The macro-level and sectoral impacts of Energy Efficiency policies

Final report

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Glossary of acronyms and abbreviations

Commission	European Commission, unless specified otherwise
DG	Directorate-General
Directive	Energy Efficiency Directive, unless specified otherwise
EcoDesign	EcoDesign Directive (2009/125/EC)
EE	Energy efficiency
EEA	European Economic Area
EED	Energy Efficiency Directive (2012/27/EU)
EPBD	Energy Performance of Buildings Directive (2010/31/EU)
ESD	Effort Sharing Decision (DECISION No 406/2009/EC)
ETS	Emissions Trading System
EU PDA	EU Project Development Assistance
FI	Energy agency or regulator
GHG	Greenhouse Gas
GDP	Gross Domestic Product
GVA	Gross Value Added
ICT	Information and Communication Technologies
IEM	Internal Energy Market legislation
ktoe	kilotonnes of oil equivalent
MS	Member State(s)
MSR	Market Stability Reserve under the ETS
mtoe	Million tonnes of oil equivalent
NEEAP	National Energy Efficiency Action Plan
RES	Renewable Energy
SME	Small- and medium-sized enterprise

Executive Summary

1.1 Purpose and scope of this report

This report sets out the potential positive and negative impacts of improvements to energy efficiency in Europe. The analysis presented in this report covers the macroeconomic, social and environmental impacts that could come about through increasing the EU's 2030 target for energy efficiency beyond a level of 27% in comparison to baseline projections, to 30% or beyond. Parts of this report (notably the literature review included in Appendix D) build also on the work carried out for a previous study for the European Commission[1], which focused on the economic, environmental and social impacts of improved energy efficiency in buildings. This is referred to in the text as 'the EPBD report'.

Successive studies have shown that energy efficiency offers many of the most cost-effective options for meeting global greenhouse gas emission reduction targets. In many cases, energy efficiency measures have been shown to be 'negative cost', meaning that it would be economically advantageous to implement them. In this analysis, a wide range of potential effects is considered, covering the three pillars of economic, social and environmental sustainability.

In this report, four different scenarios are assessed, based upon the policy options set out in the EED Impact Assessment (EC, 2016). The timeframe for the analysis is 2030. Some of the results of the work undertaken have been included already in the EED Impact Assessment. This report offers a more detailed explanation of the methodology used and additional results from scenarios produced by the E3ME model which are not fully comparable to the results of scenarios presented in the EED Impact Assessment.

The inputs for each scenario have been derived from PRIMES model results, providing consistency with the full Impact Assessment. Six impact areas have been covered:

- Economy and labour market
- Health
- The environment
- Social cohesion
- Public budgets
- Industrial competitiveness

All other factors apart from energy efficiency policy are assumed to remain constant across the scenarios, so that the model results isolate the effects of the specific policy changes. The investments are assumed to be self-financed, meaning that the agents that benefit from the energy efficiency must pay the up-front costs, leading to:

- A substitution away from consumption of other goods (households)
- Additional costs met through increases in final product prices (businesses)
- An increase in VAT rates to fund public investment (government)

An additional variant, in which all the investment is financed by the public sector (with tax increases to fund it) is also considered. This provides a closer comparison with a previous analysis carried out in 2015[2].

Two further variants of the scenarios are presented throughout this report, based on different assumptions about how the European economy might be able to meet the challenge of large-scale improvements to energy efficiency. In the first set it is assumed that firms can produce and install new efficient equipment using existing spare capacity,

[1] https://ec.europa.eu/energy/sites/ener/files/documents/final_report_v4_final.pdf
[2] http://ec.europa.eu/energy/sites/ener/files/documents/CE_EE_Jobs_main%2018Nov2015.pdf

meaning that no other economic production is 'crowded out'. In the second set of results, some of the additional economic production replaces production in other sectors.

1.2 Economic and labour market impacts

Macro economy

Implementing measures to meet the energy efficiency targets has a positive impact on both GDP and employment. As the extent of energy efficiency improvements increase, so do the positive impacts on GDP and employment. In the scenario with a 30% energy efficiency target, GDP increases by 0.4% compared to the (27% target) by 2030 and employment increases by 0.4%. In the most ambitious EUCO40 scenario, there is the potential for GDP to increase by more than 4% and employment by more than 2%.

Many of the jobs would be created in sectors directly relevant to energy efficiency (e.g. construction, engineering) but there would also be increases in employment in the wider economy. Unemployment in the EU could be reduced by up to 3 million people by 2030.

Table I-1: Summary of GDP and employment impacts, EU28, % from EUCO27

	Degree of crowding out	EUCO30	EUCO33	EUCO35	EUCO40
Efficiency target		30%	33%	35%	40%
GDP	No crowding out	0.4	1.5	2.1	4.1
	Partial crowding out	0.4	1.3	1.6	2.2
Employment	No crowding out	0.2	0.7	1.0	2.1
	Partial crowding out	0.2	0.6	0.9	1.4

Source(s): E3ME, Cambridge Econometrics

The degree of crowding out is clearly important in determining the macroeconomic outcomes. If European industry is able to increase production to the levels required to manufacture and install the energy efficient equipment, then the full benefits could be realised. If investment in energy efficiency displaces other production, however, around half of the benefits could be lost. While the actual degree of crowding out is uncertain, policy makers could reduce it by signalling the ambition clearly to companies in advance; they would then be able to take a view on the prospective increases in demand. Ensuring an adequately skilled labour force could also mitigate potential crowding out.

There are also other economic benefits. Investment could increase substantially and household consumption could also increase due to the incomes earned by the additional people in employment. Reducing imports of fossil fuels would boost Europe's trade balance, and also improve the energy security of Member States that are exposed to a highly concentrated source of supply for gas.

The sectors that benefit the most in the scenarios are those that produce and install energy efficient equipment. These are principally the construction and engineering sectors, where by 2030 output could increase by 2.5% compared to the reference case in the 30% energy efficiency increase scenario and by more than 10% in the more ambitious cases. A necessary condition for realising these increases is that companies in these sectors have the capacity to increase production.

Public budgets

A more ambitious target for energy efficiency would have a positive effect on Member States' public sector budget balances. Meeting the energy efficiency targets set in the scenarios would impact on public budgets in several different ways. For example, the public sector must fund some of the energy efficiency improvements (e.g. those in public services) but would later benefit from lower energy bills. However, indirect effects would have much larger impacts on public budgets. For example, as employment increases, revenues from labour taxes and workers' social contributions increase and social welfare payments will be reduced.

The positive effects on public sector budget balances could be as high as 2% of GDP on average in the EU. When compared with the 3% ceiling on budget deficits imposed by Europe's Stability and Growth Pact, this is a substantial amount.

Industrial competitiveness

Impacts on industrial competitiveness focus on the energy intensive industries in Europe. Although these sectors account for a relatively small share of GDP they often play an important role in the supply chains for manufactured goods (including some energy efficient equipment). Even in a reference scenario, these sectors reduce their use of energy (per unit of output) consistently over the period to 2050. However, in the scenarios where the higher energy efficiency targets are met, firms in these sectors reduce their use of energy further and may therefore see a boost to competitiveness.

1.3 Health impacts

The potential of energy efficiency measures to generate health-related cost savings is considerable. The extent of cost savings related to healthcare costs, morbidity and mortality are affected by the scale of investment in energy efficiency: greater savings are derived from greater levels of investment, although it the relationship is not linear.

Table I-2: Potential health benefits in 2030, EU28, % from EUCO27 scenario

	Mortality & morbidity cost savings due to lower NOx, SOx, PM_{10} and $PM_{2.5}$ in 2030
Efficiency target	**bn€ / year**
30%	-28.3
33%	-54.8
35%	-57.6
40%	-77.0

The benefits also accumulate over time. By 2030, moving from a 27% efficiency target to a 30% efficiency target would lead to annual health savings of €28.3bn. Going to a 40% target could result in savings of around €77bn each year. Most of these savings result from reductions in the emissions of particulates. Indoor air pollution accounts for a large proportion of the overall savings[3].

1.4 Social impacts

A large share of the energy savings in the scenarios comes from improved energy efficiency in buildings and many of the social impacts depend on which sorts of buildings

[3] These figures differ from the results produced with the GAINS model for the Impact Assessment in part because of the different modelling methodology used, but also the inclusion of indoor pollution.

are targeted. There is therefore the potential to enhance the social benefits of energy efficiency by, for example, improving homes that are occupied by low income households. Analysis of proposed revisions to the EPBD suggests that more than 8 million households could be removed from fuel poverty if ambitious programmes to renovate and improve buildings were implemented and targeted specifically at low-income households. If the programmes were not targeted at low income households the benefits would be smaller but could still lift more than 2 million households out of energy poverty.

Table I-3: Potential reductions in energy poverty by 2030 compared to reference based on three different indicators of energy poverty (thousands of households in the EU, ambitious scenario)

	LOW variant	HIGH variant
Arrears on utility bills	1,456.4	5,171.3
Leaks, damp, rot	2,327.4	8,255.8
Ability to keep home warm	1,748.4	6,203.8

Source(s): Wuppertal Institut

There are other potential social benefits from improving energy efficiency. By reducing expenditure on expensive heating fuels, income inequalities could be reduced slightly (as low income households spend a larger share of their incomes on heating). The scale of these effects varies across Member States, depending on income and consumption patterns, but follow broadly the same qualitative trend.

Higher rates of energy efficiency are also likely to lead to lower unemployment in the EU. In the most ambitious scenario, EU unemployment could be reduced by 3m by 2030.

1.5 Environmental impacts

There are also several environmental benefits attached to energy efficiency. Despite 'rebound' effects (see below), energy consumption in the EU falls in all the scenarios, by between 7% and 18%. Greenhouse gas emissions are also reduced; in all the scenarios the 40% reduction target for 2030 is met and in the more ambitious scenarios it is exceeded by up to 7 percentage points.

At EU level there are reductions in emissions of SO_2, NOx and particulates. The health impacts described previously result from these emissions reductions. In some Member States, however, there may be increases in certain emission types. This is due to the interaction between energy efficiency and the EU ETS; lower demand for ETS allowances leads to a fall in price, which could mean more use of coal for electricity generation. The environmental and health benefits would be larger if additional regulatory measures were taken to prevent coal from playing a major role in the energy mix.

Less positively, higher levels of energy efficiency could lead to increases in material consumption. Much of the energy efficient equipment that would be installed is quite material intensive in nature, for example the use of aggregates by the construction sector. Total Domestic Material Consumption (DMC) in the EU could increase by between 0.6% and 5.5% in the scenarios that were assessed.

1.6 Key factors in implementing the measures

Throughout the analysis, several themes emerge that influence the results across the different impact areas and could have important policy implications:

- Rebound effects – Rebound effects are closely linked to the economic benefits described above. They mean that the full energy savings are not realised because, for example, the incomes generated in producing and installing energy efficiency equipment may be spent on other products that require energy to produce. While rebound effects reflect better economic and social outcomes, they may lead to worse environmental outcomes, thus representing a trade-off between benefits.
- Crowding out effects and constraints on production – If European firms are not able to increase production in response to higher energy efficiency targets, then the positive impacts on the economy and public budgets could be smaller. The scenario variants assessed in this report consider a case where European firms are only able to meet some of the additional demand, based on Eurostat data on capacity utilisation. The results show that almost half the benefits could be lost.
- Financing the energy efficiency – How to finance the measures remains a key question. This report does not attempt to answer the question of how different financing measures might encourage the uptake of energy efficiency, but it does consider how the split between public and private financing might influence the economic impacts. The results from the exercise show that the choice of financing method determines how the benefits of energy efficiency could be shared between the public and private sectors.

1.7 Conclusions and policy measures

This report attempts to quantify many of the multiple benefits of energy efficiency that have been identified by the IEA and others. It covers potential costs as well as benefits but shows that, for the EU as a whole and for most of its Member States, the benefits largely outweigh the costs. These benefits cover all three of the economic, social and environmental spheres.

Several important policy measures have emerged from the analysis. In order to maximise the potential benefits from energy efficiency, the following should be considered:

- The EED and related policies must be implemented fully and properly enforced; otherwise results will be weaker across all impact areas. The modelling results show clearly that the higher the degree of energy efficiency that is achieved, the more positive the results in most impact areas.
- There is an important question about how energy efficiency investment will be financed. Aside from the crucial question of how to incentivise energy efficiency improvements to make sure that the targets are met (especially for the most ambitious 40% scenario), results in this report show that how the benefits of energy efficiency are shared will depend on the financing mechanism.
- Competitiveness and economic benefits will be maximised if the energy efficient equipment and materials are manufactured domestically (within the EU). Many of the economic benefits accrue because spending on imported fuels is diverted towards other areas of spending, not necessarily related to energy efficiency. Although not assessed in this report, in the more ambitious scenarios it is possible that a larger domestic market would incentivise more firms to locate production in the EU, enhancing these benefits.

- The potential crowding out of economic activities remains a key concern in the more ambitious scenarios. If ambitious targets were to be met, firms that manufacture and install energy efficient equipment would need to ensure that they had adequate capacity to meet market demands. Providing advance warning of future demands and ensuring a suitably skilled workforce will assist in the process.
- The impacts on social welfare and income distribution could be enhanced if there were specific measures to target energy efficiency in buildings at low income households. Such measures could also reduce fuel poverty rates across the EU by around 8 million households.
- The environmental impacts depend not only on the amount of energy efficiency that is implemented but also what happens in the wider energy system. Most notably, if more energy efficiency leads to a lower EU ETS price, this could encourage more use of coal-fired power generation. To realise all the potential benefits of energy efficiency, supporting policy measures will likely be required.

In summary, the EED provides the framework for advances in energy efficiency across Europe which, as this report shows, could result in substantial economic, social and environmental benefits. The challenge for policy makers is to further design specific measures that will realise the full potential of the possible benefits, which may vary between Member States. Most important, however, is to implement policy that ensures that the energy efficiency improvements are actually carried out.

Part I. Introduction

1 Introduction to the project

1.1 Overview

This document presents the final report for:

Study for a comprehensive assessment of the macro-level and sectoral impacts of Energy Efficiency policies

The study team was led by Cambridge Econometrics and included Ernst & Young Special Business Services (EY) and SQ Consult.

The report presents the full set of results from the study and describes the methodology that was used in the assessment. The detailed literature review that was carried out for the study is also provided in the appendices of this report.

1.2 Background to the study

The efficient use of energy is recognised as a key pillar of energy policy in the EU. 'Energy Efficiency First' is a central element of the Energy Union, and energy efficiency sits alongside GHG reduction ambitions and renewables targets as part of the EU's overall climate and energy policy package. The Energy Efficiency Directive (2012/27/EU and 2013/12/EU[4], hereafter the EED) and the 2030 framework for climate and energy policies have provided targets for reducing energy consumption for the years 2020 and a first indication for 2030.

When first introduced in 2012, the EED established a set of binding measures to help the EU reach its 20% energy efficiency target by 2020 and improve energy efficiency beyond 2020. These measures cover all stages of the energy chain from its production to its final consumption, and were informed by EU's 2020 Energy Strategy objectives to reduce greenhouse gases by at least 20%, to increase the share of renewable energy in the EU's energy mix to at least 20% of consumption and to reduce energy demand by at least 20% compared to baseline projections. To reach the EU's 20% energy efficiency target by 2020, individual EU countries were required to set their own indicative national energy efficiency targets. The Energy Roadmap 2050 was introduced to provide a practical, independent and objective analysis of pathways to achieve a low-carbon economy in Europe, in line with the energy security, environmental and economic goals of the European Union.

On 30 November 2016, in the context of the "Clean Energy for All Europeans" package, the Commission proposed amendments to the EED, including a new 30% energy efficiency target for 2030, extending beyond 2020 the obligation to save 1.5% of energy each year, and improving metering and billing of energy consumption for heating and cooling customers. The overall legislative proposals included in the "Clean Energy for All Europeans" package have three main goals: putting energy efficiency first, achieving global leadership in renewable energies and providing a fair deal for consumers. The key implementing measures cover energy efficiency, renewable energy, the design of the electricity market, security of electricity supply and governance rules for the Energy Union. The package also provides measures to encourage public and private investment, to promote EU industrial competitiveness and to mitigate the societal impact of the clean energy transition.

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[4] Available at: http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=OJ:L:2012:315:TOC; http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:32013L0012

In addition to the EED, relevant energy efficiency legislation at the European level includes the Energy Performance of Buildings Directive (2010/31/EU, hereafter EPBD) and the Ecodesign and Energy Labelling framework directives (2009/125/EC and 2010/30/EU). The EPBD addresses energy consumption in buildings, among others by setting a target that all new buildings must be nearly zero energy buildings by 31 December 2020, and by requiring EU countries to set minimum energy performance requirements for new buildings and for major building renovations or the replacement or retrofit of building elements. The Ecodesign and Energy Labelling framework directives set standards and labelling requirements for energy consumption for a range of appliances used by households and commercial organisations. There are also many measures that have been enacted at Member State or subnational level, covering a range of different sectors.

Parts of this report (notably the literature review included in Appendix D) build on the work carried out for a previous study for the European Commission, Directorate-General for Energy ("The macroeconomic and other benefits of energy efficiency", Contract no. ENER/C3/2013-484/03/FV2015-523, submitted in August 2016[5]), which focused on the economic, environmental and social impacts of improved energy efficiency in buildings. This is referred to in the text as 'the EPBD report'. While the present report does not aim to duplicate the findings from the EPBD report, there is a very large contribution to energy efficiency from buildings in the scenarios assessed in later chapters, and hence many of the findings from the EPBD report are also relevant here. However, the relative importance of the different impact areas is not the same as in the EPBD report (e.g. social impacts are more important when considering buildings; competitiveness impacts can be more important when considering industrial energy efficiency).

Some of the results presented in this report fed in to a previously published Impact Assessment (European Commission, 2016) for the proposal to amend the EED published in November 2012 in the context of the "Clean Energy for All Europeans" package ("Proposal for a Directive of the European Parliament and the Council amending Directive 2012/27/EU on Energy Efficiency, which assessed a range of options for achieving improved energy efficiency[6]). Different variants of target reductions of primary energy by 2030 compared to a baseline scenario performed in the year 2007 were assessed: 27%, 30%, 33%, 35% and 40%. The analysis showed that as the level of energy efficiency in 2030 increased, the investment requirements also increased, with large increases in investment needed in the more ambitious cases. In addition to the E3ME analysis presented in this report, the GEM-E3 model was also used to assess the scenarios in the Impact Assessment. The GEM-E3 results showed that there could be positive impacts on economic growth and employment, but the positive results depend on how the energy efficiency investment is financed. Both the models found a positive impact on the security of Europe's energy supply, affecting the scale of gas imports in particular.

