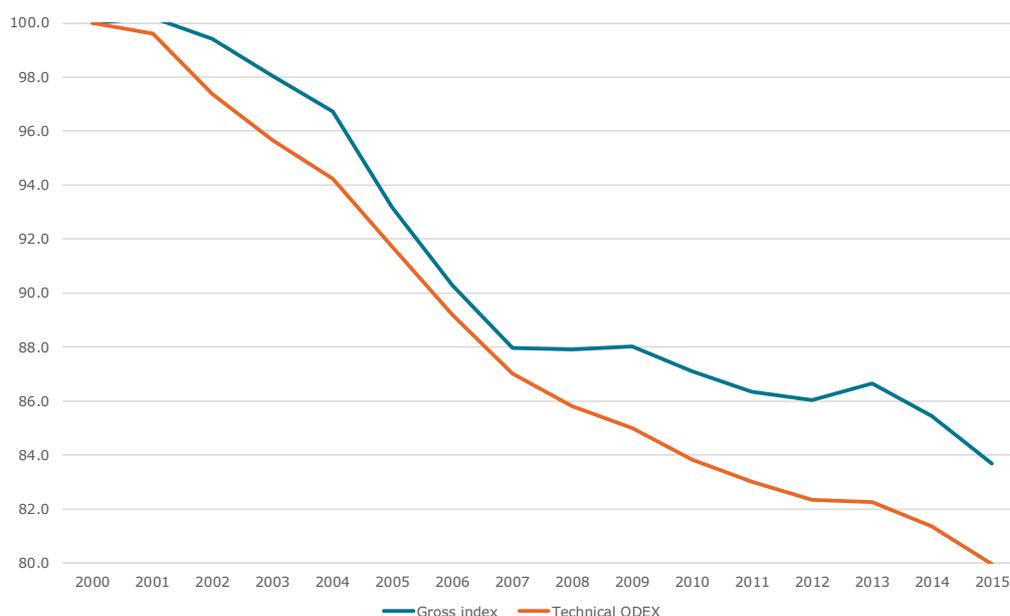


Source: Eurostat Industrial Production Volume Index, http://ec.europa.eu/eurostat/product?code=sts_inpr_a&language=en&mode=view

3.2.3 Improvements in industry energy efficiency

Didier Bosseboeuf presented decomposition analysis from the ODYSSEE project²⁶ for the period between 2000 and 2015. EU total final energy consumption would have been 230 Mtoe higher in 2015 had it not been gains in energy efficiency since 2000, i.e. final energy consumption would have been 21% higher. The analysis showed that the industry sector had been responsible for around 30% of the energy savings generated by efficiency gains over the period.²⁷ In France energy efficiency in industry improved by 1,2% per year in the period between 2000-2015, in line with the EU average. At EU level the rate of improvement had been 2% per annum in the period before the economic crisis (2000-2007) and only 1% per year thereafter, however the rate of improvement had increased again in 2015. This relationship may be owing to the higher levels of investment seen during periods of economic growth. This hypothesis is supported by the composition of the efficiency savings identified in the ODYSSEE analysis, which see the savings concentrated in the chemicals and transport equipment sub-sectors. The improvement in the efficiency index (ODEX) between 2000 and 2015 in these two sub-sectors was more than twice that in any other sub-sector. These two subsectors also saw double the output growth of any other subsector over the same period. If such trends are maintained, the recent uptick in the EU industrial growth should lead to more investment and greater energy efficiency gains to moderate the impact of activity growth.

Figure 3.5 EU industry sector gross efficiency index and technical ODEX (3 year moving average)



Source: ODYSSEE-MURE (2018), reproduced from workshop presentation by Didier Bosseboeuf.

The energy efficiency of production is not only a function of the efficiency of the capital used in production processes. The efficiency with which existing capital is used also affects the amount of energy used to produce a given level of output. Discussion at the

²⁶ <http://www.odyssee-mure.eu/>

²⁷ Savings calculated using the ODEX methodology, <http://www.indicators.odyssee-mure.eu/odex-indicators-database-definition.pdf>

workshop touched on this issue, focussing on the impact of lower capacity utilisation during the economic crisis. This both lowered the absolute amount of energy used in the industry sector and raised the average amount of energy used to produce a unit of output. While differences in the efficiency with which energy consuming equipment is used can arise at all points of the economic cycle, the effect is particularly noticeable during the economic crisis (2007-09) and the more recent recession (2011-13). This was highlighted by Didier Bosseboeuf, who presented indices comparing the gross efficiency of the industry sector (the traditional output of decomposition analyses which factor in output growth and structural change) and a technical index of efficiency (ODEX), which does not allow for negative efficiency trends in individual sub-sectors in its calculation (Figure 3.5). The current period of economic growth should mean that the observed efficiency trend (gross index) improves at a rate closer to the technical index implied by improvements in the underlying efficiency of the equipment used in industrial processes. It was also mentioned by René Kemna that energy needs for space heating are not non-negligible and often underestimated in statistics, and that therefore weather variability affects energy consumption in the industry sector too.

Patrik Thollander explained how the barriers to improving energy efficiency in the industrial sector through the use of energy audits and energy management, to both identify investment opportunities and support the deployment and ongoing use of energy using equipment. Energy management diffusion could be supported by policies, such as voluntary agreements with tax exemptions. Countries in the European Union have been at the forefront of the introduction of energy management systems, with 85% of all ISO 50001 certifications having been issued to European companies between 2011 and 2015 also as a result of the implementation of the energy audit requirement under the EED²⁸, with the overwhelming majority of those businesses being located in Germany, which has a tax exemption associated with the take-up of this particular energy management system.²⁹

3.3. Prospects for industry sector energy consumption

In the short-term the projected continuation of relatively strong economic growth suggests that industry sector energy consumption is likely to rise between 2016 and 2019. However, a number of factors suggest that any growth in energy consumption will be small. Industry output growth has been strongest in the machinery and transport goods sub-sectors (not the most energy intensive industry sub-sectors); there has been a recent upturn in efficiency improvements between 2013 and 2015; and the increase in investment seen in 2016 and 2017 is likely to have continued to drive efficiency improvements. The increase in EU Emissions Trading System (ETS) prices in 2018 may drive further investment in energy efficient equipment.

An average increase of 0.2% per annum over the 2016-2020 period would add around 0.2% to 2016 EU final energy consumption by 2020.

In the medium-term, the outlook for industry energy consumption is for a return to the recent downward trend. Industry output growth rates are expected to moderate, putting downward pressure energy consumption and there are downside risks for the EU economy from Brexit and the potential for an escalation in tariffs on the international trading of goods. The medium-term structural shifts in the EU economy are difficult to

²⁸ Directive 2012/27/EU on Energy Efficiency <https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52013SC0447>

²⁹ Energy Efficiency 2017, International Energy Agency (2017), https://www.iea.org/publications/freepublications/publication/Energy_Efficiency_2017.pdf

predict, but a continuation of recent trends would also put downward pressure on energy consumption. Meanwhile, the continuing dispersion of energy management practices, allied with product efficiency improvements driven by Ecodesign regulations, higher ETS prices³⁰ and digital energy consumption analytics should enable efficiency gains to accelerate.

³⁰ See for example, <https://www.carbontracker.org/eu-carbon-prices-could-double-by-2021-and-quadruple-by-2030/>

4. RESIDENTIAL SECTOR

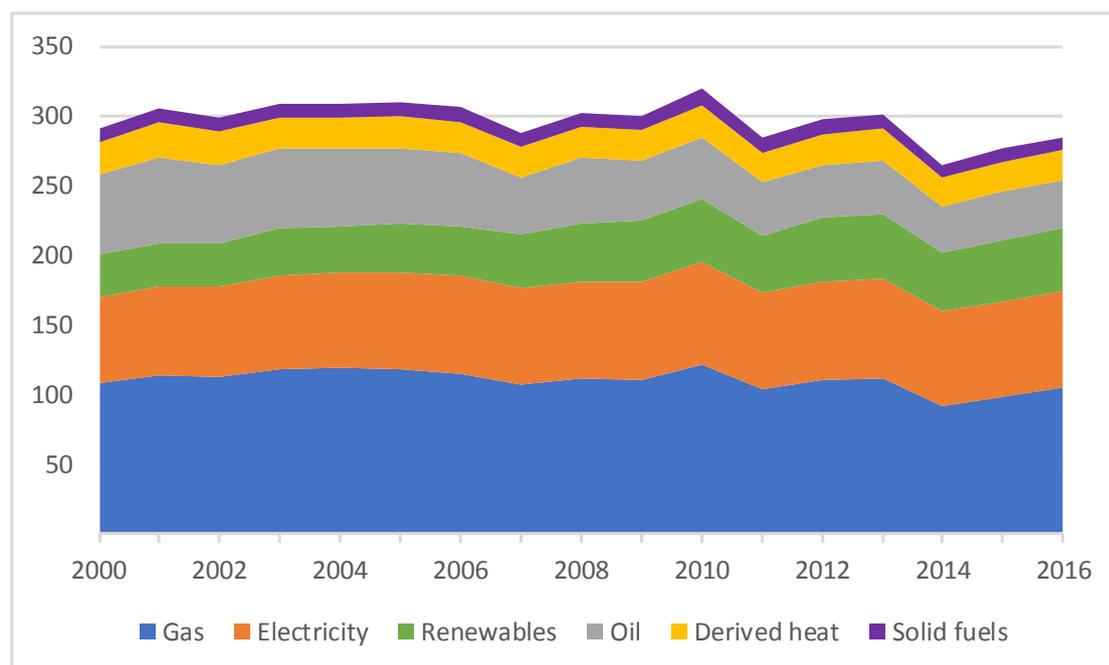
This section discusses recent trends affecting energy consumption in the residential sector and short-term future prospects. At the workshop, presentations from the NGO sector (Mariangiola Fabbri (BPIE)), research consultancy (Kees van de Leun (Ecofys) and René Kemna (VHK)), the public sector (Peter Bach, Danish Energy Agency) and the international research community (Willem Braat (IEA)), supplemented the European Commission's presentation of recent trends and JRC's decomposition analysis results. Discussion focussed on the extent to which recent trends were driven by changes in efficiency levels or by other factors, such as the weather.

The residential sector accounts for around 1/4 of EU final energy consumption. Consumption in the sector rose by 7.4% between 2014 and 2016 but was still 3.1% below the average for the previous decade.

4.1. Background

The residential sector has seen falls in energy consumption in recent years despite increases in population, floor area and energy service levels. Between 2008 and 2016 (two years with relatively similar winter weather conditions), energy consumption in the sector reduced by 5.7%. Since 2000, the share of oil has declined while renewables and electricity have increased. The fuel mix has remained fairly stable during the current decade, with year-to-year changes in weather conditions causing fluctuations in the amount of gas consumed in particular. In 2016, gas comprised 37% of residential energy consumption and electricity 24% (Figure 4.1).