Other previous studies of the EED include an evaluation of the EU Framework for Metering and Billing of Energy Consumption (EC, SWD(2016) 399 final), an overview and assessment of good practice in energy efficiency, and an evaluation of Articles 6 and 7 of the Energy Efficiency Directive (2012/27/EU) (EC, SWD(2016) 402 final), which set out the requirements for the public sector in EU countries to purchase energy efficient buildings, products and services; and for energy distributors and retail energy sales companies to achieve an additional 1.5% energy savings per year through the implementation of energy efficiency measures until 2020.

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[5] https://ec.europa.eu/energy/sites/ener/files/documents/final_report_v4_final.pdf
[6] See http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52016SC0405&from=EN

1.3 The 'multiple benefits' of energy efficiency

Successive studies have shown that energy efficiency offers many of the most cost-effective options for meeting global emission reduction targets. In many cases, energy efficiency measures have been shown to be 'negative cost', meaning that it would be economically advantageous to implement them as consumers will save money in the long run.

The IEA's authoritative report 'Capturing the multiple benefits of energy efficiency' (IEA, 2014) shows that the potential benefits from improved energy efficiency are not only socio-economic but could help to address a range of political, social, economic and environmental issues. In this study, we have divided these benefits into six impact areas:

- economy and labour market
- health
- the environment
- social impacts
- public budgets
- industrial competitiveness

It is important to note that, although this report is structured around these six impact categories, there is considerable cross-over and interaction between many of them.

2 Introduction to this report

The analysis in this report estimates the positive and negative impacts of improvements in energy efficiency that could come about through a reduction of primary energy consumption, compared to a 2007 baseline projection, of 27%, 30%, 33%, 35% and 40% by 2030. The specific policy scenarios are described in Part II and the approach that was used to assess each of the six impact areas is described in Part III. Part IV presents the detailed results from the analysis and the key policy messages are outlined in Part V.

The appendices include further information about the E3ME macroeconomic model that was core to the analysis, along with the literature review that was carried out early in the study to inform its methodology.

Part II. Scenarios

1 Introduction

In this report, the E3ME model has been applied to assess a range of scenarios related to the Energy Efficiency 2016 Impact Assessment (SWD(2016) 405 final). E3ME is a computer-based model with three modules – energy, environment and economy - that is used to provide insights in interactions between these three modules and for understanding and comparing the impact of different policy options[7].

Six different scenarios were assessed. These include a reference scenario and five different policy scenarios with different levels of ambition for energy efficiency policy. The reference scenario is described as the 'reference' option and is discussed further in the next section. The following sections then introduce and describe the wide range of policy 'measures' that were considered and the five energy efficiency target scenarios that included a selection of the different policy measures. These five energy efficiency target scenarios form the scenarios that are assessed later in this report.

The scenario descriptions provided in this chapter are taken from European Commission documentation[8], calibrated or amended where necessary for consistency with the modelling that was carried out.

2 Reference option

The reference option means no additional measures beyond the existing ones, including continued implementation of the current EED and related regulatory and non-regulatory instruments. All the EU initiatives in relation to energy efficiency are unchanged in the reference option. Related legislation, such as the EPBD, are expected to continue in their current form. It is to be noted, however, that the reference option doesn't mean automatically that the current policies would remain and continue in the future with the same intensity. This is notably the case for the provisions of the Art. 7 of the EED, which in the current legislation is not supposed to continue after 2020.

The reference option used for the purpose of this report was developed with the PRIMES model into the 2016 Reference Scenario[9], which forms the starting point for the analysis with the E3ME model that is at the heart of the analysis conducted in this study (see Appendix A). Inputs to E3ME, including both assumptions (e.g. energy prices, economic growth rates) and the full energy balances are taken from the detailed PRIMES model spreadsheets.

The PRIMES Reference Scenario indicates that, with no new policies beyond those adopted by the end of 2014, there is only an 18.4% reduction in primary energy consumption compared to the 2007 baseline projections by 2020 (hence missing the 2020 indicative target of 20%). It is assumed that national policies to achieve the required savings under Article 7 are mostly phased out after 2020 because of the expiry of this article. A 23.9% primary energy consumption reduction compared to the 2007 baseline is projected for 2030[10]. Renewable energy would account for 24.3% of gross final energy consumption and greenhouse gas emissions would be reduced by 35.2%

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[7] A short description of E3ME is included in Appendix A.

[8] Primarily the Energy Efficiency 2016 Impact Assessment (SWD(2016) 405 final).

[9] https://ec.europa.eu/energy/en/data-analysis/energy-modelling

[10] 2007 Baseline modelled with PRIMES projected for 2030 primary energy consumption reaching 1,436 mtoe and final energy consumption 1,081 mtoe.

(37.7% in the ETS sectors and 23.7% in the Effort Sharing Decision (ESD) sectors) by 2030.

3 Energy efficiency target scenarios

The reference scenario used in the PRIMES modelling assumes a continuation and implementation of the energy efficiency framework beyond 2020. This includes, for example, the renovation of public buildings under Article 5 of the EED or the further development of the ESCO market according to Article 18. However, as described above, Article 7 will not be obligatory post-2020.

To achieve energy efficiency savings greater than 23.9% by 2030 in the reference scenario, energy consumption must decrease more rapidly than current policy measures are projected to achieve. The PRIMES modelling results presented in the EED Impact Assessment (European Commission, 2016) show the required reductions in final energy demand or consumption (compared to the PRIMES reference scenario) that are needed to achieve each of the energy efficiency target scenarios. These results are shown in Table II-1 (below).

Table II-1 Primary and final energy consumption in Mtoe, in 2030

	EUCO27	EUCO30	EUCO+33	EUCO+35	EUCO+40
Primary energy consumption	1,369	1,321	1,260	1,220	1,129
Final energy consumption	1,031	987	929	893	825
Reduction in PEC compared to reference scenario	-67	-115	-176	-216	-307
Reduction in FEC compared to reference scenario	-50	-94	-152	-189	-256

Source(s): PRIMES

The data presented in Table II-1 (above) cover the required energy consumption reductions from all sectors under the different policy scenarios and represent savings that are needed *in addition* to the existing energy efficiency framework that is represented in the reference scenario. These additional savings in 2030 will need to be compared with the anticipated impacts of the proposed, new energy efficiency policies.

The energy efficiency targets will also need to be assessed within the framework of the other targets that have been agreed by the European Council and that are included as modelling assumptions in the analysis of each of the energy efficiency target scenarios. These include:

- An overall reduction in greenhouse gas (GHG) emissions (at least 40% with respect to 1990).
- A reduction in GHG emissions in ETS sectors (43% with respect to 2005, including the Market Stability Reserve and the proposed revision of the linear reduction factor).
- A reduction in GHG emissions in sectors covered by the Effort Sharing Decision (30% with respect to 2005).

- A minimum share of renewable energy in final energy consumption (at least 27%).

The different policy areas reinforce each other and were analysed as a package. The ETS and Effort Sharing Decision targets in 2030 are met by construction in the EUCO27 and EUCO30 scenarios, but overshoot in some of the more ambitious scenarios. In contrast to the reference scenario, all policy scenarios are consistent with the EU's long-term GHG reduction objective for 2050.

A wide range of policy alternatives was considered in the different scenarios. These included both regulatory and non-regulatory measures, as well as action at different spatial levels (EU, national, regional and local).

All measures build upon or amend the current EED and are linked explicitly to a series of drivers for policy development in the Impact Assessment. In the PRIMES modelling, different policy measures were packaged into broader sets of policy options, which enable the delivery of energy efficiency targets that form the basis for the analysis in this report.

3.1 Policy packages and energy efficiency target scenarios

The energy efficiency targets are achieved by simulating a realistic mix of European and national energy efficiency policies in all sectors which was intensified with higher energy efficiency levels in 2030: residential, tertiary, industrial, transport and energy supply. This policy mix involves policy instruments, including carbon pricing to reduce emissions in the ETS and non-CO_2 emissions in the non-ETS sectors, performance standards, policies leading to a reduction of market barriers, incentives and obligations related to energy efficiency. These policies are implemented in a coherent manner across Member States, taking into account the current policy framework (as developed in the reference scenario).

The full Impact Assessment used results from the PRIMES model to show the impacts of different energy efficiency levels on the energy system (e.g. the energy mix). In the modelling, however, energy efficiency policies were depicted only in an aggregated and stylised manner, which does not allow quantifying the achieved savings or costs of individual policy measures (e.g. Article 7 or 9-11 of the EED).

3.2 Policy options

The first policy option is to achieve a target of 27% reduction of primary energy consumption (compared to the 2007 baseline). This option corresponds to the minimum energy efficiency ambition level agreed by the European Council in 2014, and can therefore be considered to be the real "baseline" for the analysis in this report. As a consequence, most the results are presented as a comparison to, or as a difference to, the impacts corresponding to an energy efficiency target of 27%. Four further policy options explore 2030 targets of 30%, 33%, 35% and 40% reductions in primary energy consumption (compared to the 2007 baseline). A sensitivity with a 30% energy efficiency level in 2030 and a RES share of 30% was also included which makes it closer to the 2030 renewable energy target called for by the European Parliament.

The five policy scenarios which reflect the different policy options are called respectively EUCO27, EUCO30, EUCO33, EUCO35 and EUCO40[11]. Comparing the policy scenarios against reference scenario shows the costs (notably investment expenditure) necessary to achieve the 2030 GHG targets, Effort Sharing Regulations and RES target all together.

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[11] In the Impact Assessment, these scenarios were referred to as EUCO27, EUCO30, EUCO+33, EUCO+35 and EUCO+40.

Likewise, benefits shown by each policy scenario represent the combined benefits of achieving all the targets.

To achieve a rate of at least 27% of energy efficiency, the policy scenarios assume for the transport sector policies and measures that are currently under consideration at European level. For the other final demand sectors, various standards and policies were intensified in the model to reflect the proposed updates to the EED described in Appendix C, to reflect current policies and the proposed policy changes to achieve different energy efficiency targets by 2030. The adjustments or calibration of the E3ME model are made to ensure consistency with the results from the PRIMES model. The adjustments concern:

- Intensified standards: eco-design, building codes and CO_2 standards
- Increase of Energy Efficiency Values, representing yet to be identified policy measures aiming at energy savings
- Lower behavioural discount rates to address increased energy efficiency levels in 2030
- Increase in the efficiency of the transport system to reflect the effect of additional transport measures
- Changes in the primary energy factor resulting from the uptake of heat pumps and on-site renewable energy.

A more detailed description of these adjustments is available in Appendix C. A more detailed description of the approaches and definition of the policy scenarios is available in Annex 4 of the EED Impact Assessment.

Part III. Methodological Approach

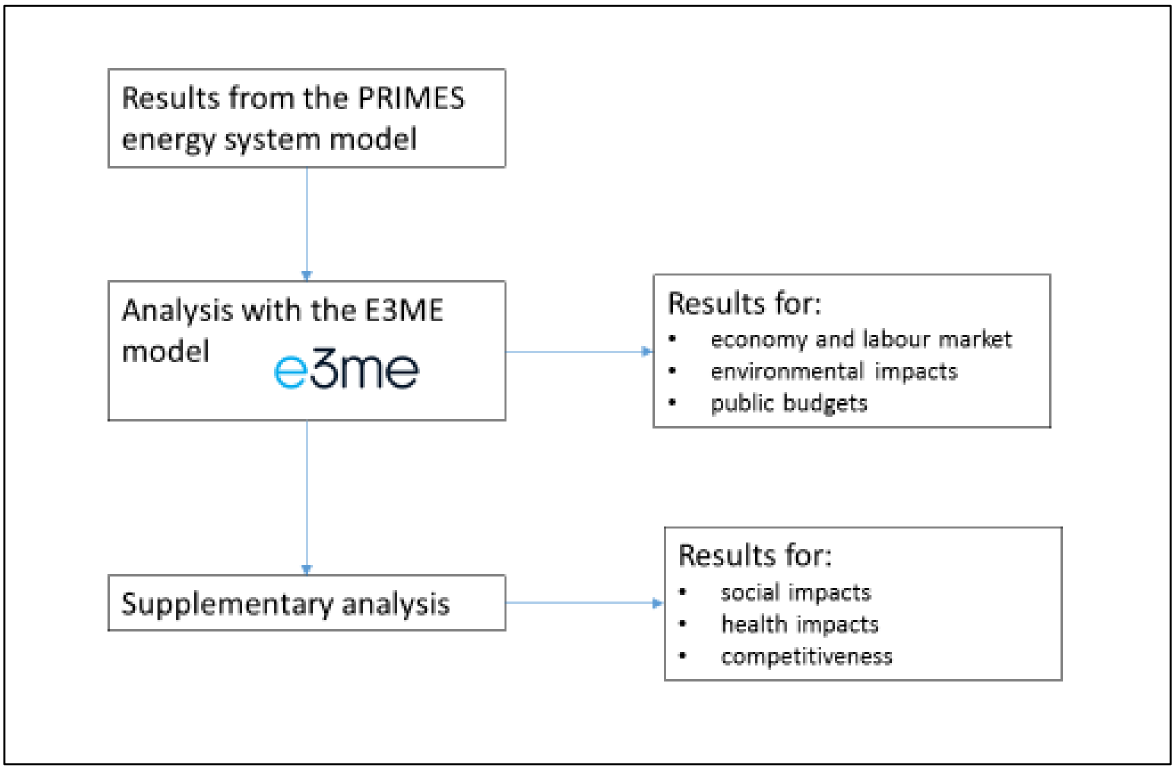
1 Introduction

This chapter describes the approach that was used to estimate quantitatively the impacts of the policy options that were implemented in each scenario, covering each of the six impact areas that were outlined in Part I. Much of the analysis is based on the E3ME macroeconomic model (see Appendix A[12]). However, because the E3ME model itself is not capable of producing all the key indicators across the six impact areas, supplementary analysis was undertaken using a range of alternative approaches.

The following sections describe the approaches that were applied in each of the six identified impact areas. The technical modelling approach for the reference scenario and the policy scenarios is described in more detail in Appendix B.

Figure III.1 summarises the main steps in the analytical process.

Figure III.1 Summary of main steps in the analysis



2 Economy and labour market

2.1 Overview of the links in E3ME

Figure III.2 presents a simplified version of the main linkages in E3ME. The key relationships are:

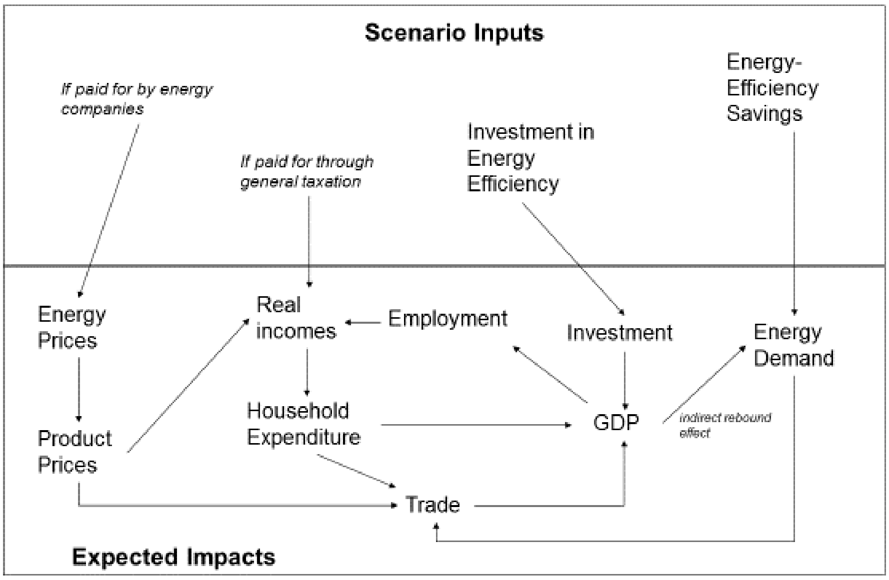
- An increase in investment will boost rates of economic activity and create jobs.

[12] Documentation is also available at the model website, www.e3me.com, which includes the full technical manual.

- However, this will displace spending from other parts of the economy, which at least partly counters the effect.
- A reduction in imported energy may be replaced with additional spending on goods and services that are produced domestically.

The model provides a framework for these relationships to be interpreted in the context of the system of national accounts, allowing quantification of the impacts. As E3ME includes equation sets for labour demand, supply and wage rates, labour market impacts are integrated in the model results.

Figure III.2 Main Model Linkages



Source(s): Cambridge Econometrics.

To assess the economic impacts, including employment and other labour market indicators, the energy savings and associated investment costs were entered into the E3ME macroeconomic model, which in turn estimated the impacts on the economy and labour market. The results from the E3ME model were also used to estimate the effects in some of the other impact areas, as described in the following sections.

For each scenario, the main inputs to E3ME included:

- an estimate of energy savings, disaggregated by Member State, sector and energy carrier (and over time)
- an estimate of the associated investment costs
- assumptions about who pays for the investment and how this might displace other spending (i.e. 'crowding out')

Both the E3ME model and the methodology outlined above have been applied previously. As well as the recent EPBD report, results of a previous 2015 study on the employment and social impacts of energy efficiency are relevant (European Commission, 2015). A comparison of results with the 2015 study is provided in Appendix D, Section 2.7. The previous studies have highlighted two key issues in the modelling, rebound effects and crowding out effects, which are still more important in ambitious energy efficiency scenarios. The approach to addressing these issues is described in the following sections.

2.2 Rebound effects

Rebound effects are increases in energy demand that result from the economic impacts of implementing energy efficiency. They mean that the expected energy savings are not fully realised. For example, if a household installs an efficient boiler they will not need to purchase as much energy as previously, but may instead purchase other goods that require energy in their production. Thus, while energy consumption falls, it will not fall by as much as the additional savings from the efficient boiler alone.

Rebound effects are often split into direct and indirect effects. Direct rebound effects relate to the specifics of the individual products (e.g. a more efficient boiler may be used more often) whereas indirect rebound effects relate to redirected spending. The literature review in Appendix D (Sections 2.2 and 2.5) highlights the importance of accounting for rebound effects. At the macro level, rebound effects have been shown to reduce the initial energy savings by up to 50% (Barker et al, 2009) while some studies that consider specific sectors have found rebounds of more than 100% (e.g. Freire-González, 2017).

In the modelling in this report, the *direct* energy savings are consistent with the results from the PRIMES model and so follow the same assumptions on direct rebound effects. The approach adopted in E3ME is designed to capture *indirect* rebound effects; if households have additional income then they are likely to spend more on energy and/or products that require energy. The extent of the indirect rebound effect is determined endogenously by the model, based on its econometric parameters.

Estimates of the scale of the rebound effect are provided in Part IV, Section 1.1. The economic impacts that drive the rebound effects are provided in Part IV, Section 2. Results for energy consumption, including rebound effects are included in the environmental indicators presented in Part IV, Section 4.

2.3 Crowding out effects[13]

Previous model-based studies have shown assumptions about crowding out to be critical to determining the estimated impacts of energy efficiency scenarios (e.g. European Commission, 2015b). Crowding out occurs due to supply constraints. If the economy is operating at maximum capacity, then any additional activity in one part will have to displace activity elsewhere, rather than be additional, for example through the adjustment of prices. The term crowding out has in the past been used by economists to refer to the specific case where additional public sector investment leads to lower private sector investment, but here we use it to refer to the effect of capacity constraints more generally.

Crowding out could occur in any economic market. Three important examples are:

- labour markets – if full employment is reached, it is not possible to increase employment further.
- capital markets – if all available finance is used, it is not possible for banks to issue new loans for investment.
- product markets – if companies are producing at full capacity they cannot produce more.

Most macroeconomic models assume optimising behaviour[14], which means that no spare resources in the economy are left involuntarily unemployed, either in the baseline case

[13] DG ENER is currently investigating this issue further, see https://ec.europa.eu/energy/en/data-analysis/energy-modelling/macroeconomic-modelling

[14] Computable General Equilibrium (CGE) models are a standard tool for long-term macroeconomic and energy-environment-economy (E3) analysis. Unlike the E3ME model, CGE model frameworks typically assume

or in any policy scenarios. Scenarios with increases in investment in energy efficiency beyond the baseline case therefore imply reductions in investment elsewhere in the economy. Furthermore, because of assumptions about optimisation, this type of scenario will almost always lead to worse outcomes for GDP.

In contrast, simulation-based models such as E3ME allow for the possibility of spare capacity in the economy. Although the model is subject to some fixed capacity constraints (e.g. the total available stock of labour), these constraints are not breached in any of the scenarios discussed in this report. Constraints in *product markets* are handled through the model's 'normal' output equations, which compare actual output with expected output to give an implicit measure of how close production is to capacity. Based on estimated parameters, these ratios feed into the model's price equations and several other equations (e.g. investment); hence, the behaviour of firms is modelled, rather than an assumption made that any additional activity is necessarily fully crowded out. Hence, economic activity that results from higher levels of investment in energy efficiency need not necessarily displace activity in other parts of the economy.

This issue goes to the heart of debates between the different schools of macroeconomics and is not unique to energy policy or energy efficiency. However, the debate is particularly intense with regards to financial markets and policies that require high levels of investment (e.g. energy efficiency, climate mitigation and adaptation). This is because the mainstream branch of economics on which most macroeconomic models are based assumes a fixed money supply (or supply of saving for investment), which does not appear consistent with the activities of modern central banks (Pollitt and Mercure, 2017; McLeay et al, 2014; Keen, 2011).

Unfortunately, the economic literature on the topic of crowding out and capacity constraints in general tends to be quite theoretical rather than applied in nature. The reason is that it is very difficult to construct counter-factual scenarios without making prior assumptions about how the economy works. For example, in the evaluation of an energy efficiency programme we do not know what would have happened if the programme had not been implemented.

There are, however, data relating to capacity utilisation that are available from Eurostat. These data cover the manufacturing and construction sectors and are based on a combination of surveys and econometric analysis. The figures show that EU manufacturing typically operates at 80-85% of available capacity and that, while rates of capacity utilisation vary over the economic cycle, long-term trends are quite stable. The rates are also broadly consistent across Member States, although it appears that there may be more spare capacity available in southern Member States. For construction (see Figure III.5), the data from Eurostat are based on surveys that ask what the constraints are on production rather than the rate of capacity utilisation. This is not directly comparable to the data for the manufacturing sector but the figures suggest that around 30-40% of firms do not report constraints on production at any one time, so it seems reasonable to draw a similar conclusion[15].

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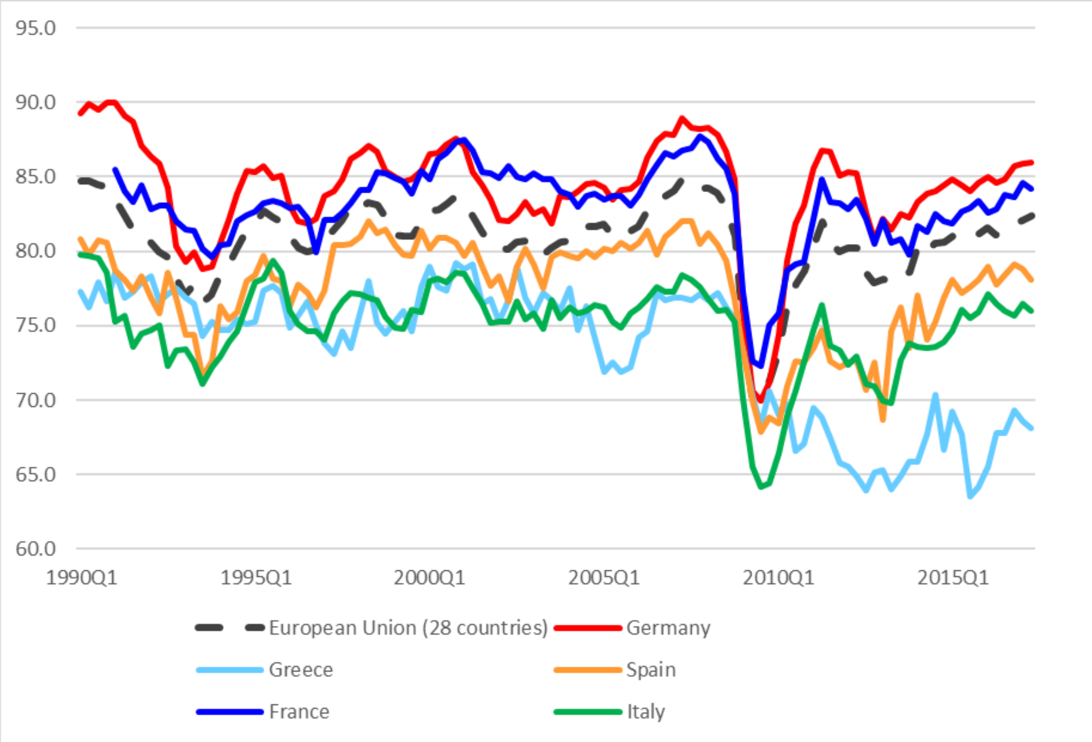
optimal behaviour, meaning that output is determined by supply-side constraints and prices adjust fully so that all the available capacity is used. Unlike the E3ME model, CGE models also typically assume constant returns to scale, perfect competition in all markets, maximisation of social welfare measured by total discounted private consumption and no involuntary unemployment. Some CGE models, including GEM-E3, have been developed to relax some of these assumptions but the modelling approach and underlying theory still contrast to that of E3ME.

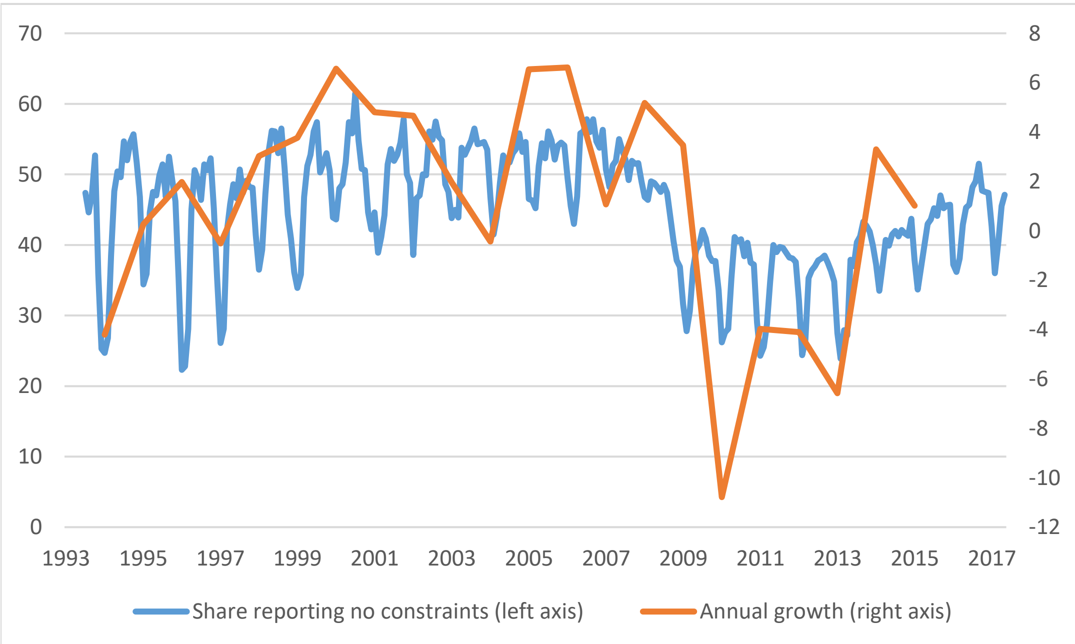
[15] The Eurostat survey includes 'lack of demand' as a constraint on production, which explains why less firms report no constraints when output in the sector falls. The actual value for the share of firms facing no supply-side constraints may thus be higher than reported in the chart.

Figure III.3: Rates of capacity utilisation in manufacturing (%)



Sources: Eurostat, ref teibs070

Figure III.4: Construction firms reporting no constraints on production (% of total)



Sources: Eurostat, ref ei_bsbu_m_r2

These findings suggest that if there were sufficient demand, manufacturing and construction firms in the EU would be able to increase production by around 15-20% in the short run without facing hard capacity constraints[16]. What is less clear is whether firms would ever be able to produce at 100% capacity; if not, then the potential for raising production in some Member States could be lower, e.g. 5-10%.

Either way, firms are unlikely to increase production by this much without raising prices, to reflect supply constraints. For example, costs could increase from paying staff overtime or renting additional machinery on short-term leases.

The issue is particularly acute when a large amount of production is required in a short period of time, as is the case in the scenarios presented in this report (see results in Part IV). However, there is quite a long lead time, so any constraints on production could potentially be offset by ensuring that firms prepare adequately, for example by investing in new production capacity.

Regarding potential capacity constraints on finance and investment, there is little empirical information in the published literature beyond that from central banks (McLeay et al, 2014), even though this is recognised as a key issue. Limitations on data are important here, as well as the absence of counter-factual scenarios to assess potential effects. Many studies avoid the issue by either showing gross effects to the sectors positively affected, or implicitly assume full crowding out. One of the few studies that address the issue explicitly is Pollin et al (2014), which notes crowding of investment out is unlikely to occur in a decarbonisation scenario because investment by the energy sector overall is reduced compared to baseline (as, for example, investments related to fossil fuel are displaced). However, this study covers the US only, where the domestic energy sector is much larger than in Europe.

In summary, constraints on capacity and potential crowding out are recognised as key uncertainties in the model results. The modelling approach adopted in this study considers how crowding out might occur in all three markets outlined above. The modelling results presented in Part IV include scenario versions without crowding out and with partial crowding out, based on assumptions about the degree of crowding out (the rate at which increases in one form of economic activity lead to reductions in economic activity elsewhere in the economy). As the results show, this is a key assumption, as it can directly impact on the magnitude and even direction of the results.

The first variant uses the default option in E3ME in which there is no crowding out of finance and only limited crowding out in product markets (i.e. the prices increase through the normal output equations described above). There is the potential for labour market crowding out through increasing wage rates but the impacts on employment in the scenarios in this report are not large enough to push Member States' economies towards full employment. It is important to be clear that all the investment is paid for and the accounting identities in the model still hold (see next section), but there is no constraint on the amount of finance or lending that is available to the economy.

The second variant assumes that there is 'partial' crowding out, which could result from capacity limits in either capital or product markets. A fixed limit was imposed on the increase in investment (compared to reference case). The following methodology was developed:

1. Assess each scenario according to the approach outlined in the first variant.
2. In each Member State find the sector that grows by the most in each scenario.

[16] There are no data available on long-term constraints. As discussed below, the direct translation from short run to long run that was used in the analysis is conservative in nature as firms could be expected to increase capacity if they expect higher rates of future production.

3. Set a limit of 15% (above reference case) growth for any single sector in each Member State up to 2030.
4. Assume any investment beyond the 15% limit in each Member State is fully crowded out, impacting on all the sectors that supply investment goods.

In each case, the sector identified in the second stage is Construction, as it plays a critical role in improving energy efficiency. It is assumed that if the construction sector is unable to *install* new equipment in buildings then demand for the equipment itself will fall, meaning that output in the supplying (i.e. manufacturing) sectors is also reduced.

The assumption that increases in sectoral output are limited to 15% is based on the Eurostat data referenced above; it could be considered conservative as the figures suggest larger increases in production would be possible. It is also reasonable to suggest that firms would increase capacity in the period to 2030, if they expected higher rates of demand, suggesting that the 15% constraint might be overly restrictive, i.e. the long-term constraints may be less restrictive than the short-term ones identified in this section.

The effect of the approach is to increase the degree of crowding out as the level of ambition increases. It should be noted that some countries (Latvia and Hungary) reach the 15% limit even in the EUCO30 scenario, but most of the larger Member States are only affected in the EUCO35 and EUCO40 scenarios. Table III-1 summarises the degree of investment that is crowded out at EU level in each scenario. A similar table with the degree of crowding out at Member State level is provided in Appendix E.

Table III-1 Share of investment that is crowded out in partial crowding case, %

	EUCO27	EUCO30	EUCO33	EUCO35	EUCO40
EU28	0.0	0.0	3.1	8.1	19.0

2.4 Financing the energy efficiency improvements

Another important assumption in the modelling is how the energy efficiency improvements will be paid for. In the main scenarios reported in Part IV it is assumed that the investment is 'self-financed', meaning that the sector that pays for the measures is the one that benefits from reduced energy costs in later years. The exact assumptions are:

- Households pay for investment in energy products by reducing spending on other products (in proportion to baseline expenditure).
- Businesses pay for investment in energy products by raising prices.
- Government pays for investment in energy products by raising standard VAT rates.

As noted in the previous section, it is important to note that all the investment is paid for and the scenarios represent shifts in expenditure patterns rather than additional spending, for example with less spending on consumption goods and more on investment goods. The discussion on crowding out in the previous sector relates largely to whether this reallocation is possible or not, between time periods and within the context and constraints of the wider economy.

This study considers one alternative option for financing the energy efficiency investment, which is that the programmes are entirely funded with public money. The results for this option are presented separately in Part IV, Section 2.8; many of the impacts are the same as in the main scenarios (as the level of energy efficiency is the same) but there are some important differences in the economic results. Under this alternative option national governments provide the financing for the energy efficiency measures and increase VAT rates to cover the costs. The direct impact is therefore budget-neutral.

It is important to note that the study is not able to address the important question of how the financing arrangements might affect the degree of energy efficiency that is implemented. This is due to the methodological approach used, in which the amount of energy savings is taken from the results of the PRIMES model (i.e. they are fixed before the assumption about financing is made).

2.5 Energy security

There are many different factors in energy security, including exposure to changes in costs and restrictions to supplies either from international sources or domestic providers. In general, an improvement in energy efficiency could be expected to lead the economy being less exposed to shocks in energy supply, therefore improving security. However, the actual situation may be more complicated than that and national circumstances must be taken into account.

This study focuses on the share of energy imports in GDP as a key indicator of energy security. A reduction in the ratio of energy imports to GDP for one country means that it is less exposed to changes in international commodity prices or geopolitical movements.

Although this is not a standard output from the E3ME model, this estimate of energy security may be inferred from the model results. A similar indicator may be derived from the PRIMES model results, but the E3ME figures include the effect of impacts on GDP (see Part IV , Section 2) and further changes in energy demand due to rebound effects[17].

Any further discussion of energy security becomes rather qualitative in nature, as it must account for the risks associated with exposure to particular suppliers. The European Commission published an assessment of exposure at Member State level in 2014[18]; in this study an additional calculation was made using 2016 data. The method applied was:

- Obtain shares of domestic gas extraction from the IEA or national government estimates.
- Obtain from COMEXT data in the Eurostat database[19] import shares for natural gas and LNG natural gas for each Member State.
- If a Member State imports from another Member State, split this between the second country's domestic production and its imports (i.e. follow back along the pipeline).
- Supplement missing data from COMEXT with IEA or national government estimates.

Although the approach is quite simple, it gives quite a clear indication of exposure to individual suppliers. Results are presented for key Member States in Part IV, Section 2.7. A list of references is provided in Appendix G.

[17] i.e. GDP is given as exogenous in PRIMES but calculated endogenously in E3ME.
[18] See https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/energy-security-strategy
[19] See http://epp.eurostat.ec.europa.eu/newxtweb/

3 Health

3.1 Key issues and scope of work

Outdoor (ambient) and indoor pollution have many negative effects on human health and mortality. Even when concentrations are below the thresholds determined by the EU and national regulations, health damage can be serious over the long run. Energy efficiency has an important role to play in decreasing health problems related to both indoor and outdoor pollution.

Being exposed to high levels of outdoor pollution is linked to a large range of health complications and premature mortality related to respiratory, coronary and cardiac diseases as well as cancers (e.g. lung cancer). The origin of ambient pollution is multi-source, but a few sectors dominate. In France, for instance, the four main sectors that contribute most to outdoor pollution are: transportation, residential (wood), industry, agriculture (French Senate, 2015). At the scale of OECD countries, road transport is likely responsible for about half the total health-related costs due to outdoor pollution (OECD, 2014). Several studies have shown that actions to decrease air pollutant concentrations bring about benefits to public health (OECD, 2014; WHO, 2004; WHO, 2014; WHO, 2016). Actions that would reduce key sources of outdoor air pollution include supporting cleaner transport, power generation, industry and better municipal waste management.

When it comes to indoor air pollution, properly designed actions to improve building energy performance could have major co-benefits for public health. However, there are also risks involved with the possibility of poorly designed interventions leading to unintended consequences, as energy efficiency retrofits that alter the fabric heat loss can also increase the air tightness of the dwelling. Living in cold and poorly ventilated homes is linked to a range of health problems. Retrofits that improve indoor temperatures may have positive impacts on mental health and cardiorespiratory diseases, but could also have negative impacts on respiratory conditions due to the increased levels of indoor pollutants.

To measure and quantify the major positive and negative impacts of energy efficiency, this report focuses on outdoor air quality, as a decrease of the concentration of a variety of air pollutants is likely to have considerable public health benefits. To measure and quantify the major positive and negative impacts in improved energy performance of buildings, this study focuses on the following issues that particularly affect public health:

- temperatures and ability to keep homes adequately warm, that are directly related to energy efficiency improvements in buildings
- air tightness levels that are generally increased through energy efficiency improvements, and adequate ventilation which needs to be considered cautiously when setting energy efficiency requirements
- indoor air quality, resulting from the concentration of major indoor air pollutants (VOC pollutants such as benzene, radon, carbon monoxide, NOx): indoor air quality strongly depends on energy efficiency, even if the links can be either positive or negative, depending on the ventilation level resulting from the efficiency improvements
- mould and dampness, generally resulting from the temperature level and the ventilation level of the building
- indoor lighting, which is in most cases improved thanks to energy efficiency improvements, and has major impacts on occupants’ health and well-being

3.2 Literature review and data sources

The literature review provides figures, ratios and statistics on the relationships between air pollutant concentrations, health physical impacts (increase/decrease in mortality, morbidity and sometimes other health damages) and the monetary valuation of these outcomes.