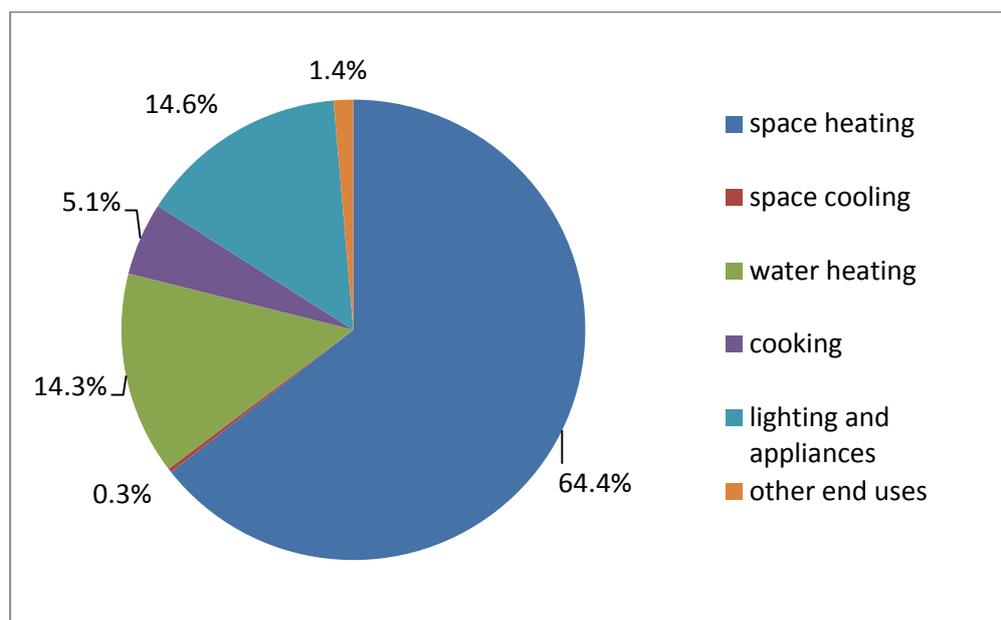
Figure 4.1: EU residential sector final energy consumption by fuel



Source: Eurostat Energy Balance May 2018, <http://ec.europa.eu/eurostat/documents/38154/4956218/ENERGY-BALANCES-May-2018-edition.zip/310265d9-6adf-45aa-ba41-2dce8e5f78eb>

Around two-thirds of EU residential energy consumption is used for space heating, making it by far the most important end-use in terms of overall energy consumption trends. Water heating comprises a further 14% and lighting and appliances 15% in total. Space cooling makes up only 0.3% of the sector's energy consumption (Figure 4.2).

Figure 4.2 EU residential sector energy consumption breakdown by end-use, 2016



Note: Estonia, Cyprus and Slovakia are missing from the total due to the derogation in implementing this data collection.

Source: Eurostat, reproduced from EU Commission workshop presentation.

4.2. Factors influencing residential sector energy consumption

Residential sector energy consumption is influenced by demography (population and dwelling growth); lifestyle factors, the most important of which, in the EU context, include the average amount of floor area per dwelling, rising appliance ownership and comfort taking (indoor temperatures and the extent to which dwellings are heated); the efficiency with which energy is used; and the weather.

4.2.1 Changes in demography

Annual changes in EU population are small, varying between 0.0% and 0.4% since 2000. Over time, this has upward pressure on energy consumption – there are 25 million more people living in the EU in 2018 than in 2000 - but since 2010, this driver has been fairly weak, and has softened between 2016 and 2018 (Figure 4.3). Beyond 2018, population growth is expected to weaken further, with growth of between 0.0% and 0.1% per annum forecast over the period to 2030³¹.

The stock of permanently occupied dwellings has increased at a slightly faster rate than population, rising at an annual rate of 0.5% since 2010 to reach 215 million dwellings in 2016³². This reflects the trend towards smaller households; since 2010 average household size has fallen from 2.4 to 2.3 people per household³³. The increased number

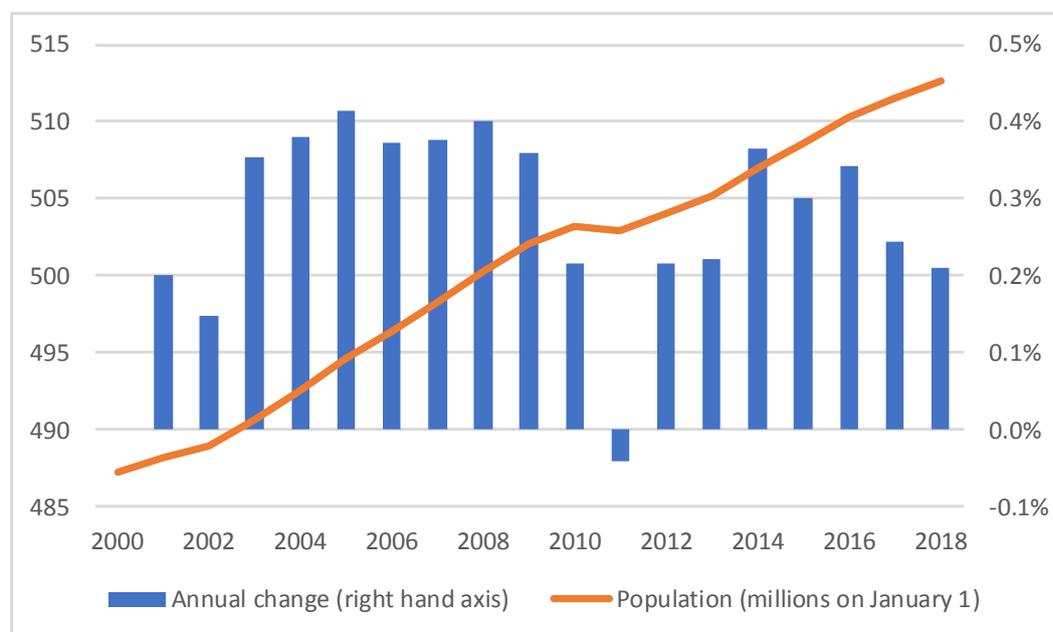
³¹ Population Estimates and Projections, World Bank Group, 2018, <https://datacatalog.worldbank.org/dataset/population-estimates-and-projections>

³² Odyssee Database, 2018, <https://odyssee.enerdata.net/database/>

³³ Eurostat (2018), http://ec.europa.eu/eurostat/web/products-datasets/-/ilc_lvph01

of dwellings put considerable upward pressure on energy consumption between 2000 and 2010. Decomposition analysis suggests that 2010 residential energy consumption would have been 8% lower without the growth in the number of dwellings. Since 2010, this effect has diminished somewhat; 2016 residential energy consumption would have been 3% lower without dwellings growth.³⁴ With lower population growth in future, this effect would be expected to moderate further.

Figure 4.3 EU population



Source: Eurostat Population change - Demographic balance and crude rates
<http://appsso.eurostat.ec.europa.eu/nui/setupDownloads.do?p=c47ee616-1c9d-42d0-8100-1fb8fb0372e7-1532345990258>

4.2.2 Changes in lifestyles

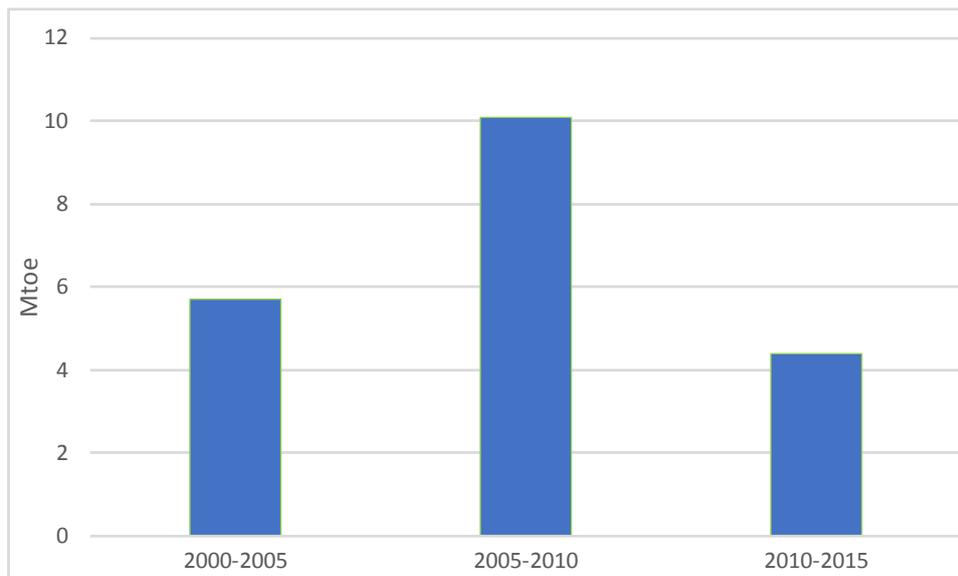
Since 2000, the average size of dwellings has tended to increase, putting upward pressure on energy consumption; decomposition analysis suggests that 2010 residential energy consumption would have been 5% lower without the growth in the size of dwellings³⁵. Since 2010, dwelling size has increased at a slower rate, exerting less upward pressure on residential energy consumption (Figure 4.4). In 2015, average floor area stood at 91.4 m², the same as in 2013 and 0.2% higher than in 2010. Between 2012 and 2015, the average size of dwellings fell in Portugal and Italy and increased at a rate of more than 1% per year in Romania, Latvia and Hungary.³⁶

³⁴ ODYSSEE decomposition analysis (2018), <http://www.indicators.odyssee-mure.eu/decomposition.html>

³⁵ Odyssee decomposition analysis, <http://www.indicators.odyssee-mure.eu/decomposition.html>

³⁶ Odyssee database, <https://odyssee.enerdata.net/database/>

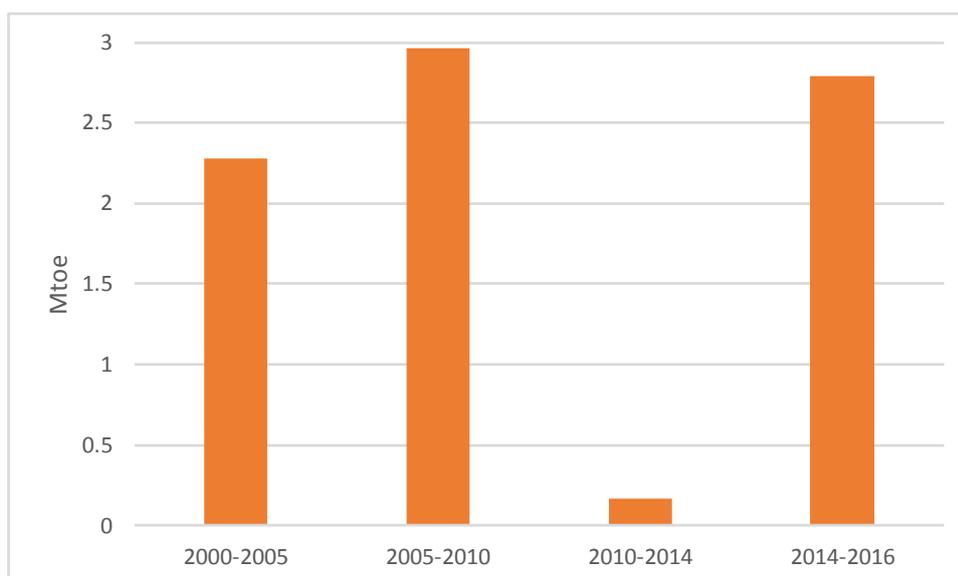
Figure 4.4 Impact on EU energy consumption of dwelling size effect



Source: ODYSSEE-MURE decomposition, <http://www.indicators.odyssee-mure.eu/decomposition.html>

The impact of increases in appliance ownership was also strongest in the period up to 2010, during which this factor added around 2.6 mtoe to energy consumption per annum. The 2011-2013 recession is likely to be responsible for the reduction in household purchases of consumer durables during the period 2014. Since 2014, however, the rate of increase in household appliance ownership has revived, putting upwards pressure on energy consumption (Figure 4.5).