The results in this report are based on the available literature on the health benefits of energy efficiency and the impacts in terms of air quality. Using an approach based on coefficients, these are translated into economic terms (e.g. health costs associated with illnesses). The review of the literature from which the information has been gathered is presented in Appendix D.

3.3 Detailed approach

The main output indicators for health and well-being are outlined below.

Baseline for current mortality and morbidity cost due to indoor and outdoor pollution in the European Union

Some studies have monetised the annual economic cost of health impacts and mortality from air pollution in France, the European Union or the OECD countries (French Senate, 2015; OECD, 2014; WHO Regional Office for Europe, 2015). We draw the following figures and parameters from these reports:

- The cost of outdoor air pollution in OECD countries, both deaths and illness, was about USD 1,7 trillion in 2010. Available evidence suggests that road transport accounts for about 50% of this cost, or close to USD 1 trillion.
- The effects of air pollution in France cost some €100 bn each year, impact to health being the major expense (between €68 bn and €97 bn euros).
- In the WHO European Region as a whole, the estimated mortality in 2010 was approximately 600 000 premature deaths, which represents a marked decrease from 2005 for the Region overall. The annual economic cost of premature deaths from air pollution across the countries of the WHO European Region stood at USD 1.431 trillion. The overall annual economic cost of health impacts and mortality from air pollution, including estimates for morbidity costs, stood at USD 1.575 trillion.

Methods employed to measure this output indicator are generally based on the mean value of life, obtained through contingent valuation studies or willingness to pay surveys.

Opportunity cost of mortality and morbidity due to outdoor air pollution

The opportunity cost indicator measures the cost of mortality and morbidity due to outdoor air pollution. One previous study (AEA Technology Environment, 2005) measures the marginal cost of damage caused per tonne of pollutant ($PM_{2.5}$, SO_2, NOx, NH_3 and VOCs) for health and crops for each EU country in 2005. The key results of this study are shown in Table III-2.

Table III-2: Average damages per tonne of emission for the EU25 (excluding Cyprus), euros

	Minimum value	Maximum value
NH3	11,000	31,000
NOx	4,400	12,000
PM2.5	26,000	75,000
SO2	5,600	16,000
VOCs	950	2,800

Source(s): AEA Technology Environment, 2005

By plugging in the estimated decrease in tonnes of pollutants for each EU country in the different energy efficiency scenarios, it is possible to estimate the savings in health costs for each scenario (by isolating the crop aspect, which is out of scope). Estimated decrease in tonnes of pollutant (SOx, NOx and PM_{10}) have been calculated through the E3ME model, given the reduction in energy use compared to the EUCO27 scenario. The detailed approach is described in Part IV, Section 3.1.

Healthcare costs

The healthcare costs describe the variation in public finance due to outdoor air pollution. One study in the literature review calculated the impact on social security spending in France (French Senate, 2015). It estimates that it costs France some €100 bn each year, citing impact to health as the major expense (between €68 bn and €97 bn euros). The results of this specific study could be used to approximate the impacts of health care costs at European level. It is to be noted, however, that such approximation would suffer from the limitations, as the French case might not be representative due to multiple factors, including the following:

- Health costs vary between Member States, for example due to differences in labour costs
- The types of treatments that are available may also vary between Member States, and also over time (e.g. due to technological advances)
- The split of costs between public and private sectors is not constant; no allowance is made for individuals who are unable to pay for treatment

Comparison with the results in the EED Impact Assessment

The EED Impact Assessment includes estimates of health impacts that are derived from the GAINS model. GAINS is a highly sophisticated model that has been designed specifically for this type of assessment. The model is more advanced than the approach used here of linking E3ME results (see Section 4) to coefficients for healthcare expenditure. However, there is one other important difference in that the application of E3ME in this study also captures rebound and other indirect effects, which are not included in the analysis by GAINS (which is linked directly to the results from PRIMES).

4 Environmental impacts

4.1 Introduction

Energy efficiency improvements can positively affect the environment in several quite different respects. Focusing our attention on the indicator framework for monitoring the EU Sustainable Development Strategy[20], the following three areas are addressed:

- Energy and climate change – Measures to improve energy efficiency naturally lead to reductions in energy demand and thus consumption of fossil fuels. Reduced consumption of fossil fuels implies reduced emissions of greenhouse gases.
- Sustainable consumption and production (SCP) - This category comprises items such as the emission of local air pollutants and consumption of materials. Energy efficiency could potentially reduce the level of emissions of sulphur, particulates and other pollutants that are damaging to human health[21]. Energy efficiency measures may also imply increases in Domestic Material Consumption (DMC) when measures such as building retrofits are undertaken.
- Natural resources – Improved energy efficiency leading to reduced energy demand could lead to reductions in water demand and land use by the power generation sector.

The review of the relevant literature is presented in Appendix D, Section 4.

The assessment of the effect of energy efficiency measures on indicators covering the themes discussed above is carried out using the E3ME model. The main quantitative output indicators that E3ME can provide are:

- reductions in greenhouse gas emissions (Section 4.2)
- reductions in emissions of local air pollutants (e.g. SO_2, NOx) (Section 4.3)
- benefits of reduced energy consumption (mainly impacts on water consumption) (Section 4.4)
- impacts on material consumption (Section 4.5)

Some of these results also come from the PRIMES model but, as described in the sections below, the results from E3ME include indirect impacts, including rebound effects.

The approach for assessing each of these indicators is presented in the sections below.

4.2 Energy consumption and greenhouse gas emissions

The direct changes in energy consumption in the scenarios are given by the energy savings that are taken from PRIMES, but the results from the modelling exercise with E3ME include rebound effects and other indirect impacts. Here, the energy demand equations in the model are important. These equations are estimated using econometric methods, linking energy consumption to rates of economic production and energy prices.

When modelling energy efficiency (and particularly rebound effects) the link between rates of economic production and energy consumption (by fuel) are key. The relationships are not necessarily linear, for example a 5% increase in production may only require a 2% increase in energy consumption. The parameters are determined from the historical data.

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[20] The framework provides the basis for monitoring economic, social and environmental progress. See http://ec.europa.eu/eurostat/web/sdi/indicator-framework

[21] Although these are not assessed in detail here because this would entail double counting with the health impact area.

The model also accounts for the energy consumption required to produce energy efficient equipment and materials.

Total final energy consumption (see Part IV, Section 4.2) is disaggregated by carrier using a further set of econometric equations. There are twelve energy carriers defined, covering solids liquid and gaseous fuels, electricity and biomass. This approach allows for fuel switching, for example if there are changes in relative fuel prices.

As with energy consumption, the impacts on greenhouse gas emissions are to a certain extent determined by the results from the PRIMES model. However, the results from PRIMES take into account only direct energy savings and do not incorporate indirect rebound effects that may lead to additional energy consumption and emissions (see Section 2.2). Applying a macroeconomic model such as E3ME makes it possible to include these rebound effects.

The relationship between energy savings and CO_2 emissions is relatively straightforward to assess. Usually a linear approach is applied using fixed coefficients of units of CO_2 per unit of fuel consumption. There are two ways of doing this: either deriving the coefficients from historical data or using published coefficients (e.g. from the IPCC). However, these two approaches should produce very similar results. E3ME uses the former approach based on historical data, which allows the model to account for differences in fuel grades between countries (see Table III-3).

Table III-3: Average emission coefficients, EU28

	Average emission factors (tCO2 / toe)
Coal	3.44
Liquid fuels	3.04
Natural gas	2.45

Source: E3ME model

The total impact on CO_2 depends on how the economy reacts to increases in investment for energy efficiency and the link between the level of economic activity and fuel consumption (by fuel type) – combined, these comprise the rebound effect.

The economic impacts are described earlier in this chapter. The impact on energy demand in E3ME is determined by the model’s econometric equations that link energy consumption to changes in energy prices and rates of economic production.

4.3 Impact on local air pollutants

The Impact Assessment for the Energy Efficiency Directive includes an assessment of local air pollutants made by the GAINS model[22]. As noted in Section 3, GAINS is a sophisticated tool that is built for the sole purpose of this type of assessment. It goes far beyond the capabilities of E3ME in this area. However, the application of E3ME in this study also captures rebound and other indirect effects, which are not included in the analysis by GAINS (which is linked directly to PRIMES).

In the modelling with E3ME, pollution is linked to certain economic activities or fuel consumption. E3ME includes a treatment of SO_2 and NOx, but does not cover $PM_{2.5}$.

Coal combustion is a key source of emissions of SO_2 emissions and, to a lesser extent, NOx. It is not the only source, however, for example activity in the agricultural and

[22] http://gains.iiasa.ac.at/models/

transport sectors can also lead to these types of emissions. The data for emissions are taken from the EDGAR database[23]. All sources are included in the balances, even if they cannot be modelled endogenously in E3ME.

It is quite common for emissions of SO_2 and NOx to be converted to monetary terms. Usually most of the cost is attributed to healthcare and loss of productivity. Since in this study the estimation of the monetary effects is limited to human health effects (see Section 3 above), to avoid double counting, the environmental impacts are not monetised.

4.4 The energy sector's water requirements

Section 4.5 in Appendix D describes how it is possible to estimate water consumption by the power sector by converting from generation in GWh to cubic metres of water. The coefficients that are taken from Macknick et al (2011) are provided in Table III-4.

Most of the water that is consumed by the power sector is used for cooling. Renewable technologies have been allocated values of zero in the study because they do not use water in generation (although water may be used in their production). Hydro power has also been allocated a value of zero because its use of water does not preclude other use and therefore it is not defined as a withdrawal.

The results from the calculation depend on the power sector fuel mixes, which are derived from the PRIMES model. As EU ETS prices change in the EUCO scenarios there is some substitution between conventional and renewable power generation technologies which influences the results.

Table III-4: Water withdrawals by generation technology

	Water withdrawals m^3/MWh
Natural gas	1.16
Hydro	0.00
Nuclear	5.01
Wind	0.00
Biomass	3.99
Geothermal	0.00
Coal	4.57
Solar PV	0.00
Solar CSP	0.00

Source: Macknick et al (2011)

The literature review in Appendix D also presents an approach for land use requirements for the power sector, suggesting a proxy that could be used as impact on the natural environment. However, results tend to be dominated by changes in biomass use (which has a far larger land requirement than any other generation technology), which does not provide insights with respect to local amenity. As generation from biomass changes

[23] http://edgar.jrc.ec.europa.eu/

in the scenarios assessed in this report (again, for example, due to variations in the ETS price), results from this type of analysis could be quite misleading.

4.5 Impacts on material consumption

E3ME's submodel of material consumption is similar in approach to its energy submodel. It consists of a set of econometric equations that assess the rate of material intensity in each sector across seven material types (covering minerals and biomass), based on rates of economic production and material prices. There is feedback to the economic sectors that produce/extract materials (mainly agriculture, forestry and non-energy mining) through modifications to the sectoral linkages that are built into E3ME's economic accounting framework.

As material prices do not change by much in the scenarios presented in this report, the main impacts on material consumption are derived from changes in production. Even if material *intensity* does not change, increases in economic production will lead to higher usage of materials. In particular, the construction sector is an intensive user of materials and so material consumption would be expected to increase in scenarios where there is a rapid uptake of energy efficiency.

The main metric that comes from the modelling is Domestic Material Consumption (DMC), which is used as a key indicator by DG Environment in its analysis[24]. DMC only includes materials that are consumed domestically and does not include goods that are exported outside Europe. DMC usually includes consumption of fuels but this is excluded in the analysis in this report to avoid double counting.

5 Social aspects

5.1 Introduction

The E3ME model can only give a limited set of indicators for social impacts. The model results include:

- estimates of effects on income distribution
- estimates of employment and unemployment impacts

These are described in the following two sections. The third section summarises the findings from the EPBD report. These findings are highly relevant as many of the social impacts arise from the investment in energy efficiency in buildings.

It should be noted that the analysis is limited by the fact that it does not make any assumptions about the types of households that are most affected by the energy efficiency improvements, as this depends on policy details that are not yet available (in particular relating to finance mechanisms). However, it could be expected that if low income households were *targeted* in the overall efficiency programmes for buildings, then the results would be much more progressive than in the opposite case.

5.2 Impacts on purchasing power and the treatment in E3ME

In scenarios with more focus on energy efficiency in industrial sectors (or transport), it is important to consider indirect effects. For example, household real incomes could be

[24] See e.g. http://ec.europa.eu/environment/resource_efficiency/about/roadmap/index_en.htm

affected by changes in food prices or changes in the prices of other household goods. As different types of households have different purchasing patterns, the distribution of the indirect impacts can be quite uneven.

Without going to micro level, it is possible to use data published by Eurostat on household expenditure patterns to estimate the impacts of changes in product prices on different socio-economic groups (drawing on the modelling results). This approach is now well established through use in E3ME and other macroeconomic models (e.g. see the review in Ekins et al, 2011). Nevertheless, the limitations of the approach should be recognised, particularly with regard to the estimates of responses to changes in energy prices across different socio-economic groups (for which the necessary data are not available). The modelling therefore does not include the possibility that more wealthy household groups have more potential to change consumption patterns in response to changes in price. We provide a short separate discussion of this factor in Part IV.

The E3ME approach is based on two components. The first of these is the income component. For each social group, the shares of income from wages, benefits and other income (minus their tax deductions) are scaled in line with the aggregate model results for wages and welfare benefit payments, and so forth. This means that a scenario that includes increases in social benefit rates would show positive results for low income groups who rely more on benefits. The second part links household expenditure survey data to the model results for consumer prices by category of consumption. This is mainly used to assess the effects of changes in energy prices, as in many countries low income households use a larger share of their incomes for space heating; it is less relevant for energy efficiency scenarios in which energy prices do not change, but it is noted that the prices of other goods may change in the scenarios due to indirect effects.

5.3 Unemployment as a social indicator

Unemployment is one of the key social indicators that policy makers review. It is also one of the outputs from the E3ME model. In the modelling, unemployment is defined as the difference between labour supply and employment (labour demand) and so can be affected by changes in either supply or demand. Labour market results are reported in Part IV, Sections 2.2-2.5.

Issues relating to unemployment are not generally well explored in model-based studies, in part because the standard CGE models that are often used are very limited in their treatment of unemployment (GEM-E3 is an exception as it has been developed further). The amount of literature that describes unemployment effects is therefore quite limited, and it is usually left to the reader to infer changes in unemployment from changes in employment (when gross impacts are quoted) or not mentioned as part of the analysis.

A bigger issue, that is very difficult to explore with a modelling approach, relates to the skills requirements across different sectors. This has been explored in considerable detail in a study that was published by DG EMPL in 2011 (European Commission, 2011)[25] and with reference to energy efficiency in the study for DG ENER in 2015 (European Commission, 2015)[26]. The 2011 study in particular showed that skills constraints could lead to both issues of displaced workers unable to find jobs and companies in growing

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[25] The full report *Studies on Sustainability Issues – Green Jobs; Trade and Labour*, Final Report for the European
Commission, DG Employment, 2011. Available at:
http://www.camecon.com/EnergyEnvironment/EnergyEnvironmentEurope/ModellingCapability/E3ME/publications.aspx

[26] The full report *Assessing the Employment and Social Impact of Energy Efficiency* (2015) is available from http://ec.europa.eu/energy/sites/ener/files/documents/CE_EE_Jobs_main%2018Nov2015.pdf

sectors experiencing skill shortages. The result could be both higher unemployment levels and a loss of production, potentially endangering the environmental targets that have been set.

Macroeconomic models are unable to address this issue, because they do not have the necessary detail in terms of skills. As outlined in the DG EMPL study (2015), available modelling approaches can convert sectoral results into occupations and skills groups but the skills groups are limited to low, medium and high. This is well short of the level of detail (e.g. machine operator) that would be required to assess potential skills gaps. At present, it is necessary to apply a qualitative assessment about whether it is possible for the required number of workers to move between sectors. However, existing literature has not sought to identify specific links of jobs resulting from energy efficiency with unemployment, or types of unemployment.

5.4 Incorporating results from the EPBD report

Most of the social impacts from energy efficiency arise from efficiency measures that are implemented in buildings. The EPBD report presents an approach with which to assess impacts on fuel poverty from energy efficiency. The analysis is not duplicated in this report, but given the relevance of those results in the context of this report, they are summarised in Part IV.

A more detailed description of the approach, including how the levels of energy savings were estimated at Member State level and how the approach was used to estimate quantitatively the impacts of each policy option in each of the impact areas, is available in Part III of the EPBD report.

6 Public budgets

6.1 Introduction

IEA (2014) provides a comprehensive overview of the potential public budget impacts of energy efficiency. The evidence review presented in the IEA report informs the discussion of public budget impacts presented both in the EBPD report and in this report.

The discussion of the impacts of energy efficiency on public budgets in the EPBD report focused on the public budget impacts of energy efficiency in buildings. The approach used in the EPBD report categorised the sources of the impacts of energy efficiency in buildings into three groups:

- investment impacts
- energy cost reduction impacts
- public health impacts

The mechanisms through which public budgets are affected by energy efficiency are largely the same, whether the efficiency measures are in buildings or other sectors of the economy. A similar approach is therefore applied in this report. Taking IEA (2014) as the starting point for assessing the effects of energy efficiency on public budgets, the main impacts that have been identified in the literature are summarised in Figure III.5. A review of the limited amount of relevant literature is presented in Appendix D.

6.2 Key issues and scope of work

A brief overview of the potential public budget impacts of energy efficiency across the whole economy is summarised below. More detailed information is available in the review of relevant literature in Appendix D.

Investment impacts

Investment impacts are the fiscal budget effects arising from public and private investment in energy efficiency. In many cases, investment is the first, essential, step in order to secure future benefits associated with energy cost reduction or public health outcomes (IEA, 2014).