Figure 4.5 Average annual impact on EU energy consumption of increases in appliance ownership

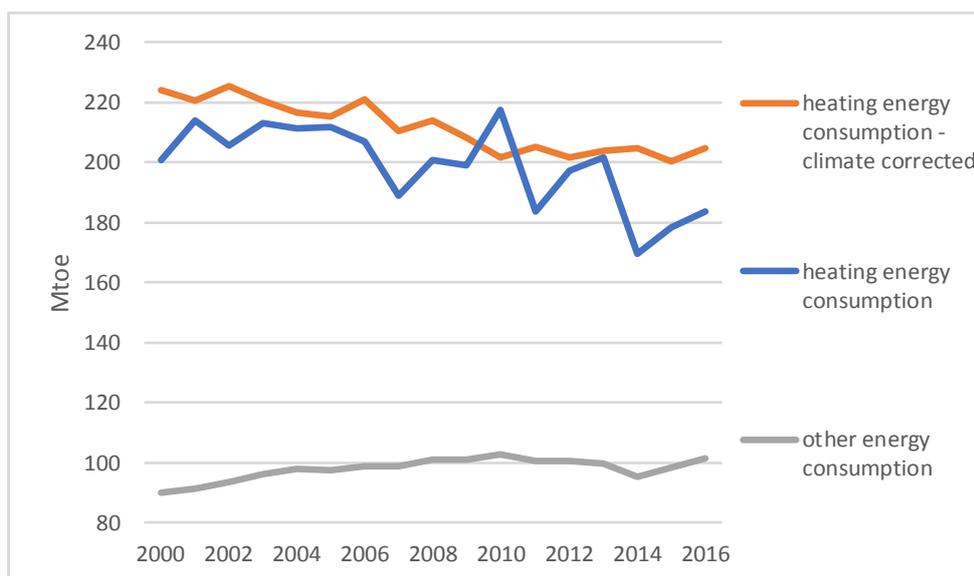


Source: ODYSSEE-MURE decomposition, <http://www.indicators.odyssee-mure.eu/decomposition.html>

4.2.3 Energy efficiency and comfort taking in the residential sector

The reduction in residential energy consumption since 2010 is largely owing to reductions in heating energy consumption and yet, since 2010, weather-corrected heating energy consumption has been fairly flat, following a decade during which this variable fell by around 10% (Figure 4.6).

Figure 4.6 EU residential heating energy consumption and other energy consumption



Source: Eurostat and Odyssee data supplied by European Commission.

Mariangiola Fabbri set out some of the key efficiency indicators for the residential sector. The amount of energy used per unit of floor area each year varies considerably across the EU, with some of the countries with the coldest climates (Denmark and Sweden) consuming considerably less than many other EU member states. The renovation rate across the EU is difficult to ascertain, with BPIE estimating it at around 1.2% per annum³⁷. Estimates in individual countries in 2014 put the major renovation rate at around 2.0% in France, 1.8% in Slovakia, and 1.5% in Germany and other countries at less than 1.2%; data however are scarce and it is not possible to tell whether the rate of renovation has been increasing or decreasing in recent years, or indeed the quality of the renovations undertaken.³⁸ A number of potential explanatory variables behind recent trends was raised. In addition to the weather (see section 4.2.4), the recovery from the economic crisis, the alleviation of some energy poverty with falling energy prices, shifts from the use of traditional biomass (which may not have been fully recorded in the data) towards gas central heating in some countries, higher efficiency in the heating equipment and increasing preferences for higher winter indoor temperatures were discussed. The pick-up in economic activity should also have some positive impacts on energy efficiency in the medium-term increasing both household investment levels and new construction rates. EU energy efficiency policies and energy performance regulation and financial instruments dedicated to house refurbishment and deep renovations have also been attributed an important role in addressing market barriers and in aggregating

³⁷ BPIE workshop presentation.

³⁸ Zebra 2020, <http://www.zebra-monitoring.enerdata.eu/overall-building-activities/equivalent-major-renovation-rate.html>

and upscaling funding. However, policies were discussed only in general terms and did not lend themselves to accurate data analysis with currently available tools.

The fall in climate-corrected heating energy consumption in the period to 2010 occurred despite increases in the number and size of dwellings. A number of factors may have influenced this trend and the subsequent levelling off in falls in consumption; these include changes in income levels, energy prices and improvements in energy efficiency (more efficient appliances and heating equipment, better insulated buildings). Changes in income are positively correlated with heating energy consumption, although the responsiveness of household energy consumption tends to be greater at lower levels of income, where there is more likely to be latent demand for heating energy services. While the responsiveness of residential energy consumption to income growth is not generally estimated to be large³⁹, it is noticeable that, over the period between 2000 and 2010, weather-corrected heating energy consumption fell at its fastest rate during the 2008-2010 period, when income growth slowed⁴⁰.

Changes in energy prices are negatively correlated with heating energy consumption. There is a wide range of estimates of the price elasticity of energy demand which show that energy goods are price inelastic in both the short and long-term, i.e. that energy consumption will fall by less than 1% in response to a 1% increase in energy prices. The response to changes in prices has been shown to be asymmetric to the extent that rising prices induce more purchases of thermal insulation products and more efficient heating equipment, which remain in place when prices fall.⁴¹ At the EU level, the fall in weather-corrected heating energy consumption between 2008 and 2010 was accompanied by a levelling off in the growth of household incomes during the economic crisis and volatile energy prices, both of which may have contributed to falling energy consumption (Figure 4.7).

Energy efficiency gains in space heating were particularly strong in the period to 2010 (or even 2012), according to decomposition analysis; between 2000 and 2012, the ODYSSEE decomposition tool identifies 73 Mtoe of energy savings, whereas between 2012 and 2016, it only finds 5 Mtoe of savings.⁴² The explanation for this apparent reduction in efficiency gains may lie in the combination of the pace and nature of refurbishment. René Kemna showed that the amount of boiler sales was 15-20% higher in mid-2000s than in the current decade, while the big gains in market share of condensing boilers occurred in the period 2009⁴³. As the stock of boilers become more

³⁹ The income elasticity of household energy demand tends to be small but positive – see for example, Krishnamurthy C. and Kriström (2013), Energy demand and income elasticity: a cross-country analysis, http://www.cere.se/documents/wp/2013/CERE_WP2013-5.pdf - although there can be significant variation across the energy expenditure distribution.

⁴⁰ Mean equivalised net income for the EU before the accession of Croatia (Eurostat, 2018), <http://appsso.eurostat.ec.europa.eu/nui/setupDownloads.do?p=8e732127-80a4-459d-8ec5-d0bcce87efc2-1532428498982>. Data for Croatia unavailable before 2010.

⁴¹ Boonekamp, P.G. (2007), "Price elasticities, policy measures and actual developments in household energy consumption – A bottom up analysis for the Netherlands", Energy Economics, Vol. 29, No. 2, Elsevier B.V., Amsterdam, pp. 133-157, <http://dx.doi.org/10.1016/j.eneco.2005.09.010>. <https://www.sciencedirect.com/science/article/pii/S0140988305000927>

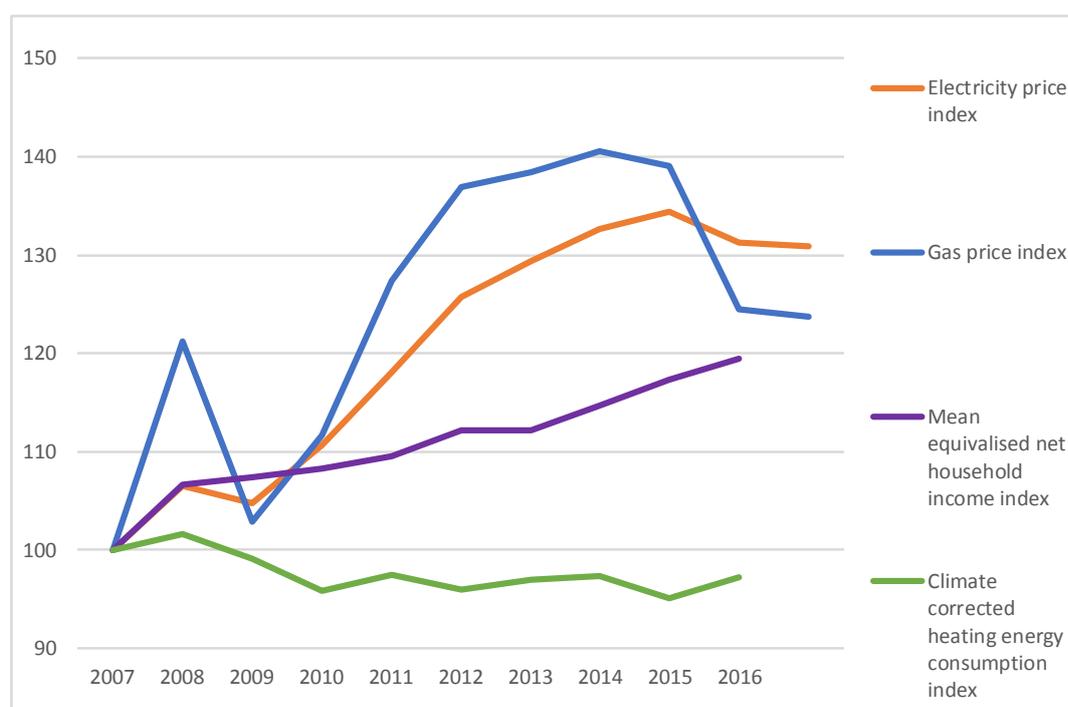
⁴² ODYSSEE decomposition analysis (2018), <http://www.indicators.odyssee-mure.eu/decomposition.html>

⁴³ René Kemna workshop presentation, referencing BRG (2017).

efficient, replacement boilers have less impact on the overall efficiency of the sector. Policy-driven improvements to the thermal efficiency of buildings may also have slowed down as the most cost-effective energy efficiency gains were exhausted through programmes such as energy utility obligations, which incentivise obligated parties to find the cheapest ways of meeting their regulated targets. This appears to have been the case in the United Kingdom, where the rate of cavity wall insulation installation peaked at 500 000 per year in 2012, the final year of the extension to the Carbon Emissions Reduction Target programme, leaving only around 1 million cavity walls that were both unfilled and not categorised as “easy to treat”. The successor programme targeted more expensive solid wall insulation and fuel poverty reduction, reducing space heating energy savings.⁴⁴

Between 2010 and 2013, income growth remained fairly subdued, while energy prices rose quickly; while between 2013 and 2016, income growth has picked up, while gas prices have fallen and electricity prices have levelled off. The relative stability of weather-corrected energy consumption during this period suggests that household incomes and energy prices have not been strong drivers of energy consumption at the aggregate level (Figure 4.7).

Figure 4.7 Indices of EU domestic gas and electricity prices, household income and weather-corrected residential heating energy consumption, 2007=100



Notes: Gas and electricity price indices include taxes and levies and are for the second half of each year and are available only from 2007. The household income index is for the EU before the accession of Croatia.

Sources: Eurostat and Odyssee heating energy data supplied by the European Commission; Eurostat electricity prices for household consumers, <http://appsso.eurostat.ec.europa.eu/nui/setupDownloads.do?p=ee9bdeda-cb58-4b84-8d1d->

⁴⁴ Energy Efficiency Market Report 2015, International Energy Agency (2015), <https://www.iea.org/publications/freepublications/publication/MediumTermEnergyefficiencyMarketReport2015.pdf>

bcfbaf61fec9-1532431555089 ; Eurostat gas prices for household consumers, <http://appsso.eurostat.ec.europa.eu/nui/setupDownloads.do?p=8e732127-80a4-459d-8ec5-d0bcce87efc2-1532428498982> ; and Eurostat Mean and Median income by household type, <http://appsso.eurostat.ec.europa.eu/nui/setupDownloads.do?p=8e732127-80a4-459d-8ec5-d0bcce87efc2-1532428498982>

At both the regional and individual country level, different trends for weather-corrected energy consumption emerge, but in most cases, most of the significant changes occurred prior to 2010, with more stable patterns appearing during the current decade. In the older member states of north-west and central Europe, which accounted for 60% of heating energy consumption in 2016, weather-corrected heating energy consumption fell on average by 18% between 2000 and 2010, since when it has remained at or around the same level. On the other hand, in the older member states of southern Europe, weather-corrected heating energy consumption increased by 23% between 2000 and 2009; in 2016, this measure of consumption stood 19% higher than in 2000 (Figure 4.8).

The older member states of northwest and central Europe were the main drivers of the fall in consumption during the period to 2010, with Germany (30%) and Belgium (24%) seeing the biggest percentage reductions amongst countries in this region. Between 2010 and 2016, only the Netherlands (10%) and Ireland (12%) have seen significant reductions in weather-corrected energy consumption while Austria has seen a 12% increase.

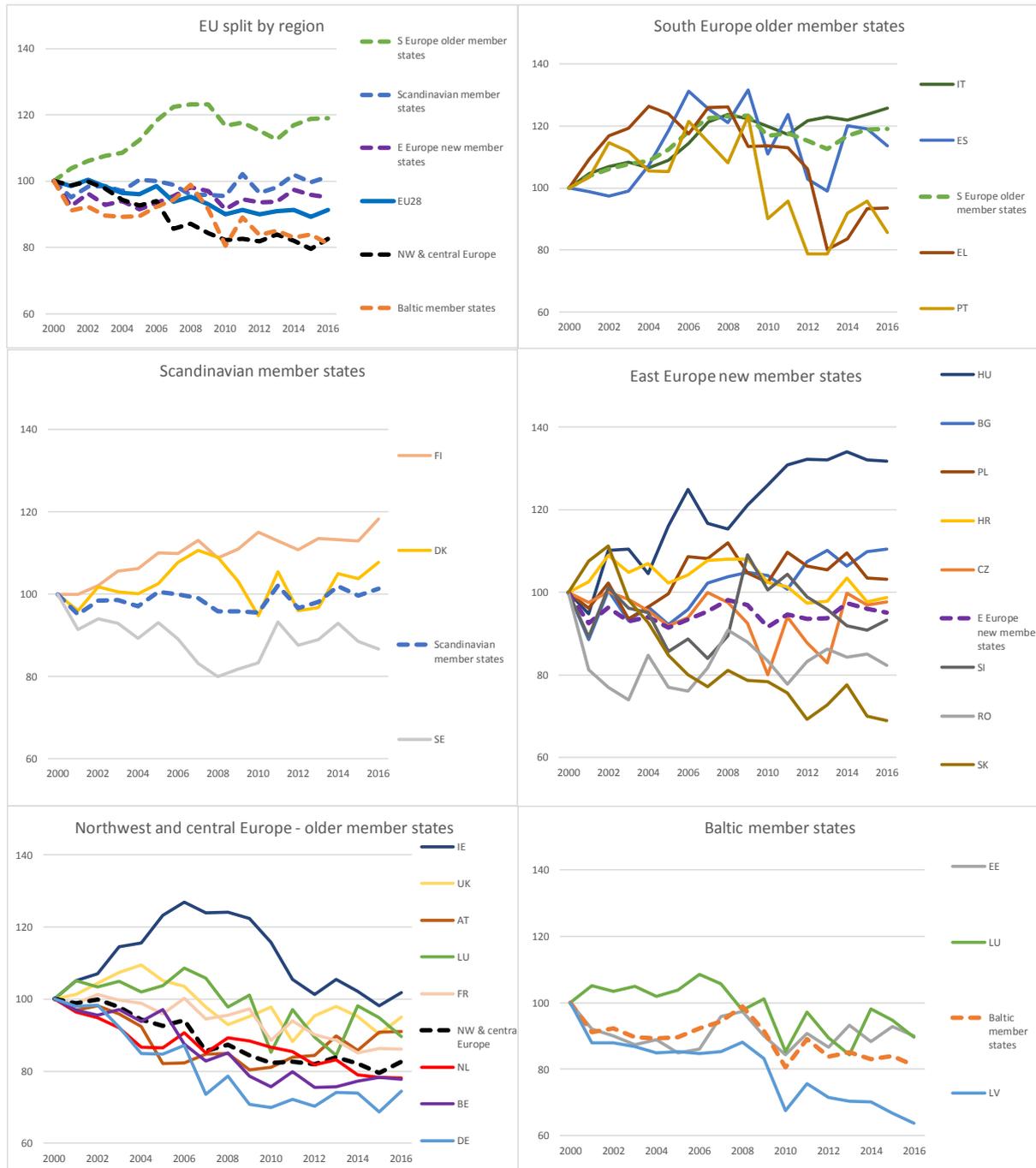
Germany consumes the most residential energy for heating in the EU. During the current decade it has had a comprehensive policy framework aimed at improving efficiency in the residential sector, including grants and loans administered through the KfW development bank, energy efficiency checks for low-income households and district level energy-related urban renewal grants. Investment in energy efficiency is thought to be considerably larger in Germany than any other European country.⁴⁵ In addition, the demographic and economic drivers for energy consumption growth in Germany (increases in dwellings and the sizes of homes and economic growth) were stronger in the decade to 2010 than in recent years

The strong reductions in weather-corrected heating energy consumption in Germany in the decade to 2010 appear to have been driven by the switch from the use of oil to other more efficient heat carriers, particularly natural gas and district heating. On the other hand, the use of non-renewable solid fuels (mostly coal) has remained low throughout the 2000-2016 period, at between 3.2% and 3.8% of residential sector total final consumption. The shift away from oil slowed down after 2010, and this is a likely explanation for the flat trend in weather-corrected heating energy consumption in the current decade (Figure 4.9). Across the EU as a whole, the major shift away from oil for heating also occurred in the period to 2010. This trend is supported to some extent by data on boiler unit sales in the EU. René Kemna showed that annual sales peaked at 7.2 million in 2006, declining to 6.3 million per year in 2010; during the current decade, sales have been fairly flat, varying between 5.8 million and 6.2 million per year (Source: BRG, 2017). The changing market segmentation of the boiler market also backs up the different composition of residential heating systems in the current decade, compared to the previous decade; between 2004 and 2014, the amount of replacement boiler sales increased by 12% while sales to first-time users fell by 73% and sales for new dwellings decreased by 46%, underlining the reduction in construction activity in the current decade. He also pointed out that, although the switch to more efficient condensing boilers had happened by 2014, and the space and water heating Ecodesign regulations

⁴⁵ Energy Efficiency 2017, International Energy Agency (2017), https://www.iea.org/publications/freepublications/publication/Energy_Efficiency_2017.pdf

had come into force in late 2013⁴⁶, inefficient non-condensing boilers still represented 1/4 of sales for both first time installation and replacements in 2014. On the other hand, in new buildings, gas condensing boilers and heat pumps represented 64% and 18% of sales respectively.

Figure 4.8 EU weather-corrected heating energy consumption by region and member state



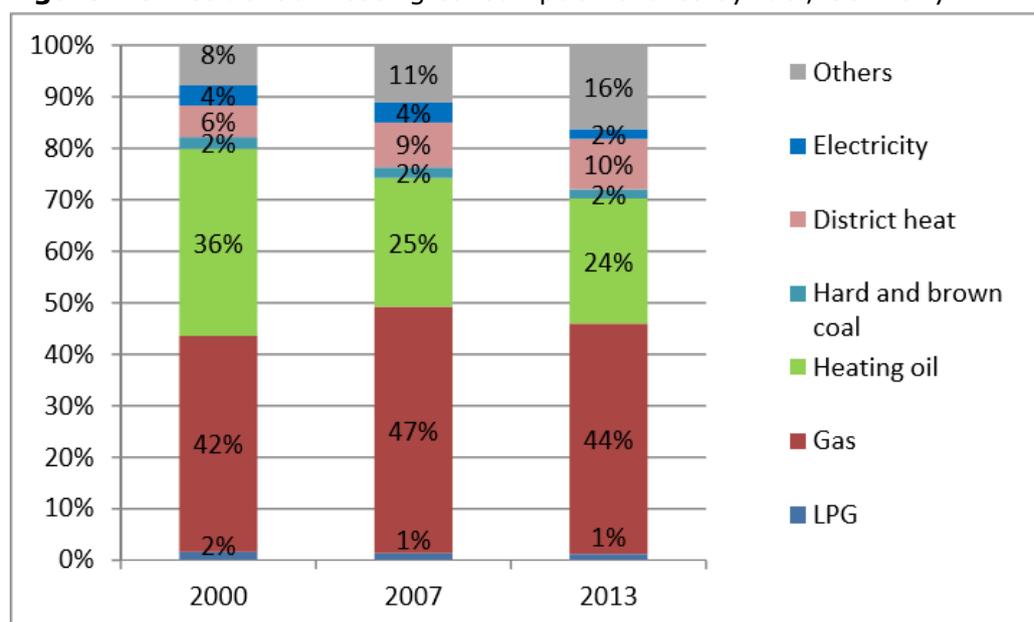
⁴⁶ European Commission (2018), <https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficient-products/heaters>

Note: Cyprus and Malta are not included in these charts. These countries have very low levels of annual weather-corrected residential space heating energy consumption (0.11 Mtoe and 0.02 Mtoe respectively in 2016), although both countries have seen increases since 2000 (61% and 97% respectively).

Source: Eurostat and Odyssee data supplied by the European Commission.

Meanwhile, the lack of comprehensive data on renovation rates makes it difficult to draw firm conclusions on the effectiveness of policy in driving down energy consumption for residential heating, however it would appear that, for the underlying, weather-corrected trend in heating consumption to fall in the future, an increase in both new build rates and renovation rates, allied to a move towards more efficient heat sources, would be needed, both in Germany and elsewhere in the EU.

Figure 4.9 Residential heating consumption shares by fuel, Germany



Source: Odyssee-MURE database

Kees van der Leun explained the situation for residential heating in the Netherlands, where natural gas is the dominant heat source (97% of consumption). The Netherlands is aiming for 100% renewable heating by 2050, potentially through the use of heat pumps and renewable biogas during winter peaks, when the wind is not blowing. The shift to heat pumps would need to be accompanied by major improvements in insulation, given the low temperatures in these types of heating systems. He explained that, in order to meet energy and climate targets, the Netherlands needed to ramp up its renovation rate quickly and that new programmes were currently being put in place to drastically increase the renovation rate from around 2 000 homes per year now to between 30 000 and 50 000 per year by 2021. If these types of programmes are instituted across Europe in response to the need to meet climate targets, energy consumption in the residential sector should decline in the medium-term.

In the older member states of southern Europe, which accounted for 17% of EU heating consumption in 2016, increases in the number of dwellings put strong upward pressure on heating energy consumption in the period to 2010, as did the rise in the number of central heating systems in Italy. Since 2010, the penetration of central heating systems has slowed down considerably and the impact of adverse economic conditions during the 2010-2015 period is most likely a strong driver of the big reduction in the growth of new dwellings and possible reductions in comfort taking. In the short-term, a return to more

favourable economic conditions may lead to increases in weather-corrected heating energy consumption in these countries, although this may be offset by more ambitious policies aimed at meeting energy and climate targets in the medium-term.

In the EU's new member states, trends are more difficult to discern. In the Baltic countries, which accounted for 1% of EU heating energy consumption in 2016, weather-corrected heating energy consumption has fallen since 2000, again with most progress occurring by 2010. Amongst all EU countries, the fall in weather-corrected heating energy consumption has been strongest in Latvia. The big fall in consumption occurred here between 2009 and 2010, when a 16% fall in household incomes was accompanied by a 12% increase in the HDD (Heating Degree Days) metric. Since 2010, however, following a rebound in 2011, weather-corrected energy consumption has continued to fall over the period to 2016. After Spain, Latvia has the largest proportion of its population living in multi-family buildings;⁴⁷ more research into policies that have driven energy consumption reductions in the Latvian context might be useful for other EU member countries with similar building stock characteristics.