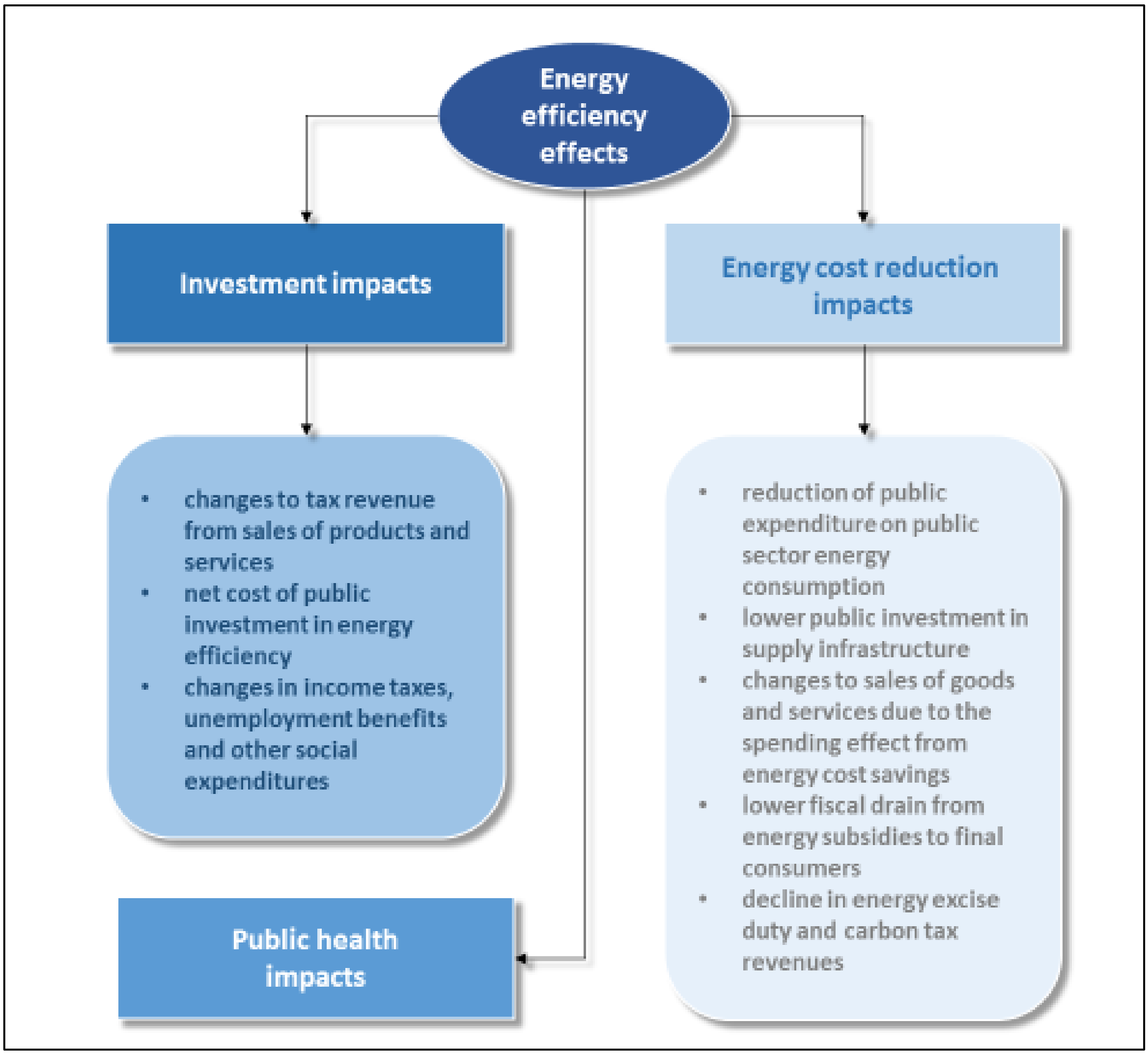
The direct impacts of investment in energy efficiency include:

- changes to tax revenue
- public sector investment in energy efficiency

The indirect impacts of investment in energy efficiency include:

- changes to employment levels and income tax revenue
- additional public revenues from other sources

Figure III.5 The effects of energy efficiency on public budgets



Source: Cambridge Econometrics' elaboration based on IEA (2014).

Energy cost reduction impacts

Energy cost reduction impacts are the effects arising from a reduction in energy expenditure as a result of improvements in energy efficiency. Assuming that there are no increases in energy prices as a result of reduced demand, energy demand reductions (or cost savings) can have a significant impact on the entire economy through second- and third-round effects. The impact of the energy cost reduction is often estimated to be significantly greater than investment effects, assuming that the energy efficiency measures that are implemented are cost-effective.

The direct impacts of energy cost reduction include:

- reduction in (ongoing) public expenditure on public sector energy bills
- reduction in public investment in energy supply infrastructure and maintenance (where this is a public sector responsibility)
- lower fiscal drain from energy subsidies
- decline in revenues from energy excise duty and any carbon tax

The indirect impacts of energy cost reductions arise primarily from changes to sales of goods and services due to the spending effect from energy cost savings.

Public health impacts

A key outcome arising from the assessment of health impacts is an estimate of reductions in healthcare costs (see Section 3). In most countries, at least part of these savings will accrue to public budgets and there may be further impacts on public budgets from changes to labour productivity induced by health impacts (e.g. reduced absenteeism or presenteeism). The impacts of both types of change on public finances can be substantial (see e.g. OECD, 2016) and, as noted by IEA (2014) are usually not included in analyses of energy policy.

In this report, the impacts of improved health are quantified in monetary terms in the health impact area. To avoid double counting they are not used in the calculation of public budget impacts as well. However, when interpreting the results from a narrow public budgets perspective it should be remembered that there will be additional impacts within public health services.

Pathways to impacts

Not all impacts or potential impacts of energy efficiency on public budgets fall neatly into one of the three categories presented here (investment impacts, energy cost reduction impact and public health impacts). Many of the impacts listed here under one heading can, at least potentially, generate further indirect (i.e. second- and third-round) effects that lead to an increase in overall economic output. For example, if supply chains increase production and employment rises as a result, this may cause further demand-based growth as newly employed individuals spend their wages across the economy (IEA, 2014), leading to further increases in taxation revenues.

6.3 Linkages to the modelling with E3ME

One of the main advantages of applying a macroeconomic modelling approach is that many of the factors that affect public budgets are included automatically in the model results, and they are fully consistent with the wider economic results, e.g. for GDP and employment. However, the macro modelling cannot cover all relevant aspects to public budgets and therefore the model results need to be extended. Our estimates therefore build on the results from E3ME, further disaggregating them to take into account certain specific factors.

Table III-5 summarises the main factors that are accounted for in our estimates.

Table III-5 Factors in the budget calculations

Factor	Availability
Factors affecting public revenues	
VAT receipts	In the E3ME results
Fuel excise duties	In the E3ME results
ETS auction revenues	In the E3ME results
Income tax receipts	In the E3ME results
Employees' social contributions	In the E3ME results
Employers' social contributions	In the E3ME results
Corporation tax receipts	In the E3ME results
Other tax receipts	Not estimated
Factors affecting public expenditures	
Public sector energy expenditure	Estimated off-model
Social benefits	Estimated using E3ME results
Public health expenditure	Not included to avoid double counting
Public investment in energy efficiency	Estimated off-model
Other public expenditure	In the E3ME results

The net impact of energy efficiency on public budgets will depend on the sum of several variables. First, the impacts of energy efficiency on public budgets can be either direct or indirect[27]. Second, the likely duration of the effects can vary considerably: some may be relatively short-lived, while others may be more enduring. Third, the impacts of energy efficiency on public budgets can be either positive (increasing revenue or reducing costs) or negative (increasing costs or reducing revenue). In some instances, a crowding out effect cancels out any positive effects, or simultaneously occurring positive and negative effects outweigh each other (IEA, 2014).

Results for public budgets are also influenced by how investment in energy efficiency in the private sector is financed. In the main scenarios, it is assumed that all investment is 'self-financed', meaning that it is paid for by the beneficiaries. In practice, there are provisions in the EED to provide public support for the investment, although the scale of financial support in absolute terms is difficult to model. Even if subsidies had been included, however, the net impact on public budgets would have been cancelled out if the modelling maintained the assumption that VAT rates are adjusted to cover energy

[27] Direct effects include factors that relate specifically to the energy efficiency, for example financing or lower public-sector energy bills. Indirect effects include those related to rebound effects or developments in the wider economy.

efficiency investment costs. The net impact on public budgets would only change if this kind of offsetting tax rate adjustment is not made automatically.

Part IV, Section 2.8 of this report provides economic results for a case in which *all* the investment is financed by national governments. As described above, this leads to higher VAT rates to cover the costs to the public sector. Given these assumptions, the results show that the impacts of changing the financing approach do not lead to qualitatively different outcomes.

The final point to note is that the financing mechanism could affect VAT receipts directly as well. If households pay for their own energy efficiency measures then they will pay VAT on the equipment that they purchase together with any installation costs (unless the products are exempted from VAT). When businesses or governments purchase the equipment, they would expect to deduct the VAT costs. The source of financing therefore influences overall taxation receipts, with higher receipts in scenarios where households make the purchases.

6.4 Tax revenues from E3ME

In each scenario, E3ME provides projections of the following tax receipts:

- VAT (on all products, including energy)
- income taxes
- social contributions (both employers' and employees')
- corporation taxes
- excise duties on energy expenditure, energy subsidies where relevant

Direct taxes

In the E3ME modelling, it is assumed that each Member State's tax rates remain unchanged, so direct tax revenues will vary in line with changes in the levels of wages or profits.

A single average tax rate is used in each country, with the rate calculated as tax revenues divided by the tax base (i.e. wages)[28]. This approach means exemptions from taxation are implicitly included in the average tax rate. It also means, however, that movements of individuals between income tax bands are not taken into account. In general, it can be assumed that the boundaries between the tax bands are held constant in real terms, so overall changes in wage rates do not affect the average tax rate (i.e. the scenarios do not present results in which many workers move into higher-rate tax bands, increasing the overall ratio of labour taxes to wages).

The key question here is whether there is any way that the composition of jobs in energy efficiency scenarios affect the average tax rates paid. For example, if all the additional jobs created had high wage rates then they would fall into higher tax bands and pay a higher average tax rate. However, the assumption of an unchanged tax rate is justified because:

- the jobs that are created in the scenarios cover a range of different sectors with different skills requirements, so not all additional jobs are either high or low-paid
- the changes in the levels of employment are not big enough to cause large shifts in taxation patterns

Social contributions, both from employees and employers, are estimated in the same way, based on fixed rates in relation to wages. It is assumed that current rates for social

[28] Data on tax revenues are obtained from DG Ecfin's AMECO database while data on labour costs are taken from Eurostat.

security payments are maintained throughout the projections. The approach for corporation tax is also similar in that a fixed rate is applied based on current data, although in this case the tax base is company profits.

Indirect taxes

The treatment of VAT in E3ME is to assign a rate to each of 43 product groups in the model for each Member State. The data are taken from Eurostat and the European database maintained by DG Taxud[29]. Energy products are distinguished in the categories so that, for example, the reduced rate of VAT for energy products in the UK is accounted for. The treatment therefore captures the effects of shifts in spending across product categories on total VAT receipts.

As described above, VAT rates are adjusted in the scenarios to compensate for both public expenditure on energy efficiency and any loss of revenue from auctioned ETS allowances that result from lower ETS prices.

Revenues from auctioned ETS allowances

ETS auction revenues, which are effectively treated as a tax, can also be obtained from the model results. The revenues are estimated as power sector emissions multiplied by the carbon price; with more energy efficiency, the power sector's emissions could be expected to fall due to reduced demand for electricity. There is clearly some approximation here as allocations do not match exactly against use of allowances (either between sectors or Member States) but this should not have a major impact on the outcomes.

In the analysis we have assumed that auctioning of ETS allowances is only required for the power sector, accounting for around half of the total allowances issued. In the future, industry sectors will be expected to purchase an increasing share of allowances but it is at present not clear the proportions that each sector would have to cover. The assumption of free allowances does not affect the results for energy consumption and ETS prices (which come from PRIMES) but if there were a higher share of auctioned allowances then a fall in the ETS price would have a larger negative impact on government budgets (and vice versa). Following the modelling assumptions in this report, that would have been compensated for by a small increase in VAT rates so that net public balances remain unchanged.

Other taxes

There are other taxes that contribute to public budgets, and if GDP increases then receipts from these taxes may increase too. Possible examples include charges on assets or other activities that lie beyond the scope of the E3ME model. Again, the impacts are likely to be small in all Member States but, again, the E3ME assumptions are conservative.

6.5 Public expenditure in E3ME

Public expenditure in E3ME includes final demands (e.g. health, education) and social transfers in the form of benefits. Final demand is given as exogenous in real terms in the model[30]. The only impacts on the costs of public services are therefore through changes in prices in the economy that result from variations in inflation rates. For example, if inflation increases then public sector wage demands are also likely to increase, which will mean higher costs for government.

[29] Taxation in Europe. See http://ec.europa.eu/taxation_customs/tedb/taxSearch.html

[30] To avoid double counting, we do not account for induced changes in healthcare costs (see Section 3).

There is a measure of social benefits in E3ME, but it is not very detailed, compared to the treatment in micro-simulation models. We therefore make a separate off-model estimate of the impacts on social expenditures. We assume that:

- pension payments (usually the largest category) are unchanged
- other payments are adjusted linearly with rates of unemployment plus labour market inactivity (for example, if the non-working share of the working age population falls by 1% then these benefit payments also fall by 1%)

These assumptions are based on a link between the scale of benefit payments and the size of the non-working population. As long as most of the non-pension payments are made to those who are not working, the representation is reasonably accurate. If a large share of benefit payments were made to the working population (e.g. through child or income support benefits) then the relationship could become stretched. It is clear that this is a simplification of highly complicated systems across Europe but it is the most suitable and transparent approach given the available data. As the results show, however, changes to benefit payments are in fact a relatively small part of the overall impact on public budgets.

Costs and savings related to public energy efficiency

In addition, the estimate of the effects of energy efficiency on public balances must take into account activities within the public sector. This is derived from the inputs to E3ME (see Section 2). The calculation must account for both the expenditure on energy efficiency and the energy savings made by the public sector.

The analysis should also account for public financing of private energy efficiency schemes, for example through subsidies or guaranteed loans (see discussion above). Results are provided for the public financing variant of the scenarios in Part IV, Section 6.3.

6.6 Interaction with the economic results

It is important to be clear about the interaction between the different impact areas to avoid double counting of the benefits. This is particularly the case for public budgets because there is a direct interaction with GDP and employment levels.

In the analysis, tax rates are in general held constant, matching the last year for which data are available, so that government receipts and expenditures change in line with wider economic conditions. The exception to this rule, as described above, is that VAT rates are adjusted to compensate for public expenditure on energy efficiency measures and any loss of ETS auction revenues in the scenarios.

Changes in GDP growth rates will therefore affect government incomes and expenditure, and the model has allowed these to accumulate. The economic and public budgets results presented in Part IV are thus additional.

7 Industrial competitiveness

Industrial competitiveness is a key issue for European policy makers. In this study, competitiveness is defined at the sectorial level for energy intensive industries (EIIs), with a focus on international trade. Competitiveness concerns are most evident in the sectors that are exposed to international trade, while there is a strong base in the local market. For example, if firms in these sectors have a large home market, they have more scope for benefitting from economies of scale, allowing them to charge a lower price for products that are consumed both domestically and in other countries.

7.1 Key issues and scope of work

The EU objectives set out to achieve higher levels of energy efficiency, both in manufacturing and in the construction sector, may have several effects on European competitiveness. In particular, the present report offers data on, and discusses the following:

- *Energy costs for energy-intensive industries*: energy costs account for a substantial share of costs in some sectors. This is especially the case for energy-intensive industries, for which energy costs may represent more than 3% of total production costs, and more than 10% of added value. Energy efficiency is thus one of the key opportunities for cost reduction and competitiveness improvements.
- *Impacts on SMEs:* Energy efficiency may be more difficult to implement in small enterprises and this report identifies the important and often overlooked role of SMEs in EIIs. For the construction sector, where the majority of companies are SMEs, the analysis pays extra attention to weaknesses and strengths regarding energy efficiency improvements, while offering projection of future demand and international competitiveness.
- *Global market shares of European sectors related to improved energy efficiency in construction and industry:* European energy-intensive industrial sectors (such as steel, pulp & paper, aluminium, cement, glass or chemicals), that are particularly exposed to international competition, may benefit from new opportunities arising from the shift in demand towards more efficient and higher quality materials and processes. This report examines the impact of EU energy efficiency target-setting in improving industrial competitiveness.
- *Emergence and positioning of European firms on breakthrough technologies and innovation in energy efficient products and solutions:* New technologies and innovation will certainly be a key pillar to achieving energy efficiency targets. For example, innovation on energy-saving building materials, new efficient cooling and heating technologies, or even smart-meters, will contribute to improved energy efficiency across all sectors, and for EIIs in particular. European firms may position themselves on disruptive innovation and improve competitiveness in these fledgling markets.
- *Investment attractiveness of the European construction sector:* Market trends for construction, renovation and rehabilitation in the housing and services sectors may trigger new opportunities for value creation. Emerging business models of energy service companies (ESCOs) have the potential to improve the value added of European SMEs.
- *Increase in productivity:* Workers' productivity is closely tied to their indoor working environment; the health effects of improved energy efficiency in buildings may result in a better productivity and, ultimately, affect competitiveness.

7.2 Competitiveness indicators for Energy Intensive Industries

Evaluating competitiveness is realised by examining comparable indicators, which in the case of EIIs are the number of patents these industries (to evaluate innovation), the historical prices for energy, the energy intensity and the energy cost impact.

<u>Energy intensity and the energy cost impact</u>

The indicators for energy intensity and the energy cost impact are estimated for industrial sub-sectors, to provide information on how effectively energy is used in comparison to the value added of the industry. The formula's for estimating these two indicators are as follows:

$$\text{Energy intensity} = \frac{Total\ energy\ consumption\ of\ the\ industry\ (ktoe)}{Value\ added\ of\ the\ industry\ (million\ €)}$$

$$\text{Energy cost impact} = \frac{Total\ energy\ cost\ of\ the\ industry\ (million\ €)}{Value\ added\ of\ the\ industry\ (million\ €)}$$

Energy intensity is based on data retrieved from the PRIMES 2016 results. Its evolution represents the effect on sub-sector efficiency in each scenario. The energy cost impact indicator evaluates the effectiveness of production, and thus competitiveness, by comparing the profitability of the industry, to its energy cost requirements. It has been calculated by converting the ktoe quantity into MWh-equivalent before multiplying it with the electricity price assumptions taken from PRIMES. To allow for a more comparable result, it uses the pre-tax energy cost.

Innovation

Innovation is evaluated by examining the number of accepted patents. Patents specifically for energy efficient equipment, per industrial sector are not available as aggregates, and as such this methodology makes use of the accepted number of patents for the EIIs, in the EU and globally. It is assumed that in EIIs, since energy costs are a significant share of the expenditure, new technologies are adopted only if they provide better performance for the same or less cost, and a short payback period – i.e. patents that broadly include some element of energy efficiency. Patent statistics are retrieved from the WIPO statistics database under the categories of:

- Electrical machinery, apparatus, energy
- Basic materials chemistry
- Materials, metallurgy
- Chemical engineering
- Environmental technology
- Textile and paper machines

International competitiveness

Data on international competitiveness are drawn from the database of Oxford Economics, as value added of EIIs by region, historically. The Oxford Global Industry Model (GIM)[31] is used to forecast over 100 sectors across 68 countries. Gross value added and gross output forecasts are available across all countries and sectors, with capital expenditure available for 35 countries across all sectors, and output price data available for the US, Japan, China, Germany, France, UK and Italy. Data are classified using the NACE revision 2 sector classification at the 2-digit level, with more detail available in most manufacturing sectors. Forecasts are updated on a quarterly basis and take into account the latest production data available, as well as changes to the macroeconomic environment and corporate and regulatory developments.