Amongst the other new EU member states in eastern Europe, which consumed 17% of EU residential heating energy in 2016, the amount of weather-corrected heating energy consumption has remained fairly constant. However, considerable diversity in trends between countries can be observed. Slovakia has made considerable progress in reducing its weather-corrected heating energy consumption; most of the reductions occurred in the period between 2000 and 2007, however since 2007, it has continued to make progress at a faster rate than any other country in the region. Slovakia has been held up as a leading country in the field of the large-scale renovation of multi-family residential buildings and useful learnings could be spread to other countries facing similar issues with their building stocks.⁴⁸ Amongst some eastern European member states, the move away from traditional biomass to other forms of heating may have led to more recording of energy consumption, understating progress in reducing energy use; more work would be needed to understand whether this is an issue and whether it is moderating over time. Overall, a continuation of recent trends would lead to flat weather-corrected heating consumption; in the medium-term, a fall in consumption might be expected, as countries aim to meet climate targets.

In Scandinavian EU member states, which consume 6% of EU residential heating energy, have seen fairly flat weather-corrected energy consumption since 2000, with reductions in Sweden offset by increases in Finland and Denmark. It should be noted that Scandinavian homes are the most efficient in the EU,⁴⁹ however, recent increases are worrying for policy makers. Peter Bach highlighted the recent increases in residential sector energy consumption in Denmark, explaining that the reasons for the increase were unknown, with behavioural shifts, perhaps towards warmer indoor temperatures being one potential explanation. However, more work would need to be done in this area before conclusions could be drawn.

Outside of space heating, lighting and appliance energy consumption constitutes the largest energy use in the residential sector, representing 14.6% in 2016 (Figure 4.2).

⁴⁷ State of the building stock briefing, BPIE (2017), http://bpie.eu/wp-content/uploads/2017/12/State-of-the-building-stock-briefing_Dic6.pdf

⁴⁸ See for example, REELIH (2016), <https://getwarmhomes.org/case-study-residential-energy-efficient-renovations-subsidies-in-slovakia/>

⁴⁹ Monitoring of energy efficiency trends and policies in the EU, ODYSSEE-MURE (2015), <http://www.odyssee-mure.eu/publications/br/synthesis-energy-efficiency-trends-policies.pdf>

Energy consumption for uses other than space heating increased in the EU in the period to 2010, declined between 2010 and 2014 and has been rising again since 2014. In 2016, EU residential energy consumption for uses other than space heating reached a level only previously exceeded in 2010 (Figure 4.6).

The increase in energy consumption since 2014 does not appear to be driven by the consumption of large household appliances. The increase in the number of large appliances (fridges, freezers, dishwashers, washing machines and dryers) was strong between 2000 and 2010 but has not re-emerged as an important factor since 2014.⁵⁰ Meanwhile, the efficiency of large appliances has continued to improve, and the recent pick-up in consumers spending should have sped up the turnover of the stock of large appliances, improving efficiency levels.

René Kemna set out some trends in appliance efficiency, showing the household fridge energy consumption had fallen at a fairly linear rate between 2002 and 2016. Consumption was lower than projected in impact assessments but could have been even lower had consumer spending been higher during the current decade of economic underperformance. He also pointed out the increased significance of appliance energy consumption trends to overall energy consumption when it is expressed in primary energy terms, given the relative inefficiency of the current electricity generation mix.

Amongst other appliances, René Kemna set out the large historic and future energy efficiency gains per unit of screen area in the television and monitor end-use category, driven to a large extent by Ecodesign measures. However, the huge growth in screen area, particularly in electronic display signage, has meant that energy consumption has increased since 2010. The energy consumption from signage is projected to grow substantially to 2020, accounting for around 25 TWh per annum, most of which will be attributed to the services sector.

René Kemna also set out lighting energy consumption trends, showing that the consumption of products within the scope of Ecodesign measures had been relatively flat since 2009 and should decline over the next decade, with most of the savings expected outside of the residential sector.

With the energy consumption of large appliances and lighting declining, the relative importance of smaller appliances to residential (and service sector) energy consumption is increasing. These devices and equipment – e.g. computers, coffee makers, phone chargers, home security systems, escalators – do not consume large amounts of energy individually, but in aggregate they are becoming more important as the number of electricity-using products increases and their functionality expands. Both large and small appliances (including lighting) are now being sold with the capability to be connected (the “Internet of Things”), meaning that they are both performing more functions and, at least to some extent, “always on”, drawing additional power to ensure that they are able to communicate with other devices on the network. The extent to which new functionality will enable more energy savings, as a result of the ability to use interconnected devices as part of a smart system, to offset the increases in energy consumption required to power them is a matter of debate.⁵¹ The US Department of Energy estimates that primary energy consumption from “miscellaneous plug loads” will increase will increase by 13% between 2016 and 2030 in the United States and by

⁵⁰ ODYSSEE decomposition (2018), <http://www.odyssee-mure.eu/publications/br/synthesis-energy-efficiency-trends-policies.pdf>

⁵¹ Connected Devices Alliance, 4E TCP (2018), <https://cda.iea-4e.org/about-the-g20>

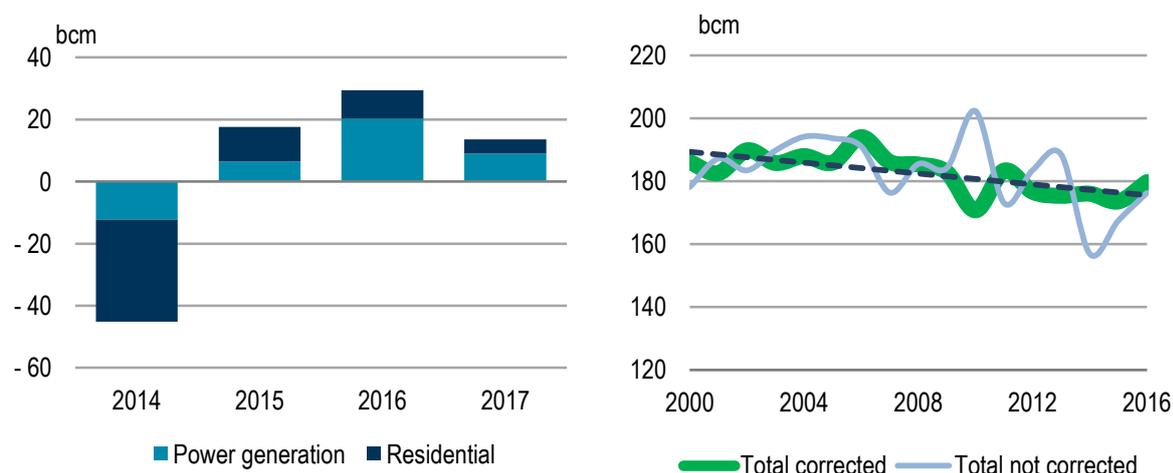
double that amount in the services sector.⁵² A similar increase in the EU would put upwards pressure on energy consumption and may be behind the uptick in energy consumption in non-heating energy consumption between 2014 and 2016.

4.2.4 The weather

Willem Braat presented recent gas market trends that showed pre-crisis growth between 2000 and 2008, declines between 2010 and 2014, to levels below 2000, and increases again between 2014 and 2017. Residential gas demand accounts for around 40% of total gas demand, with power generation taking 30% and industry 25%. Given that in 2016, gas consumption represented 37% of all residential consumption (to which the amount consumed indirectly through electricity use can be added) and 43% of heating consumption, trends in gas are important to analyse to understand drivers of consumption. He showed that weather-corrected residential gas demand had declined over time, with the rate of decline driven by demand falls in northwest Europe, offset to some extent by rises in south Europe. Actual residential gas demand had varied considerably over the current decade, owing to the weather. 2010 had the coldest winter temperatures over the period since 2000 and gas demand peaked during this year. A relatively mild 2011 was followed by another relatively cold winter in 2012, while 2014 had the mildest winter temperatures in the last 40 years, causing gas demand to fall dramatically. In this context, the increase in demand between 2014 and 2017 should be seen as a return to trend following the abnormally low consumption seen in 2014 (Figure 4.10).

2016 and 2017 were fairly average years for heating degree days over the last decade, although they were relatively warm years compared to the 25-year average often used to weather-correct heating energy consumption data, perhaps as a result of broader climate change trends (Figure 4.11).

Figure 4.10 Changes in EU gas demand (left hand graph) and EU residential gas demand (right hand graph)

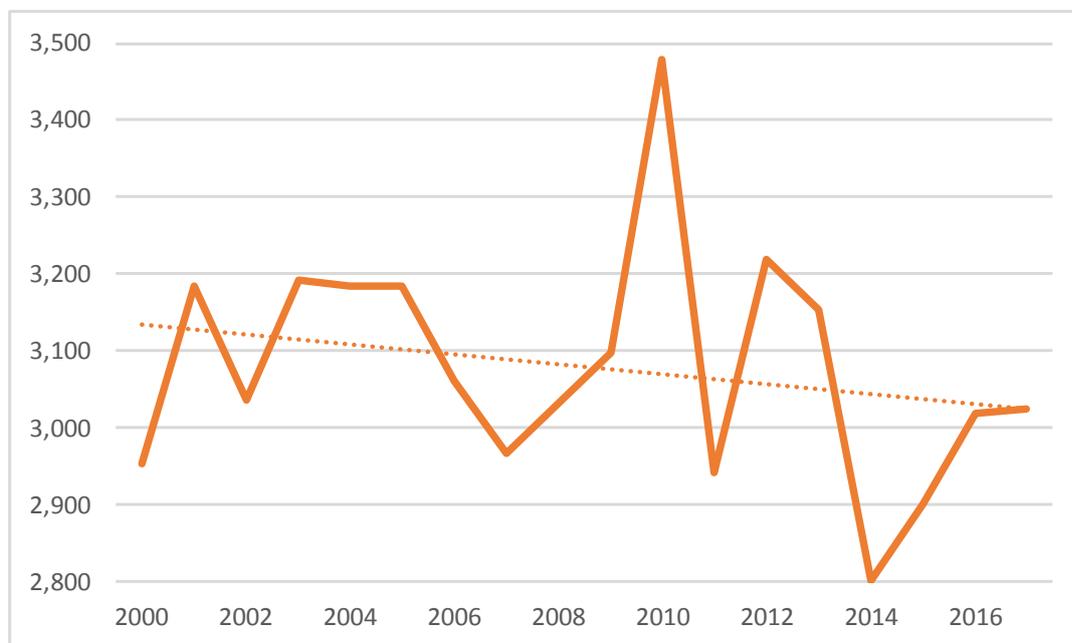


Source: IEA (2018) from workshop presentation by Willem Braat.

⁵² Annual Energy Outlook 2015 with projections to 2040, US Department of Energy (2015), [http://www.eia.gov/forecasts/aeo/pdf/0383\(2015\).pdf](http://www.eia.gov/forecasts/aeo/pdf/0383(2015).pdf)

While 2016 and 2017 look to be fairly average years for winter temperatures, the wide variation in possible temperatures between years means that the residential heating energy consumption seen in 2016 (184 mtoe) could be significantly higher, as in 2010 (217 mtoe), or lower, as in 2014 (170 mtoe). This type of variation puts into context the importance of the weather for year-to-year variations. Between 2000 and 2016, weather-corrected heating energy consumption fell by 20 mtoe in total.

Figure 4.11 EU cooling and heating degree days and linear trend



Source: Eurostat data supplied by the European Commission

At the workshop there was also some discussion around the extent to which heating energy consumption and the impact of the weather on it was adequately captured using the current data framework. Heating degree days were thought to be the best predictor of heating demand but need to be examined alongside other metrics. For example, the spike in HDDs in 2010 did not lead to a commensurate increase in energy consumption, in part because of the state of the economic cycle, with depressed income levels in many member states.