Sector forecasts are driven by aggregate demand from three regional blocs – Americas; Asia-Pacific; and Europe-Middle East-Africa – as well as by national trends. Sector

[31] http://www.oxfordeconomics.com/forecasts-and-models/industries/scenario-analysis-and-modelling/global-industry-model/overview

demand from the three blocs is allocated to individual industries using weights based on regional input-input relationships. These relationships – derived from input-output tables – show the share of each industry's output that is driven by total final expenditure (consumer spending, investment, government spending and exports) and by intermediate demand. The model also takes into account the impacts of changes in competitiveness on an industry's market share, both regionally and domestically.

Finally, energy cost shares for EIIs are retrieved from the World Input Output Database based on information on inputs by energy product.

7.3 Literature review and data sources

The approach starts from analysis of the key energy efficiency legislation, notably the EED, the Eco-design Directive and the Energy Labelling Directive. The team identified provisions that are relevant to competitiveness for energy-intensive industries, industries that deliver/produce energy efficient investment goods, SMEs or the construction sector. The literature review from the EPBD report was then updated and the findings that showed a link between EU legislation and industrial competitiveness were further assessed.

The review in Appendix D discusses the EU provisions that are most relevant for competitiveness and the related literature sources that were analysed. The review also presents relevant sources of literature that consider the effects of smart financing on competitiveness.

Part IV. Results

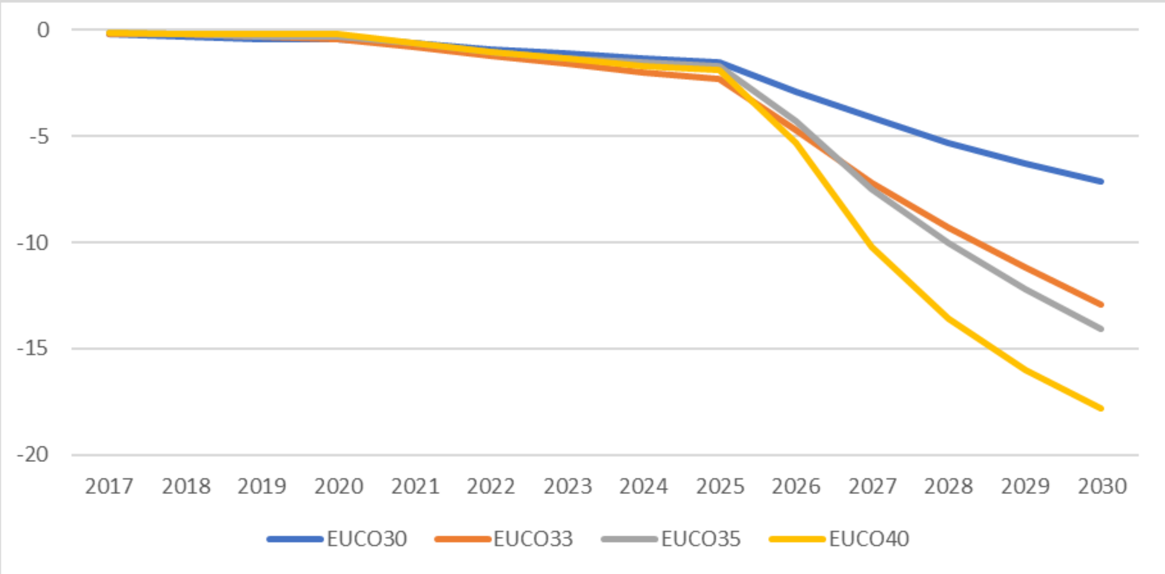
1 Introduction

This chapter presents the quantitative results from the analysis. It is split into the six impact areas, which are discussed in turn. Unless otherwise mentioned, the results are shown as percentage or absolute difference from the EUCO27 scenario. Therefore, they do not represent all the effects that energy efficiency could have, but just those that are additional to the impacts of a 27% energy efficiency target.

Where relevant, the modelling results include scenario versions without crowding out and with partial crowding out, based on assumptions about the degree of 'crowding out' (the rate at which increases in one form of economic activity lead to reductions in economic activity elsewhere in the economy, see Part III, Section 2.3 for more detail).

To put the impacts into context, Figure IV.1 shows the final energy reductions that are achieved in each scenario. As the tables show, the degree of crowding out has only a minor impact on final energy demand.

Figure IV.1 EU28 Final energy demand, % from EUCO27 scenario (no crowding out)



Note(s): Figure shows final energy demand, excluding consumption for non-energy purposes.

Source(s): E3ME, Cambridge Econometrics

1.1 Rebound effects

The changes in final energy demand in the scenarios are not the same as the changes in final energy demand reported by PRIMES. The direct changes in final energy demand that result from the investment in energy efficiency from PRIMES are entered to E3ME as closely as possible, subject to the differences between the models' historical data and classifications.

However, energy consumption is not fixed as exogenous in E3ME and secondary, endogenous effects also affect rates of energy demand. The endogenous effects can be positive or negative but one factor typically outweighs the others: rebound effects.

The importance of rebound effects is discussed in Part III, Section 2.2 of this report. Direct rebound effects are already incorporated in the results from PRIMES but indirect rebound effects are generated by E3ME. There are both potential short and long-run impacts:

- In the short run energy consumption may increase in order to produce and install energy efficient equipment.
- In the long run, savings from reduced expenditure on energy may be used to buy other goods and services that require energy in their production processes.

The rebound effect is strongly linked to many of the other impacts described in the sections below. For example, rebounds in energy consumption are in part driven by higher levels of GDP and employment in the scenarios.

Table IV-1: The scale of indirect rebound effects and implications on energy savings achieved (compared to 2007 baseline), EU28 in 2030

	No Crowding out		Partial crowding out	
	Rebound effect	EE savings in 2030	Rebound effect	EE savings in 2030
EUCO30	0.0%	30.0%	0.0%	30.0%
EUCO33	6.1%	32.6%	6.1%	32.6%
EUCO35	9.4%	34.2%	8.7%	34.3%
EUCO40	27.4%	36.4%	25.6%	36.7%

Source(s): E3ME, Cambridge Econometrics

Table IV-1 shows the extent of the rebound effect in the model results. The scale of the rebound effect is calculated by dividing the outputs from E3ME (which include rebound effects) by the inputs to E3ME (which do not). So, for example, in the EUCO40 scenario without crowding out, E3ME predicts that energy consumption would increase due to indirect rebound effects by enough to counteract 27.4% of the energy savings in the model inputs for that scenario.

In the less ambitious scenarios, the scale of the rebound effect is close to zero, as other impacts in the economy (e.g. through prices) offset the changes to energy consumption. However, as the level of ambition increases, it is clear that the scale of the rebound effect also increases. This means that, for example, the EUCO40 scenario achieves a reduction in energy consumption of between 36% and 37% in 2030 (compared to the 2007 baseline), rather than savings of 40%. However, for the other scenarios, the realised energy savings are quite close to the targets specified.

The reason for the increase is that, as the level of ambition increases, the amount of investment per additional unit of energy saving also increases (see next section). Higher investment levels require more energy in production and also create more jobs, leading to increases in consumption of goods that require energy. Combined, these effects lead to around a quarter of the initial energy savings being offset by increases in energy consumption for other reasons.

2 Economy and labour market

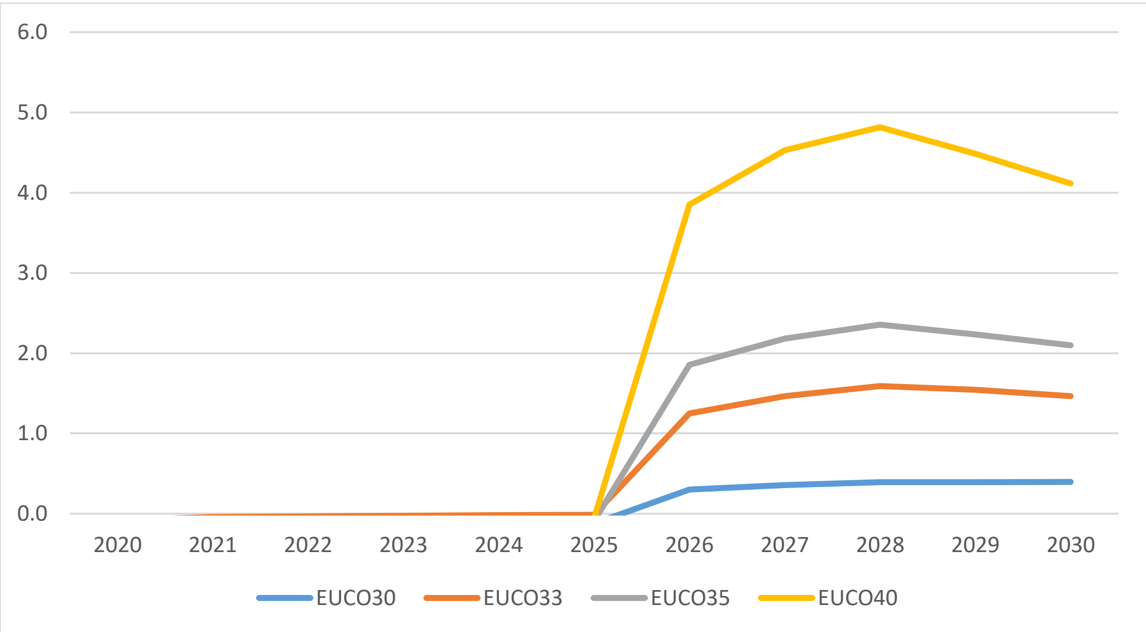
This section presents the economic results from the modelling exercise with E3ME. It starts by showing the macroeconomic impacts, then goes into more detail regarding employment impacts. The time horizon for this analysis is 2030.

2.1 Macroeconomic impacts at EU level

The economic and labour market impacts largely come from the E3ME model results. The projected GDP impacts over time for the EU28 are shown in Figure IV.2 and Figure IV.3 The results are close to zero up to 2025 and positive after 2025. By 2030, the GDP effects grow in line with the increasing levels of ambition of the energy efficiency policies (relative to the EUCO27 scenario). In the 'no crowding out' case, GDP impacts vary between 0.4% in EUCO30 and 4.1% in EUCO40. In the 'partial crowding out' case, the impacts are still positive but are smaller, reaching to 2.2% by 2030.

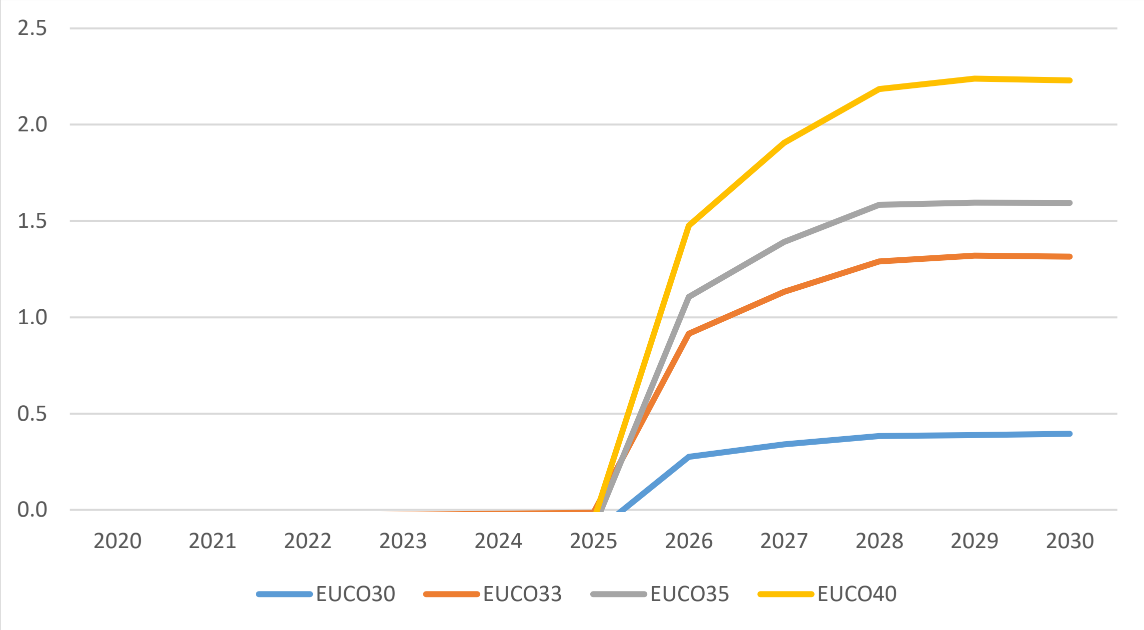
The time profile of the results shows the importance of the timing of the energy efficiency measures. The results from E3ME reflect the results from the PRIMES model. It is to be noted that given that the PRIMES model output follows a five-year period routine, it is not possible to highlight results which are likely to happen also before 2025. Between 2025 and 2030, however, investment increases rapidly according to PRIMES, especially in the more ambitious scenarios. The economic and labour markets therefore become much bigger. The quite sharp increase in production that takes place after 2025 is important in the context of crowding out (see Part III, Section 2.3), as firms would have relatively little time to expand production if they were not expecting the additional demand.

Figure IV.2 EU28 GDP, 2016-2030, % from EUCO27 scenario (no crowding out)



Source(s): E3ME, Cambridge Econometrics

Figure IV.3 EU28 GDP, 2016-2030, % from EUCO27 scenario (partial crowding out)



Source(s): E3ME, Cambridge Econometrics

Table IV-2 summarises the macroeconomic results for 2030. Overall, the magnitude of the impacts increases as the scenarios become more ambitious, reflecting the scale of investment needed to achieve the more ambitious energy efficiency targets.

In all five of the energy efficiency target scenarios there are reductions in fuel imports, with the size of the reductions increasing as the level of ambition in the scenarios increases. Reductions in fuel imports are one of the main drivers of the positive GDP results. If households spend less on fuel then their disposable income for other purchases increases. The model equations estimate how the additional income is spent but it is likely to be across a range of goods and services. As many of these goods and services are produced domestically (within the EU), there is a boost to domestic rates of economic activity, leading to higher GDP and employment (see next section). While imports of other goods and services will also increase, the import content on non-energy products is usually much lower than the import content of energy products, so a shift away from spending on energy goods is beneficial for Europe’s economies.

Trade patterns are also affected by the level of energy efficiency investment undertaken by businesses. If European firms can cut their energy bills and overall cost base by investing in energy efficient practices then their international competitiveness will be boosted, potentially leading to higher market shares both in domestic markets and abroad. However, the short-term costs of additional investment in energy efficiency may harm competitiveness and so it is important to consider how the investment may be financed (see Section 2.8). Section 7 discusses the overall impacts on competitiveness.

The impact on household real incomes and expenditure in 2030 is also positive in all five scenarios. The main driver for higher household expenditure is an increase in employment (see next section). Wage rates also increase slightly due to an increase in average productivity per worker, boosting household incomes further.

There are also impacts on real incomes from changes in prices in the scenarios. The inflationary effects shown in Table IV-2 result at least in part from changes in VAT rates, reflecting the modelling assumption that higher VAT rates are used to raise revenues to fund additional investment in energy efficiency in the public sector (see Section 6 for discussion of the impacts on public budgets). The pricing behaviour of firms is also important in determining the effects on inflation. In the modelling, it is assumed that firms will in the short run increase prices to cover the costs of the investments that they make. In the longer term, however, firms may be able to reduce costs in response to lower energy bills; this is also reflected in the model results.

Although household incomes and expenditure are often used as a proxy for welfare, in scenarios of energy efficiency policy the proxy is not accurate because investment made in earlier years also affects welfare.

For example, if households can achieve the same indoor temperature while paying for less energy, then household expenditure is reduced but welfare does not decrease. If households divert spending from energy to other products, while still maintaining the same indoor air temperatures, then welfare increases despite expenditure remaining unchanged.

In summary, if household expenditure is to be used as a proxy for welfare in this study, the limitations must be recognised. However, as the scenario results show both increases in household expenditure and less spending on energy to achieve the same (or better) indoor environment, one can conclude that there would be positive welfare impacts on European households in aggregate.

Table IV-2 also shows that assumptions about the degree of crowding out can have a considerable impact on the results. In the scenarios with partial crowding out there are limits to how much construction can increase activity without impacting on other economic sectors (see discussion in Part III, Section 2.3). As would be expected, the macroeconomic impacts become less favourable if the degree of crowding out increases because the available capacity is used up and any additional investment displaces economic activity in other sectors. The potential effects of crowding out are particularly noticeable in the most ambitions scenario (EUCO40), where capacity constraints impose the strongest restrictions on output and the degree of crowding out is greatest; while in the EUCO30 scenario there is enough spare capacity in the economy to carry out all the additional investment, in the EUCO40 scenario 19% of the additional investment displaces investment elsewhere in the economy (see Table III-1).

With partial crowding out, the potential GDP increase in 2030 falls from 4.1% to 2.2% (for the EU in EUCO40, relative to the EUCO27 scenario). In comparison, in the EUCO30 scenarios, there is no difference between the no crowding and partial crowding variants. In summary, the amount of spare capacity is important in determining the potential scale of positive outcomes, especially as the level of ambition increases.

Table IV-2 EU28 summary of macroeconomic impacts, 2030, % from EUCO27 scenario

	Degree of crowding out	EUCO27	EUCO30	EUCO33	EUCO35	EUCO40
GDP (€2013bn)	No crowding out	18,045	0.39	1.45	2.08	4.08
	Partial crowding out	18,045	0.39	1.30	1.58	2.21
Employment (m)	No crowding out	234	0.17	0.68	1.04	2.08
	Partial crowding out	234	0.17	0.63	0.85	1.40
Consumer expenditure (€2013bn)	No crowding out	10,255	0.09	0.93	1.33	2.81
	Partial crowding out	10,255	0.09	0.72	0.63	0.33

Investment (€2013bn)	No crowding out	4,131	1.68	5.04	7.67	14.95
	Partial crowding out	4,131	1.68	4.79	6.75	11.23
Exports (€2013bn)	No crowding out	3,722	0.00	0.14	0.22	0.51
	Partial crowding out	3,722	0.00	0.12	0.18	0.32
Imports (€2013bn)	No crowding out	2,921	0.28	1.31	2.25	4.75
	Partial crowding out	2,921	0.28	1.16	1.76	2.91
Price index (2013=1)	No crowding out	1.35	1.23	2.69	4.24	7.62
	Partial crowding out	1.35	1.23	2.57	3.82	6.03

Source(s): E3ME, Cambridge Econometrics

2.2 Employment impacts at EU level

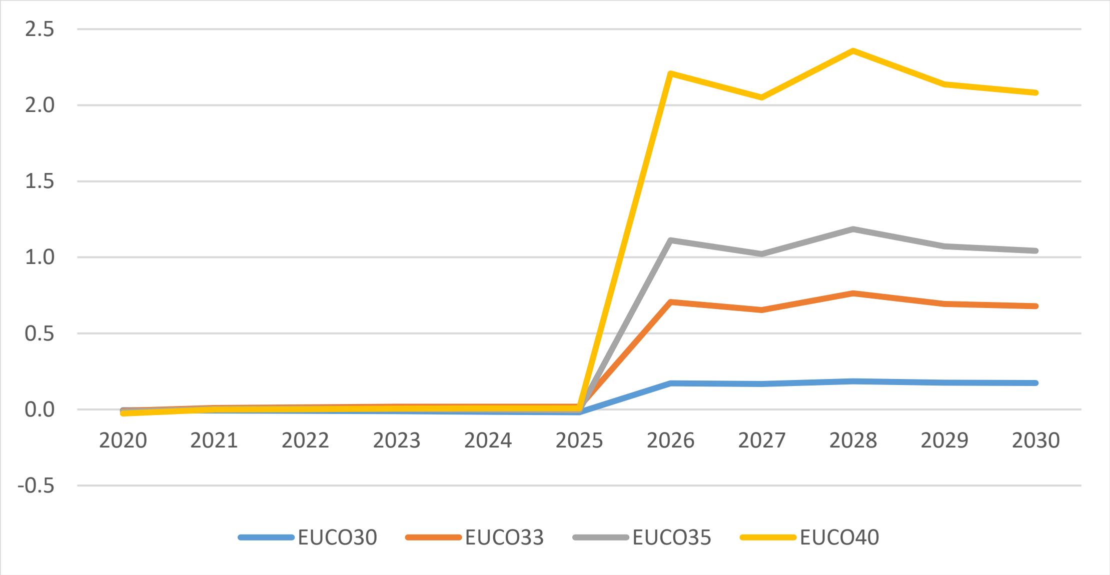
The net employment effects are shown in Figure IV.4 and Figure IV.5. The scale of the employment effects is determined by:

- how much economic production increases by
- the labour intensity of the sectors in which economic activity increases
- how wage rates respond

The scenarios all show positive impacts on employment, with most of the benefits being seen after 2025, when investment increases. Employment is boosted by both higher levels of production in the economy (i.e. higher GDP) and a shift in production towards more labour-intensive sectors (e.g. construction, engineering). While there are some increases in wage rates, these have a relatively minor impact overall.

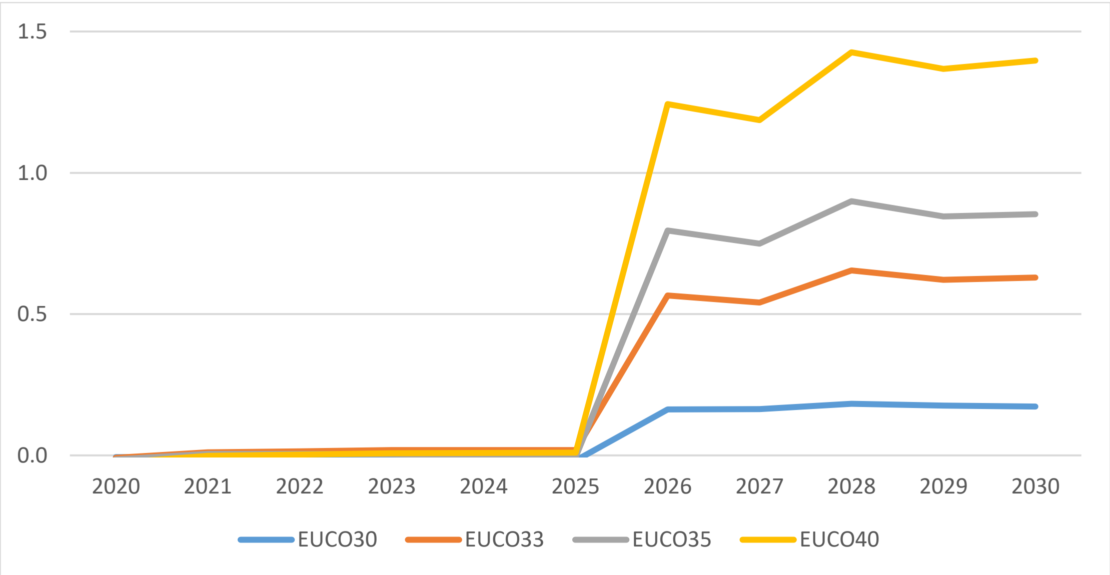
Sectoral impacts are described in Section 2.6.

Figure IV.4 EU28 employment, 2016-2030, % from EUCO27 scenario (no crowding out)



Source(s): E3ME, Cambridge Econometrics

Figure IV.5 EU28 employment, 2016-2030, % from EUCO27 scenario (partial crowding out)



Source(s): E3ME, Cambridge Econometrics

2.3 Unemployment

Table IV-3, Figure IV.6 and Figure IV.7 show the impacts of improved energy efficiency on unemployment in Europe. The results are generally positive and, beyond 2025, all scenarios show a reduction in unemployment. Again, the magnitude of the impacts grow in line with the ambition of the energy efficiency target, with the more ambitious scenarios seeing greatest decline in unemployment by 2030.

The data are again presented for both the 'no crowding out' and 'partial crowding out' scenario variants. This is because the impact on unemployment is smaller for the more ambitious scenarios when a certain degree of crowding out is assumed. The labour market itself presents one possible source of crowding out as if, for example, the EUCO40 scenario was to bring more than 3 million people out of unemployment, there would likely need to be a substantial retraining programme across Europe so that the available workers would have the necessary skills to engage with the construction and engineering sectors.

As discussed in Part III, the modelling is not able to address potential skills shortages but any bottlenecks would depend both on location (at a sub-national level) and also other labour market developments. If there were skills shortages, the economic outcomes would be worse and it might become impossible to meet the specified energy efficiency targets. Ensuring an adequately skilled workforce remains a key issue for policy makers.

In addition to the reduction in the number of unemployed workers, there is also some increase in labour market participation in the scenarios, as higher wage rates[32] and lower unemployment rates may encourage more people to seek work. The magnitude of this effect is smaller than the reduction in unemployment, but it explains why the reduction in unemployment does not match in absolute terms the increase in employment presented earlier in this chapter.

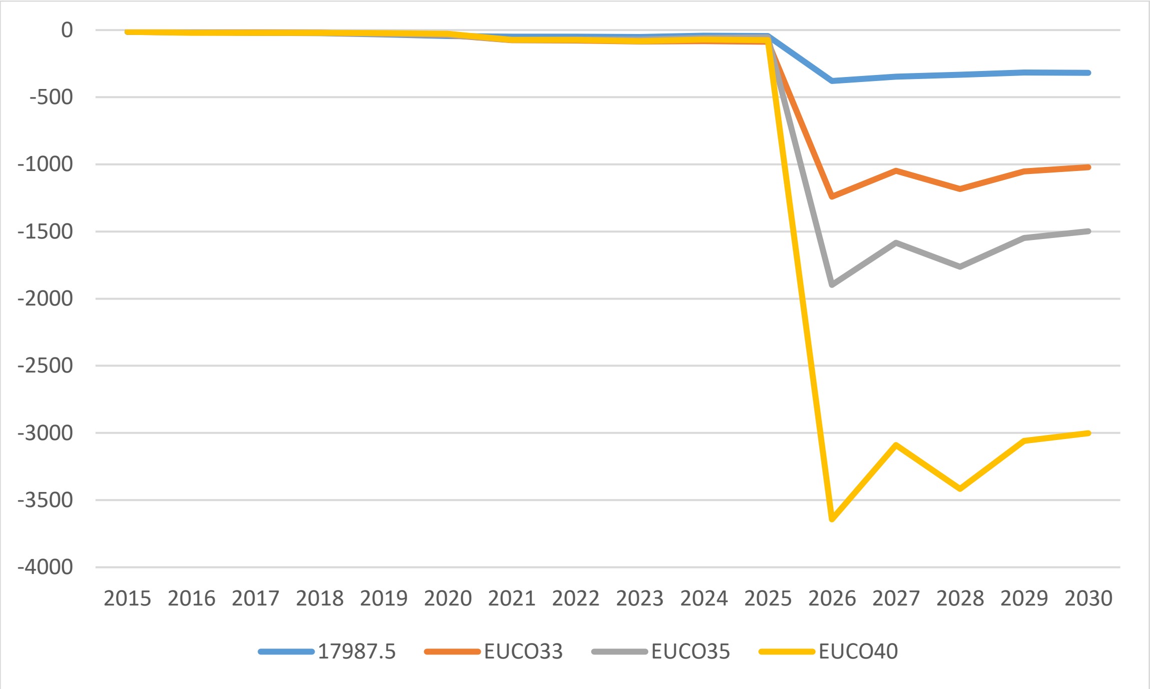
Table IV-3 EU28 unemployment in 2030, absolute difference from EUCO27 scenario (thousands of people)

	2020		2025		2030	
	No CO	Part CO	No CO	Part CO	No CO	Part CO
EUCO27 (Baseline)	22,981	22,981	19,290	19,290	17,988	17,988
EUCO30	-43.4	-43	-43.2	-43.5	-317.8	-318
EUCO33	-36.6	-36.7	-87	-86.9	-1022.5	-954.6
EUCO35	-35.2	-35.3	-54	-54	-1499.1	-1243.4
EUCO40	-27.2	-27.2	-76.3	-75.2	-3000.7	-2082.1

Source(s): E3ME, Cambridge Econometrics

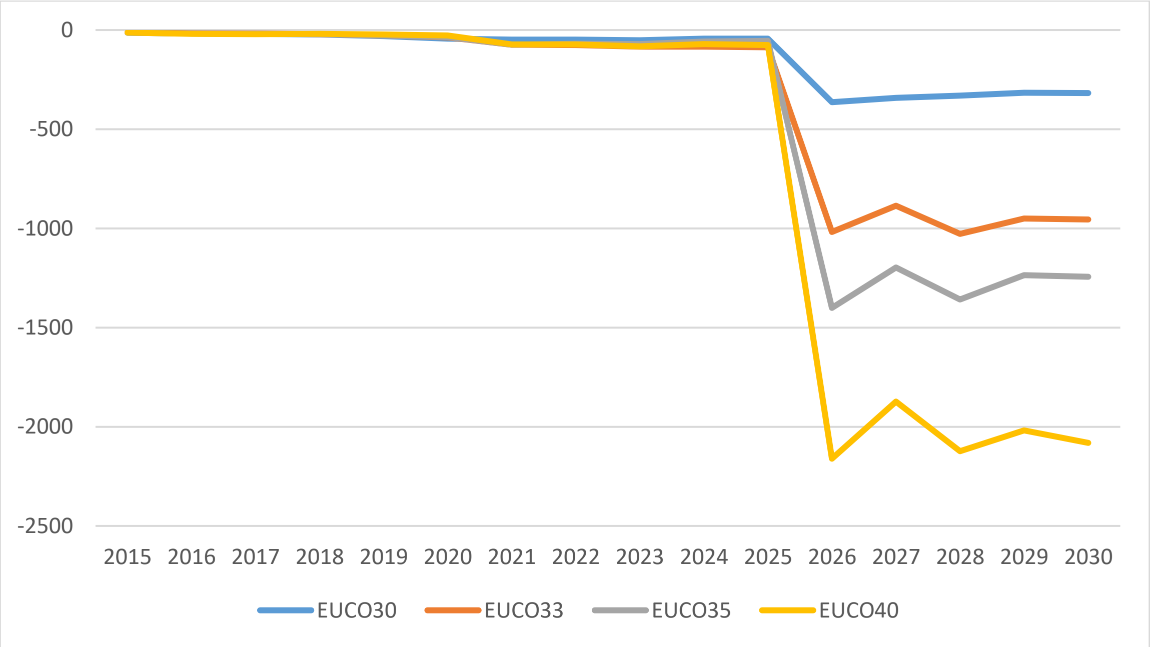
32 Wage rates are determined endogenously using a set of econometric equations. The specification is based on a union bargaining methodology at sectoral level, with higher rates of productivity and wages in other sectors having a positive effect on wage rates, and higher unemployment rates having a negative effect. Higher wage rates will encourage individuals to seek work but will dampen demand from firms (both of these relationships are also estimated empirically).

Figure IV.6 EU28 unemployment in 2030, absolute difference from EUCO27 scenario (thousands of people) (no crowding out)



Source(s): E3ME, Cambridge Econometrics

Figure IV.7 EU28 unemployment in 2030, absolute difference from EUCO27 scenario (thousands of people) (partial crowding out)



Source(s): E3ME, Cambridge Econometrics

2.4 Macroeconomic impacts at Member State level

The Member State level impacts of the energy efficiency policies on GDP are shown in Table IV-4. The impacts vary considerably between the Member States.

The main reason for the differences in results between Member States is the amount of investment in energy efficiency; in countries that invest more heavily, the impacts will be larger. The sector that makes the investment also matters; investment by businesses leads to higher prices which take some time to feed through to final demand, whereas investment by households has an immediate displacement effect on other goods and services. Trade effects can also influence outcomes and countries that export energy efficient equipment may benefit if other European countries increase their ambition levels.

Again, the impact of partial crowding out (versus no crowding out) is greater in the more ambitious scenarios with higher energy efficiency targets (EUCO35 and EUCO40). The impact of the crowding out varies between Member States, depending on the amount of additional investment foreseen. For example, if one Member State implements a particularly ambitious efficiency programme then the investment requirements will be higher and the amount of investment displaced from other sectors will also be higher. Therefore, the crowding out effects in this Member State will be greater than in other Member States and the cost to GDP related to crowding out will be higher.

In the no crowding out variant of the most ambitious energy-efficiency scenario, the countries that see the largest increases in GDP are the Czech Republic, Latvia, Slovakia, Finland and Hungary. This is almost entirely driven by the amount of energy efficiency investment required. For example, Latvia has the largest ratio of energy efficiency investment to GDP (EUCO27) among all Member States in 2030, while the other countries are also high up the list.

Table IV-4 GDP by Member State, 2030, % difference from EUCO27 scenario

	EUCO27	EUCO30		EUCO33		EUCO35		EUCO40	
	Baseline (€2013bn)	No CO	Part CO	No CO	Part CO	No CO	Part CO	No CO	Part CO
AT	426	0.4	0.4	1.5	1.4	2.3	1.9	4.5	2.6
BE	506	0.5	0.5	1.7	1.5	2.3	1.8	4.4	2.3
BG	55	0.4	0.4	1.4	1.3	1.9	1.7	3.8	3.2
CY	24	0.3	0.3	0.9	0.8	1.3	1.1	2.8	2.1
CZ	202	0.9	0.9	3.0	2.7	4.4	3.4	8.3	4.6
DE	3,404	0.4	0.4	2.0	1.6	2.8	1.6	5.9	2.2
DK	347	0.2	0.2	0.4	0.4	0.5	0.5	0.7	0.4
EE	24	0.3	0.3	1.2	1.1	1.8	1.6	4.0	3.1
EL	215	0.7	0.7	2.0	1.7	2.8	1.9	4.9	2.2
ES	1,513	0.3	0.3	1.0	1.0	1.5	1.5	3.2	3.0
FI	242	0.6	0.6	2.1	2.1	3.5	3.4	7.3	6.3
FR	2,654	0.7	0.7	1.9	1.9	2.9	2.5	5.2	3.5
HR	57	0.2	0.2	0.8	0.7	1.2	1.1	1.8	1.5
HU	179	0.9	0.9	2.5	1.8	3.7	2.0	6.4	1.8
IE	229	0.3	0.3	1.1	1.0	1.6	1.4	2.9	2.4
IT	1,971	0.5	0.5	1.6	1.5	2.2	1.7	4.3	2.1
LT	45	0.7	0.7	1.8	1.7	2.5	2.1	4.7	2.7

LU	66	0.5	0.5	0.9	0.9	1.1	1.1	1.6	1.5
LV	34	1.0	0.9	2.9	1.5	4.1	1.4	8.3	0.0
MT	9	0.5	0.5	0.5	0.5	1.2	0.9	3.1	2.2
NL	786	0.3	0.3	1.1	1.0	1.6	1.3	3.0	1.6
PL	645	0.1	0.1	0.8	0.6	1.3	0.6	3.4	0.2
PT	220	0.6	0.6	1.3	1.3	1.3	1.3	2.0	1.5
RO	201	0.0	0.0	0.5	0.4	0.6	0.2	0.6	-1.1
SI	49	0.5	0.5	1.8	1.7	2.6	2.0	4.9	2.6
SK	103	0.7	0.7	2.5	2.2	3.8	2.9	7.9	4.4
SW	552	0.4	0.4	1.1	1.1	1.2	1.1	2.2	1.5
UK	3,287	0.1	0.1	0.7	0.7	1.2	1.0	2.2	1.3

Source(s): E3ME, Cambridge Econometrics

The countries with the smallest GDP impacts on the no crowding out version are Romania, Denmark, Luxembourg, Croatia and Portugal. All these countries, except for Romania, have low requirements for additional energy efficiency investment. In the case of Romania, although the investment requirement is high, most of it comes from households (just over 75% in 2030 and the highest among all Member States), reducing demand for other household products. This is also the reason why, in the partial crowding out variant, the impact on GDP in Romania is negative. In such cases, alternative financing arrangements could be beneficial (see Section 2.8).

The trade effects are also important. Although installation of equipment must be carried out locally, the equipment itself may be made in other countries. It is quite uncertain where manufacturing of energy efficient equipment will take place in the EU by 2030 but current trading patterns give an indication. In general, smaller countries with open economies, countries with smaller manufacturing (particularly engineering) sectors and countries with projected trade deficits in manufactured goods will import a larger share of the equipment. In the model results Bulgaria, Estonia, Hungary and Romania all see relatively large increases in imports that detract from GDP in 2030. In all countries, however, benefits to local economies could be increased if the energy efficiency equipment is produced by firms based domestically.

2.5 Employment impacts at Member State level

The employment impacts at Member State level in 2030 are shown in Table IV-5. The employment impacts also vary considerably between the Member States and, again, depend primarily on the amount of efficiency that is undertaken and the assumptions on the degree of crowding out. However, local labour market conditions, as reflected in the model's econometric parameters, can also play a role. For example, countries that have more flexible labour markets (e.g. the UK) generally see quicker changes in employment in response to changes in output. Another important factor is the importance of the construction sector as an employer, as much of the additional economic activity accrues to construction.