There may also be some non-linear effects that are not captured by the HDD metric, with either equipment not being able to respond to indoor temperature demands or people accepting lower temperatures in exceptional circumstances. Nevertheless, a simple linear approach is probably the best way of approaching the calculation of the HDD metric given the need for it to be easily understood. Other concerns were raised by workshop participants about the quality of the heating data themselves, with national methodologies varying and, according to one workshop participant, heating data being calculated on the basis of heating degree days data.

It was also pointed out that examining weather data at a finer degree of temporal disaggregation could be helpful in identifying energy efficiency improvements, for example in assessing how the demand for energy evolves at particularly cold temperatures.

4.3. Prospects for residential sector energy consumption

In the short-term, residential energy consumption looks set to remain fairly stable, or even slightly increase. The trend in weather-corrected heating energy consumption has been flat since 2010, with the falls and increases in actual heating energy consumption since 2010 since 2014 owing to the weather. Similar winter conditions to 2016 over the next four years would be expected to lead to similar amounts of heating energy consumption. However, based on recent highs and lows, variations in winter temperatures means that actual heating energy consumption could be 9% lower or 18% higher. Non-heating residential energy consumption increased at a rate of 3.0% per annum between 2014 and 2016, following a period of decline between 2010 and 2014. Part of the increase can most likely be explained by the subsequent economic recovery, which continued in 2017 and is expected to soften somewhat into 2018 and 2019. Consumer spending is expected to reduce somewhat towards the end of the decade, suggesting a moderation in the increase in miscellaneous plug load from new electronic devices that may be causing the increase in energy consumption. The outlook is highly uncertain but would likely see a moderate increase in non-heating residential energy consumption.

An average increase of 0.5% per annum over the 2016-2020 period would add around 0.5% to 2016 EU final energy consumption by 2020. However, variations in winter temperatures could mean that, instead, the residential sector could reduce EU final energy consumption in 2020 by 1.0% (a 2014 winter) or add 3.5% to it (a 2010 winter).

In the medium-term, the underlying trend in residential energy consumption should decline as countries put in place policies to decarbonise heat using more efficient electrically powered heat pumps and increase the building renovation rate. Some impacts from these policies may be felt in the coming years. Improvements in the quality of building fabrics would also lessen the impact of winter weather on energy consumption. A continuation in the reduction in the average number of cooling and heating degree days should also reduce energy consumption in the medium-term, although an increasing number of cooling days would be expected to lead to an increase in the demand for space cooling, which in 2016 accounted for only 0.5% of EU residential energy consumption.

5. SERVICES SECTOR

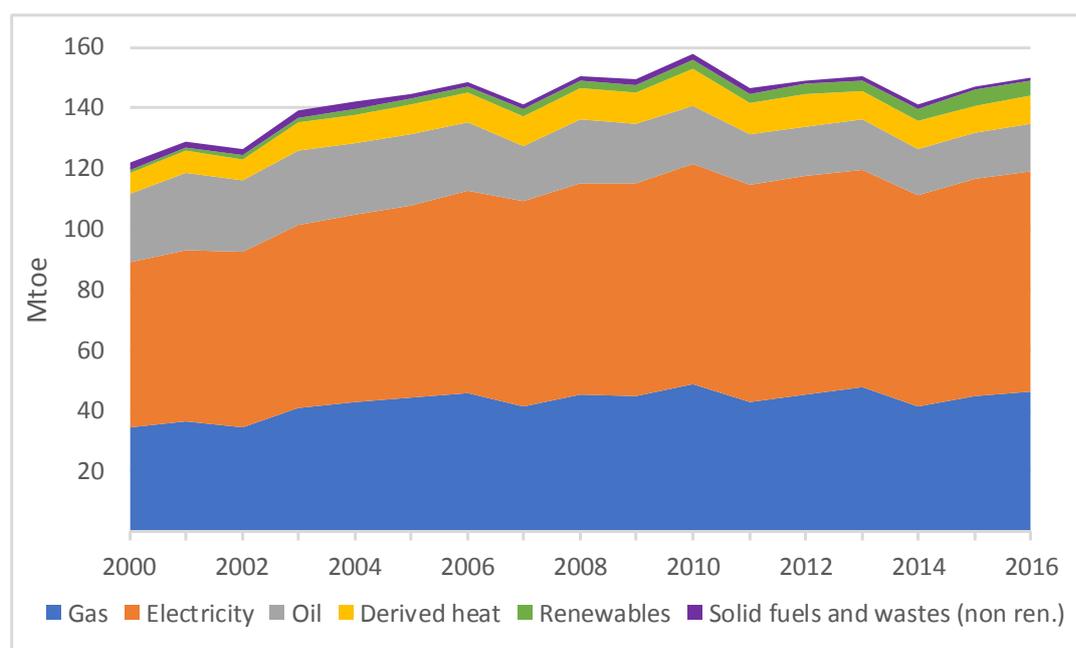
This section discusses recent trends affecting energy consumption in the services sector and short-term future prospects. At the workshop, presentations from academia (Wolfgang Eichhammer, University of Utrecht), the public sector (Jim Scheer (Sustainable Energy Authority of Ireland)) and the European research community (Paolo Bertoldi, Joint Research Centre, EU Commission) provided different perspectives, supplementing the European Commission's presentation of recent trends. Discussion covered both recent developments and issues associated with the availability of data.

The services sector accounts for around 1/6 of EU final energy consumption, making it the smallest end-use sector in this analysis. Consumption in the sector grew by 6.4% between 2014 and 2016

5.1. Background

Since 2006, final energy consumption in the EU services sector⁵³ has varied between 141 Mtoe (2014) and 158 Mtoe (2010). Consumption rose between 2014 and 2016 and sat just above the decadal average at 150 Mtoe in 2016. Electricity (48.5%) and natural gas (30.8%) comprised the majority of service sector final energy consumption in 2016. Between 2006 and 2015, the use of oil products fell steadily, from 15.0% of the sector's final energy consumption 10.4% (Figure 5.1).

Figure 5.1: EU 28 services sector final energy consumption by fuel type

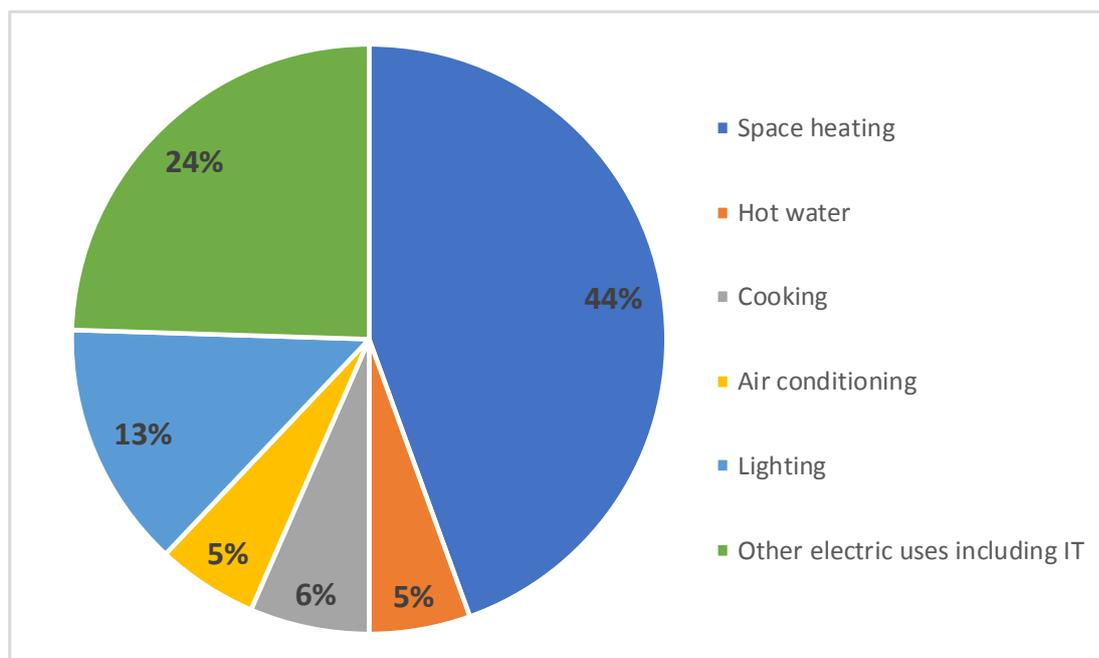


Source: Eurostat Energy Balance May 2018, <http://ec.europa.eu/eurostat/documents/38154/4956218/ENERGY-BALANCES-May-2018-edition.zip/310265d9-6adf-45aa-ba41-2dce8e5f78eb>

⁵³ In the Eurostat Energy Balances, the services sector covers all commercial and public sector final energy consumption (FEC) outside of the industry sector (including mining and quarrying, and construction), the transport sector, the residential sector, the agriculture and forestry sector (2.2% of 2016 FEC), the fisheries sector (0.1%) and non-specified energy consumption (0.3%). As such the services sector includes office blocks, schools, hospitals, hotels, retail outlets, shops etc.

Space heating uses the largest proportion of the services sector’s energy consumption (estimated at 44% in 2015), followed by the category of “other electric uses”, which includes IT and all other end-uses except lighting, air conditioning, cooking and hot water (Figure 5.2). It was pointed out that statistics might underestimate space heating loads in the services sector (as well in the industry sector) and that the ongoing work by Eurostat to provide energy end-use statistics would be a useful step towards a better understanding of energy consumption patterns in services.

Figure 5.2: EU 28 services sector final energy consumption by end-use (2015)



Source: Odyssee-Mure, www.odyssee-mure.eu (reproduced from workshop presentation by Wolfgang Eichhammer)

5.2. Factors influencing services sector energy consumption

Services sector energy consumption is influenced by activity levels within the sector; the efficiency with which energy is used; and the weather. Data availability restricts the depth of analysis that can be undertaken; time series data by services sub-sector are not available, meaning that structural changes within the sector cannot be adequately observed, with the sector treated as a whole in most analysis.

5.2.1 Changes in services sector activity levels

Service sector activity levels have outstripped the rest of the EU economy since 2005. Services sector GVA rose by 16.7% between 2005 and 2016 while GDP rose by 12.6% over the same period. At the same time, final energy consumption has changed very little. This highlights the energy extensive nature of service provision and the relatively weak relationship between economic output and energy consumption, when compared to the industry sector or the freight transport sub-sector, for example. Nevertheless, there is a positive correlation between services sector energy consumption and the economic strength of the sector.

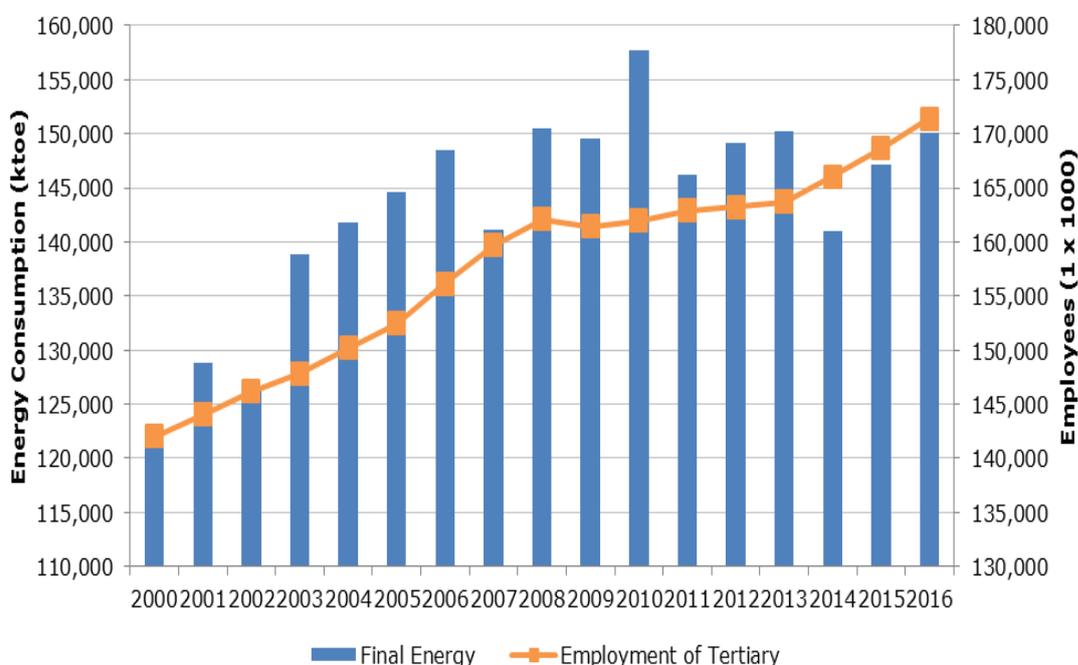
Paolo Bertoldi highlighted the importance of employment as an economic indicator, given the proportion of the sector’s energy consumption devoted to space heating. The relationship between rising employment and energy consumption in the services (or tertiary) sector is relatively strong, with energy consumption rising during the period of

relatively strong employment growth to 2008 and again in the period since 2014 (Figure 5.3).

Jim Scheer also used employment as the denominator for indicators of commercial and public services sector energy efficiency, highlighting the lack of data on floor area. In Ireland, employment in the sector rose by 14% between 2005 and 2016 while energy consumption fell by 13%. As at the EU level, energy consumption has been rising since 2014, following a period of falling demand from the pre-crisis peak in 2008.

Participants at the workshop discussed the extent to which the increase in services sector energy consumption since 2000 might be a result of catch-up in the EU’s new member states. Paolo Bertoldi showed that, at least in the case of natural gas consumption, this was not the case. Since 2000, services sector gas consumption has risen by 39% in the older member states (EU 15) and by only 11% in the newer member states (EU13) (Figure 5.4).

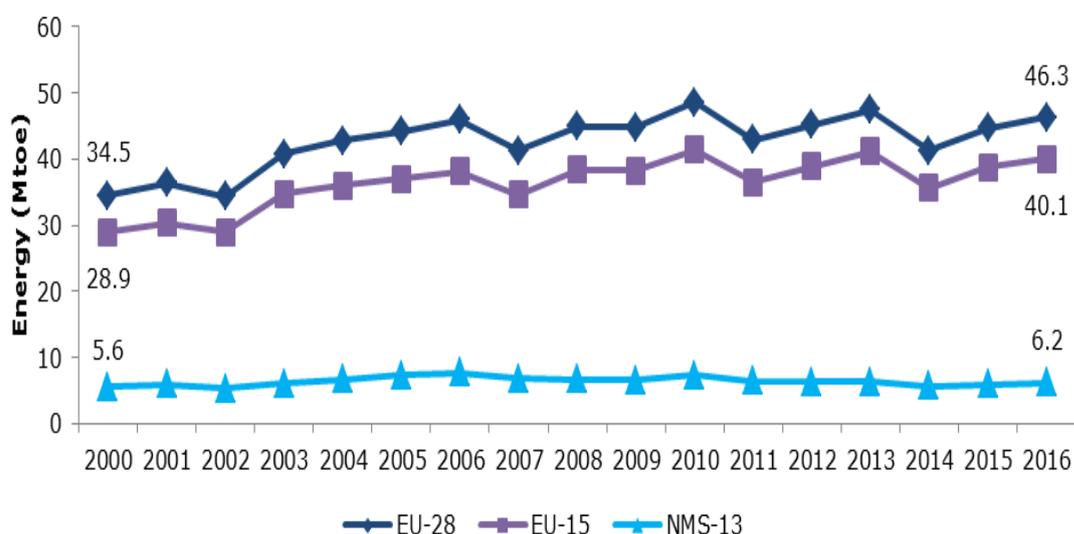
Figure 5.3 EU tertiary sector final energy consumption and employment



Source: Workshop presentation by Paolo Bertoldi (JRC).

Wolfgang Eichhammer pointed out that the long-term prospects for the EU are not for rapid economic growth, and that the area is currently enjoying “above-potential” growth rates as it recovers from the 2011-2013 recession. These growth rates are likely to moderate over time and future economic downturns will also occur. In terms of medium-term projections, not too much weight should be given to the current two years of rising energy consumption data. However, in the short-term, the EU economy does appear to be set for a continuation of relatively strong growth (2.3% in 2018 and 2.0 in 2019), following the expansion of 2.5% in 2017 (EU Commission, 2018). These growth prospects are in part a result of continued, but reducing, slack in EU labour markets. Continued growth in employment the EU services sector would suggest growth in energy consumption, all other things being equal.

Figure 5.4 EU tertiary sector gas consumption



Source: Workshop presentation by Paolo Bertoldi (JRC).

5.2.2 Energy efficiency of end-uses in the services sector

Discussion at the workshop focussed on the data issues that restrict in-depth analysis of efficiency trends. There are no regular and frequent studies of end-use energy consumption at sub-sector level.

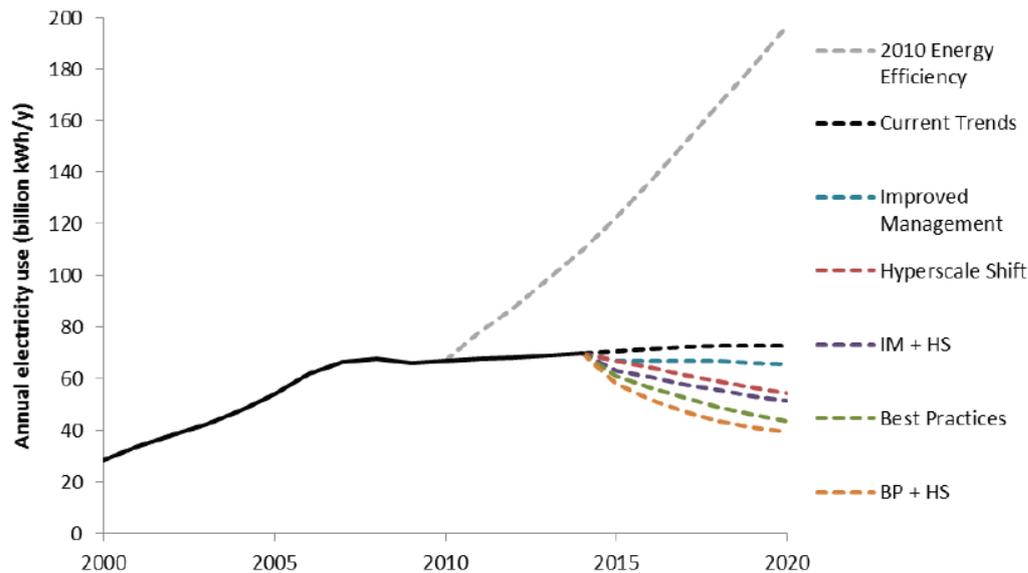
At the whole sector level, Wolfgang Eichhammer presented decomposition analysis from the Odyssee-Mure database, using sector GVA as the measure of activity. This showed that, in the period between 2000 and 2008, the activity effect (rising GVA) was not offset at all by the combination of factors that improve the ratio of output (GVA) to energy consumption, such as energy savings associated with more efficient equipment, wider productivity gains or shifts in economic activity between services sub-sectors. Between 2008 and 2015, however, the more modest increase in activity was more than doubly offset by this combination of factors. While this analysis provides some suggestion that future increases in sector GVA might be associated with moderate increases, or even falls in sector energy consumption, the lack of granularity in the data makes it difficult to mount a strong case for such an outcome. Wolfgang suggested that the impact of building regulations may have played a role here, with the demand for heating remaining flat while activity levels rose.

Amongst the other end-uses, information technology (IT) was the subject of considerable discussion at the workshop, with data centres being the main focus of debate. Increases in the number and size of data centres might be expected to push up energy consumption in some of the EU's member states with cooler climates and cheaper electricity. At the same time, cloud computing reduces the need for dispersed, and most likely less efficient computer processing in both other parts of the services sector and other energy using sectors. However, the increase in data centre activity will not necessarily have led to a large direct increase in energy consumption. Paolo Bertoldi presented evidence from the United States that showed that, without efficiency gains, US data centre energy consumption would have been around 75% higher in 2014 than it had been in 2010; instead, energy consumption had only grown by 4% (Figure 5.5).

Paolo Bertoldi also presented data centre efficiency trends for the EU, which showed that the average power usage effectiveness (PUE) of data centres - the energy efficiency of their computing equipment, as opposed to other energy uses, such as cooling - had improved by around 12% between 2016 and 2009, although the range of observed PUE

ratings had remained wide, suggesting room for further efficiency gains across the sector. Paolo also presented information and communications technology (ICT) data from Sweden that showed that, while data centres, access networks and other end-uses related to network connectivity had seen increases in energy consumption over the period from 2010 to 2015, these were offset by the decreases in energy consumption from personal computers, tablets and other consumer electronics. As digitalisation continues to affect sectors across the EU economy, these benign trends for ICT energy consumption suggest that the sub-sector will not put upwards pressure on overall energy consumption.

Figure 5.5: Data centre energy consumption in the United States



Source: Shehabi, A., Smith, S.J., Horner, N., Azevedo, I., Brown, R., Koomey, J., Masanet, E., Sartor, D., Herrlin, M., Lintner, W. (2016). United States Data Center Energy Usage Report. Lawrence Berkeley National Laboratory, Berkeley, California. LBNL-1005775 (2016), https://datacenters.lbl.gov/sites/default/files/DataCenterEnergyReport2016_0.pdf

Jim Scheer presented a case study from Ireland on how to improve the data available on energy efficiency levels in the public sector through the implementation of mandatory measurement and reporting for 350 public bodies and 3 735 schools, linked to energy saving targets. This showed the value of the collection and use of annual data at a granular level, something which is lacking in the services sector more generally. The combination of good quality data and reporting led to more action being taken on energy efficiency, as public sector leaders were able to take ownership and responsibility for the energy consumption of their organisations.⁵⁴

5.2.3 The weather

With an estimated 44% of the services sector’s energy consumption used for space heating, winter temperatures can have a large year-to-year impact on the overall consumption of the sector. Paolo Bertoldi presented data showing the relationship between heating degree days and energy consumption per employee, which showed that the impact of the increase in service sector employment since 2014 (Figure 5.3) has

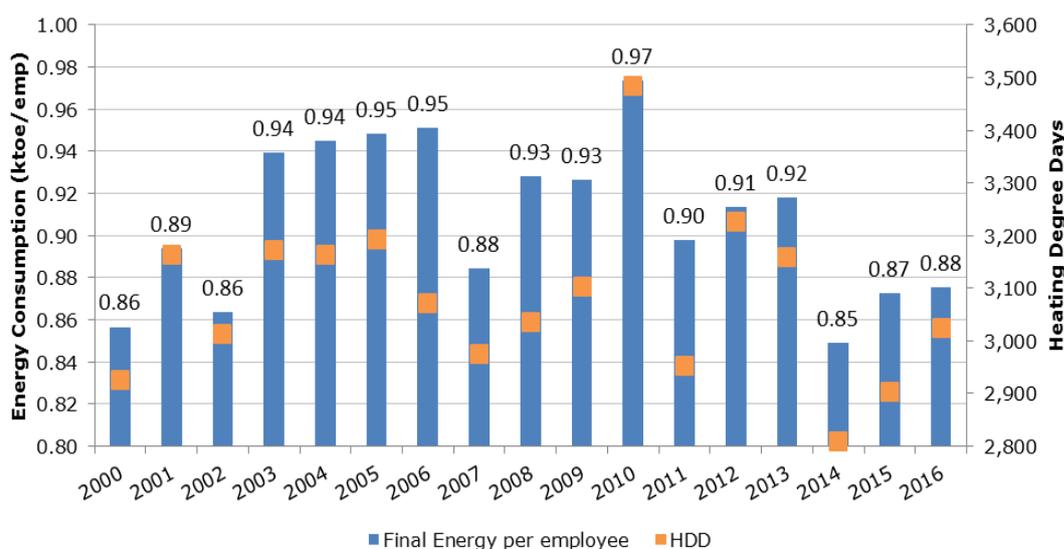
⁵⁴ Public Sector Programme, Sustainable Energy Authority of Ireland (2017), <https://www.seai.ie/energy-in-business/public-sector/public-sector-energy-programme/>

been augmented by the weather effect; the progressively colder winters since 2014 have seen an increase in the amount of energy consumption per employee (Figure 5.6).

The impact of winter temperatures can be seen clearly during the current decade. In 2011 energy consumption fell by 7% in one year, and in 2014 it dropped by 6%. Both of these warmer years were followed by colder years during which energy consumption rose again, highlighting the risks posed by the weather to the achievement of energy consumption targets. The increase in energy consumption since 2014, which had the warmest winter temperatures seen over the period since 2000, is in large part a function of the increasingly cold winters seen in 2015 and 2016.

The impact of summer temperatures was briefly discussed at the workshop. With space cooling estimated to comprise only 5% of EU services sector energy consumption in 2015, this end-use does not currently play a large part in overall trends. However, rising summer temperatures associated with climate change and the wider adoption of space cooling technologies would be expected to see this end-use rise at a faster rate than other end-uses. In the medium-term, the importance of space cooling to the sector's underlying energy consumption and its annual variations would be expected to increase.

Figure 5.6 EU tertiary sector final energy consumption per employee and heating degree days

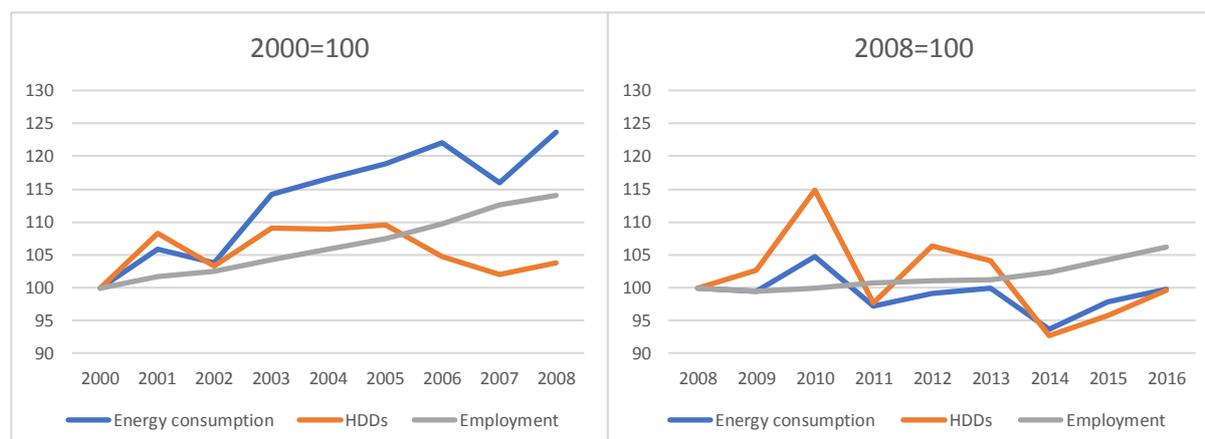


Source: Workshop presentation by Paolo Bertoldi (JRC).

5.3. Prospects for services sector energy consumption

In the short-term, to 2020, a continuation of the relatively strong economic growth seen in 2017 and predicted for 2018 and 2019, might be expected to be accompanied by moderate energy consumption growth, assuming stable winter temperatures. Winter temperatures in 2008 and 2016 were similar as was services sector energy consumption; over the same period, employment in the sector rose by 6%. Between 2000 and 2007, two fairly similar years for winter temperatures (HDDs were 2% higher), energy consumption rose by 16%; over the same period, employment rose by 13% (Figure 5.7).

Figure 5.7: Indices of EU tertiary sector energy consumption and employment and HDDs



Source: Eurostat Energy Balance May 2018, <http://ec.europa.eu/eurostat/documents/38154/4956218/ENERGY-BALANCES-May-2018-edition.zip/310265d9-6adf-45aa-ba41-2dce8e5f78eb>; Eurostat data supplied by the European Commission; and workshop presentation by Paolo Bertoldi (JRC).

At the same time, decomposition analysis suggests that the impact of activity growth in the sector has been moderated to a greater extent by other factors since 2008. These factors are difficult to identify owing to the paucity of the data in the sector but may include improvements in efficiency in ICT and space heating.

A moderate increase in services sector energy consumption of 0.3% per annum between 2016 and 2020 would add around 0.2% to 2016 EU final energy consumption by 2020. However, 2016 was a fairly average year for winter temperatures. Recent history suggests that services sector energy consumption could be around 6% higher or lower in 2020, owing to variations in winter temperatures, meaning that any estimate of the impact of the sector's energy consumption on overall final energy consumption would be subject to a range of +/-1%.

In the medium-term, economic growth might be expected to moderate, putting less upwards pressure on energy consumption and the urgency of meeting climate change targets would be expected to lead to policies that drive an increase in the rate of services sector building refurbishment and the increasing electrification of heat, both of which would put downward pressure on energy consumption. A focus on the public sector, as required under the EU Energy Efficiency Directive, would be expected to lead to more initiatives similar to the Public Sector Measurement and Reporting initiative in Ireland.

ANNEX: WORKSHOP AGENDA

Energy Consumption Trends Workshop

**Albert Borschette Congress Center (CCAB, Room 3D), Rue Froissart 36, 1040
Etterbeek, Belgium
25 May 2018**

Agenda

9.15 – 9.30 Registration and Coffee

9.30 – 10.00 Opening by DG ENER and JRC

Paul Hodson - DG ENER, C3
Paolo Bertoldi, Marina Economidou - JRC
Sam Thomas – Consultant

10.00 – 11.45 Energy consumption in the residential sector

- Mariangiola Fabbri, BPIE "An overview of trends from the Building Stock Observatory"
- Kees van der Leun, Ecofys "Analysis of gas consumption and recent trends in households"
- Willem Braat, IEA "Trends in gas demand in the residential sector"
- René Kemna, VHK "Energy consumption in relation to appliances and heating equipment"

11.45 – 12.45 Energy consumption in services

- Wolfgang Eichhammer, Fraunhofer ISI, Germany "Energy consumption in the services sector in Germany and across the EU"
- Paolo Bertoldi, JRC "Energy consumption in the IT sector"

12:45 – 13.45 Lunch

13.45 – 15:00 Energy consumption in transport

- Jean Cadu, Shell "Auto Fuels 2 main outcome and Shell view on the Road Transport Sector in Europe"
- Jacob Teter, IEA "Recent trends and drivers in road transport in the EU"
- Maria Lelli, ENEA "Recent trends in energy consumption in transport in Italy"

15.00 – 15.15 Coffee break

15.15 – 16.30 Energy consumption in industry

- Patrik Thollander, Linköping University, Sweden "Barriers, drivers, and way forward"
- Didier Bosseboeuf, ADEME, France "Energy consumption in industry in France and across the EU"
- Jim Scheer, SEAI, Ireland "Trends in industry and services in Ireland"

16.30 – 17.15 Panel discussion and Closure

Panel discussion with experts from the previous sessions
Peter Bach, ECEEE President

Questions for speakers

Energy consumption in the residential sector

- How important is the role of weather fluctuations in explaining demand trends (and does the HDD metric adequately control for it)?
- What is happening by end-use – heating obviously important, but what about other end-uses?
- What is happening by fuel use?
- Are there structural changes occurring in the building stock (size or type of dwellings)?
- What other recent trends, e.g. around appliance ownership, diffusion of new electronic devices are impacting on energy consumption?
- How important are behavioural factors?
- Are changes in income and pricing having an impact in this sector?
- Are trends homogeneous across the EU or there are marked regional differences?

Energy consumption in services

- Is it mainly an increase in activity that drives up demand in services?
- To what extent trends in this sector are influenced by weather?
- What about specifically the IT sector and data centers?
- What can new / other data sources tell us about the composition of the service sector and its implications for energy consumption?
- Are trends homogeneous across the EU or there are marked regional differences?

Energy consumption in transport

- How has the pick-up in economic activity affected the transport sector?
- How has the fall in oil prices affected fuel demand and has the impact now been felt?
- How have changes in preferences, e.g. around internet shopping, vehicle ownership, affected energy consumption in the transport sector?
- Are trends homogeneous across the EU or there are marked regional differences?

Energy consumption in industry

- Industry appears to have a stable performance on many metrics (consumption, intensity) – are there any causes for concern?
- Have reductions in energy prices slowed down intensity improvements?
- How is the shape of the economic recovery affecting energy demand, e.g. have they caused a structural shift towards more/less energy intensive sectors?
- Are trends homogeneous across the EU or there are marked regional differences?

Overarching questions

- To what extent are data quality issues and/or the omission of factors not currently included in the decomposition analysis problematic for the analysis of energy efficiency progress?
- What new analysis and data collection should be prioritised? What can other analysis (e.g. econometric) tell us beyond the decomposition analysis – for example, on the impact of changes in energy prices?
- Is energy efficiency policy driving fewer intensity improvements than in the past? What are the policy implications?

The CVs of Speakers

Paolo Bertoldi is Principal Administrator at the European Commission Joint Research Centre in charge of research activities for energy efficiency policy, the efficient use of electricity and innovative policy instruments (e.g. white certificates, financing mechanisms, emission trading).

Mariangiola Fabbri is Senior Project Manager at BPIE Buildings Performance Institute Europe (BPIE). BPIE has been working for the European Commission in the setting up of the Building Stock Observatory.

Kees van der Leun is a Director at Ecofys, he leads the development of its strategic consultancy, in the area of energy and energy infrastructure.

Willem Braat is Energy Analyst at IEA (International Energy Agency)

René Kemna of VHK Consulting is responsible for consultancy on energy efficiency policy and Ecodesign of electric domestic appliances and lighting.

Wolfgang Eichhammer is Professor for Energy Efficiency and Energy Systems Modelling at Utrecht University Netherlands, Copernicus Institute of Sustainable Development. Head of the Competence Center Energy Policy and Energy Markets at the Fraunhofer Institute for Systems and Innovation Research (Fraunhofer ISI).

Jean Cadu is Fuels Strategy Adviser at Shell.

Jacob Teter Jacob Teter joined the IEA as an energy analyst in 2015. His primary responsibilities to date have been to expand and refine modelling capacities and conduct analysis for the IEA Mobility Model (MoMo) to contribute to Energy Technology Perspectives 2016 and other IEA publications.

Maria Lelli at ENEA, is an expert on transport energy consumption and works at the Italian Agency for new technologies, Energy and Sustainable Development.

Patrik Thollander is Professor at the Department of Management and Engineering (IEI) of the Linköping University, Sweden

Didier Bosseboeuf is economist and has more than 30 years of experience on energy demand analysis and evaluation of energy efficiency policies. He is a senior expert in charge of international studies at ADEME (French Agency for Environment and Energy Management,) and coordinator of several international projects, such as ODYSSEE-MURE

Jim Scheer, Head of Department, Low Carbon Technologies at Sustainable Energy Authority of Ireland (SEAI)

Peter Bach, President of eceee (European council for energy efficient economy). He is based at the Danish Energy Agency where he works as chief adviser on energy efficiency

Samuel Thomas is an independent consultant with his own company, Samuel Thomas Consulting. He was the International Energy Agency's lead analyst on energy efficiency between 2014 and 2018, and was Head of Climate Change Economics at the UK's Department of Energy and Climate Change between 2009 and 2014.