Endogenous responses in wage rates also impact on the net changes in employment. The E3ME wage equations are based on a union bargaining system in which wages in each sector react to changes in productivity, unemployment rates and developments in other sectors. All these effects are determined at national level through the econometric equations and, again, reflect labour market flexibility and other local conditions.

The effects of the unemployment rate can be particularly important. If a country is close to full employment then any additional demand for labour will push up wage rates rather than lead to more jobs. The relative effects of additional investment in energy efficiency are therefore likely to be greater in countries with high unemployment rates in the reference case. In the short term, this could describe some of the EU's southern Member States but by 2030 it is assumed that unemployment in the reference case falls in line with historical averages.

Overall, however, the employment impacts are positive across all Member States, and increase in line with the energy efficiency target. In many countries (e.g. the Czech Republic, Finland and Hungary), the boost comes through the construction sector; even in countries where the energy efficiency investment is a modest share of GDP, but where the construction sector is a major employer, the total increase in employment is pushed up (e.g. France, Greece, Portugal and Spain). As employment in the construction sector increases, multiplier effects as additional income is spent lead to further job creation in the wider economy, particularly through consumer goods and services. Greece and Spain are prominent examples where employment increases beyond construction.

Table IV-5 Employment by Member State, 2030, % difference from EUCO27 scenario

	EUCO27	EUCO30		EUCO33		EUCO35		EUCO40	
	Baseline (000s)	No CO	Part CO	No CO	Part CO	No CO	Part CO	No CO	Part CO
AT	4,403	0.1	0.1	0.6	0.6	0.9	0.8	1.6	1.1
BE	4,974	0.2	0.2	0.8	0.7	1.2	1.0	2.2	1.4
BG	3,231	0.0	0.0	0.1	0.0	0.1	0.1	0.2	0.1
CY	424	0.1	0.1	0.3	0.3	0.4	0.4	1.1	1.0
CZ	5,374	0.3	0.3	1.2	1.1	1.9	1.5	3.8	2.5
DE	39,433	0.1	0.1	0.6	0.5	1.0	0.7	1.8	1.0
DK	3,029	0.1	0.1	0.3	0.3	0.5	0.5	1.3	0.9
EE	602	0.2	0.2	0.8	0.8	1.2	1.1	2.4	2.1
EL	4,061	0.5	0.5	1.2	1.1	1.9	1.3	3.6	1.9
ES	19,869	0.2	0.2	0.8	0.8	1.2	1.1	2.7	2.5
FI	2,625	0.3	0.3	1.2	1.2	1.8	1.8	3.5	3.1
FR	29,550	0.3	0.3	0.8	0.7	1.1	1.0	2.2	1.6
HR	1,688	0.2	0.2	0.4	0.4	0.6	0.6	1.2	1.1
HU	3,803	0.4	0.4	1.2	1.0	1.8	1.2	3.3	1.6
IE	2,234	0.2	0.2	0.5	0.5	0.9	0.8	1.8	1.6
IT	25,836	0.1	0.1	0.7	0.6	1.0	0.8	1.9	1.2
LT	1,314	0.3	0.3	1.1	1.0	1.6	1.3	3.2	2.0
LU	421	0.1	0.1	0.1	0.1	0.2	0.2	0.4	0.4
LV	942	0.3	0.3	1.1	0.7	1.6	0.8	3.0	0.9
MT	185	0.3	0.3	0.4	0.4	0.6	0.6	1.1	1.0
NL	8,867	0.1	0.1	0.4	0.4	0.6	0.6	1.3	0.9
PL	15,267	0.2	0.2	1.0	1.0	1.6	1.2	3.7	2.1
PT	4,915	0.5	0.5	1.5	1.5	2.0	1.8	3.5	2.8

RO	9,219	0.0	0.0	0.3	0.2	0.4	0.3	0.8	0.4
SI	926	0.2	0.2	0.6	0.7	1.1	0.9	2.2	1.3
SK	2,311	0.1	0.1	0.3	0.2	0.5	0.2	1.7	0.4
SE	5,096	0.2	0.2	0.4	0.4	0.4	0.3	0.9	0.6
UK	32,942	0.1	0.1	0.5	0.5	0.8	0.7	1.5	1.1

Source(s): E3ME, Cambridge Econometrics

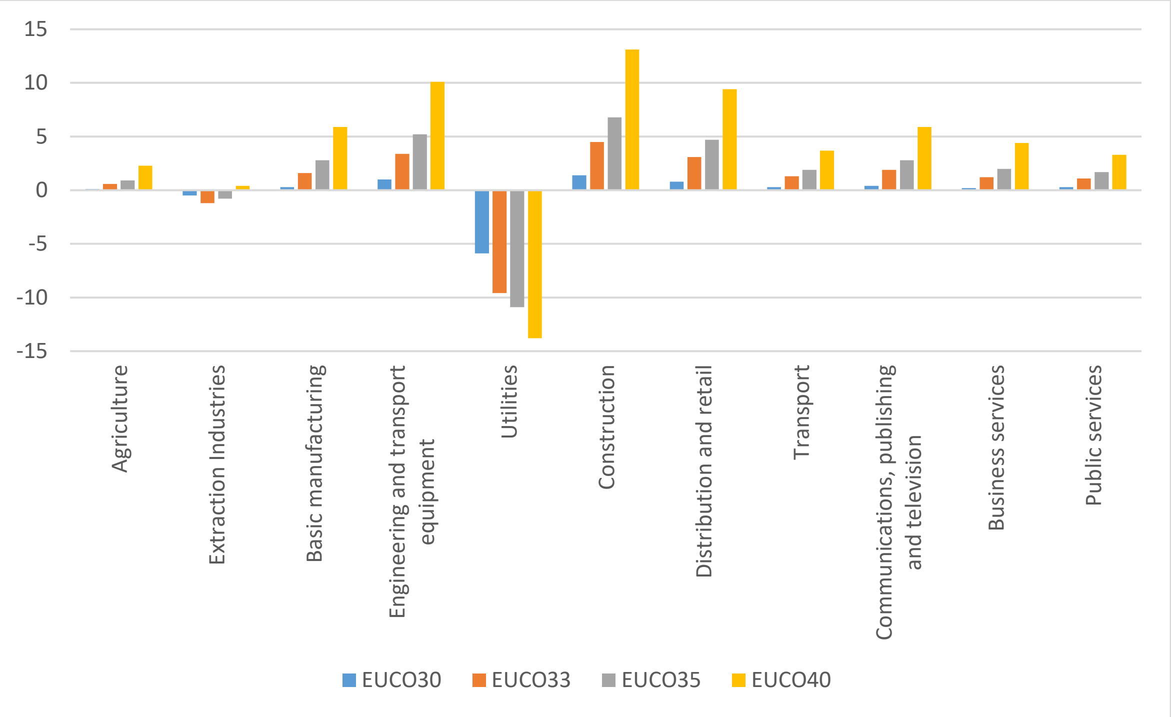
2.6 Impacts at sectoral level[33]

The E3ME model results for output and employment, split by different sectors of the economy, are displayed in Figure IV.8 and Figure IV.9. The charts show the scenarios with no crowding out, but results with partial crowding out are reported in Table IV-6 and Table IV-7.

As expected, these results show a reduction in output in the utilities and extraction sectors due to the energy saving measures, with the utilities sector seeing the largest decrease in output. The focus of the energy efficiency measures in buildings means that both domestic electricity and gas suppliers face lower demand for their products and their turnover decreases accordingly. In comparison, as Europe imports a large share of its energy, the size of the impact on domestic extraction activities is much smaller in relative terms.

[33] The sectors defined in this section are: Agriculture (NACE rev2 A), Extraction industries (B), Basic manufacturing (C10-24), Engineering (C25-C33), Utilities (D and E), Construction (F), Distribution and retail (G), Transport (H49-H52), Communications (H63, I and J), Business services (K, L, M and N) and Public services (O to U).

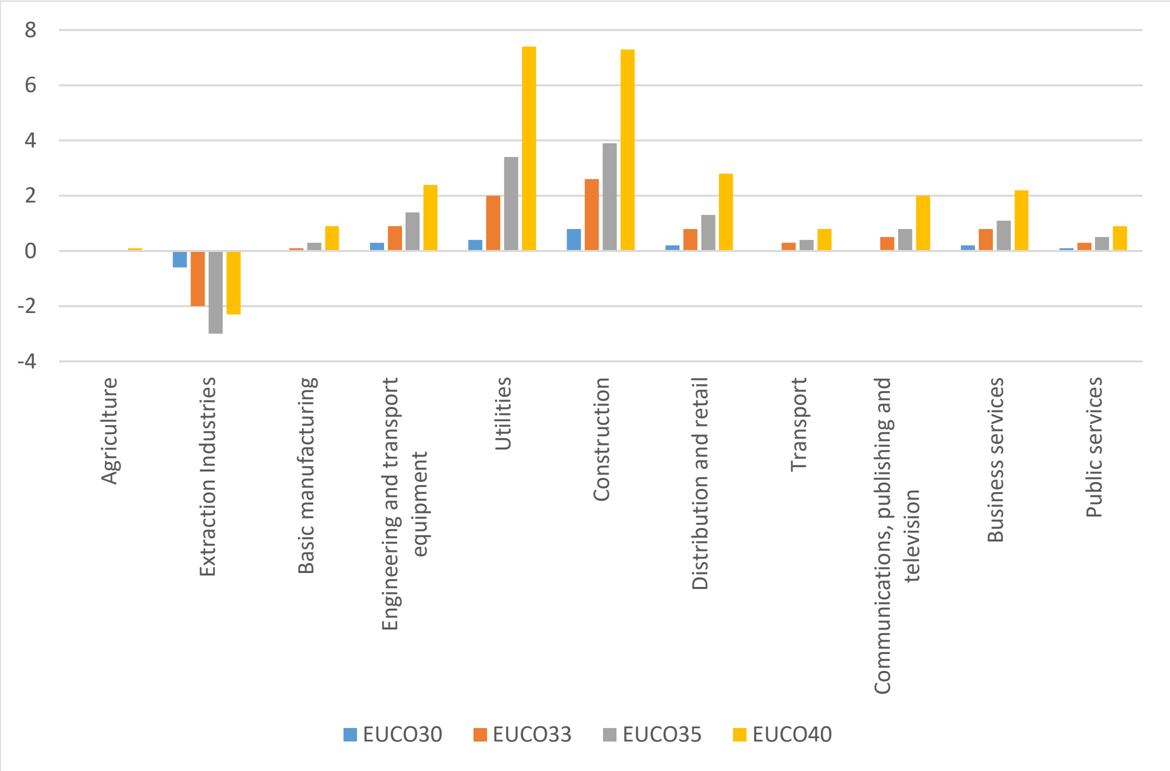
Figure IV.8 EU28 Summary of output impacts by sector in 2030, % difference from EUCO27 scenario (no crowding out)



Source(s): E3ME, Cambridge Econometrics

Other sectors, such as construction and engineering, benefit from the investment in energy efficiency and, to a lesser extent, higher demand from consumers in the long run. As a result, these sectors are expected to see an increase in output in the energy efficiency scenarios, compared to the EUCO27 scenario; and it should be noted that they are much larger than the utilities and extraction sectors in size (the extraction sector is smallest in the chart in terms of employment, construction is around 30 times larger in 2030). Because the positive economic impacts are driven primarily by higher levels of investment, the impact is greatest in the EUCO40 scenario where the energy efficiency investment is the largest.

Figure IV.9: EU28 Summary of employment impacts by sector in 2030, % difference from EUCO27 scenario (no crowding out)



Source(s): E3ME, Cambridge Econometrics

In general, the employment results at sectoral level follow the same pattern as output, although the magnitude of the impacts is smaller. The notable exception is the utilities sector, where employment increases, despite falling output. This increase in employment is not directly related to the higher rates of energy efficiency but instead to a higher penetration of renewables, which are typically more labour intensive. Thus, despite reduced demand for electricity, there is a higher labour demand in the utilities sector.

Nevertheless, the changes in employment in the utilities sector are small in absolute terms. The largest overall increase in employment comes in the construction sector, where employment could increase by up to 5.4% in the EUCO40 scenario with partial crowding out, or up to 7.3% if no crowding out is assumed. As was found in earlier parts of this section, the assumptions on the degree of crowding out do not impact the model results in the less ambitious scenarios (e.g. EUCO30).

The sectoral impacts on employment and output with no crowding out and partial crowding out are shown in Table IV-6 (output) and Table IV-7 (employment).

Table IV-6: EU28 Impacts on sectoral output by 2030, % difference from EUCO27 scenario

	EUCO 27	EUCO30		EUCO33		EUCO35		EUCO40	
	(€bn)	No CO	Part CO	No CO	Part CO	No CO	Part CO	No CO	Part CO
Agriculture	462	0.1	0.1	0.6	0.5	0.9	0.5	2.3	0.9
Extraction Industries	144	-0.5	-0.5	-1.2	-1.3	-0.8	-1.0	0.4	-0.4
Basic manufacturing	4,111	0.3	0.3	1.6	1.5	2.8	2.2	5.9	3.8
Engineering and transport equipment	4,221	1.0	1.0	3.4	3.2	5.2	4.5	10.1	7.4
Utilities	1,086	-5.9	-5.9	-9.6	-9.7	-10.9	-11.4	-13.8	-15.8
Construction	2,487	1.4	1.4	4.5	4.3	6.8	6.1	13.1	10
Distribution and retail	3,450	0.8	0.8	3.1	2.8	4.7	3.8	9.4	5.9
Transport	1,727	0.3	0.3	1.3	1.2	1.9	1.5	3.7	2.3
Communications, publishing and television	3,090	0.4	0.4	1.9	1.7	2.8	2.1	5.9	3.3
Business services	7,891	0.2	0.2	1.2	1.0	2.0	1.4	4.4	2.3
Public services	4,830	0.3	0.3	1.1	1.0	1.7	1.3	3.3	2.0

Source(s): E3ME, Cambridge Econometrics

Table IV-7: EU28 Sectoral employment impacts in 2030, % difference from EUCO27 scenario

	EUCO 27	EUCO30		EUCO33		EUCO35		EUCO40	
	Baseline (000s)	No CO	Part CO	No CO	Part CO	No CO	Part CO	No CO	Part CO
Agriculture	9,141	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1
Extraction Industries	525	-0.6	-0.6	-2.0	-2.1	-3.0	-3.1	-2.3	-2.8
Basic manufacturing	14,785	0.0	0.0	0.1	0.2	0.3	0.2	0.9	0.6
Engineering and transport equipment	15,291	0.3	0.3	0.9	0.9	1.4	1.3	2.4	2.0
Utilities	2,904	0.4	0.4	2.0	1.8	3.4	2.6	7.4	4.0
Construction	15,457	0.8	0.8	2.6	2.4	3.9	3.4	7.3	5.4
Distribution and retail	35,201	0.2	0.2	0.8	0.8	1.3	1.1	2.8	1.8
Transport	9,415	0.0	0.0	0.3	0.2	0.4	0.3	0.8	0.4
Communications, publishing and television	21,073	0.0	0.0	0.5	0.5	0.8	0.6	2.0	1.0

Business services	40,767	0.2	0.2	0.8	0.7	1.1	0.9	2.2	1.4
Public services	68,985	0.1	0.1	0.3	0.3	0.5	0.4	0.9	0.7

Source(s): E3ME, Cambridge Econometrics

A discussion of sectoral employment impacts leads into questions about whether the workforce is adequately skilled to make the transition to the new economic structure suggested in the scenario results. Furthermore, there may also be movement *within* sectors in addition to the movement *between* sectors.

As noted in Part III, Section 5.3, this is an issue that is very difficult for models to address and a more qualitative assessment is required.

Some evidence from previous studies, nevertheless, suggests that the key role played by new technologies in the greening of the economy will, at least initially, lead to higher demands for the more advanced skills groups and lower demands for lower-skilled workers. In the short term, science, technology, engineering and mathematics (STEM) related skills are likely to be in particularly high demand. As the new technologies mature, medium-skilled employees (e.g. maintenance workers) could be more sought after (European Commission, 2011). In the long run, labour markets will be able to respond to the changes in business environment but, the faster and more ambitious the change, the greater the likelihood that existing education and training systems will need support to adjust.

Particular effects could emerge at the local level, to meet specific demands or (in the case of job losses) because of a concentration of energy supply or energy-related employers. The need for skills driven by the demand for energy efficiency products can also be expected to vary between Member States, depending on their present levels of activity to address energy efficiency and current levels of inefficiency, and hence the remaining scale of energy savings potential.

In practice, the shift to a greener economy may translate into an increasing demand for generic skills (such as leadership, commercial understanding or management, and for generic green skills) and multi-skilling, contributing to the evolution of existing occupations (Cedefop, 2010; European Commission, 2011); it is possible that green skills will mainly be added to the existing skill set without substantially altering the job content (Cedefop, 2010; Eurofound, 2013).

In summary, the findings from these previous studies suggest broadly that the types of transition envisaged in the EUCO scenarios are possible but it may be necessary to develop complimentary policies to ensure an adequately skilled workforce, particularly for the period 2025-2030 where there is quite a rapid take-up of energy efficiency products. In advance of 2025, a continued investment in STEM[34] subjects could ease labour market pressures. Labour market monitoring could prevent subsequent bottlenecks in specific subsectors arising as the pace of development increases.

2.7 Energy security

The measure of energy security used in this report is the economic value of energy imports, expressed as a share of GDP. Results for this indicator are shown in Table IV-8; they include endogenous changes in GDP and energy consumption (e.g. due to rebound effects). The figures in the table are based on results from E3ME and differ from the results from the PRIMES model that are reported in the EED Impact Assessment because

[34] Science, technology, engineering and mathematics.

they are based on economic sectors rather than the physical quantities modelled in PRIMES.

The measure shows some improvements in energy security in the scenarios. However, in all the scenarios these impacts are quite small in magnitude at EU level. The scenarios without any crowding out have marginally better improvements in energy security because the denominator in the calculation, GDP, is higher.

At Member State level, there are however some noticeable differences. The countries most affected are: the Czech Republic, Latvia, Lithuania, Poland and Slovakia. While these countries are among those that make the largest investments in energy efficiency in the scenarios, they also are relatively exposed in terms of the size of their energy import bills (as a share of GDP). Furthermore, according to COMEXT data for 2016 (supplemented by IEA analysis), these countries are often exposed to a single non-EEA supplier and therefore have strong grounds for improving energy efficiency (see Table IV-9[35]).

In the scenarios, these countries are thus taking the opportunity offered by higher rates of energy efficiency to reduce their dependence on imported energy.

Table IV-8: Energy imports as a share of GDP in 2030, %

	EUCO27		EUCO30		EUCO33		EUCO35		EUCO40	
	No CO	Part CO	No CO	Part CO	No CO	Part CO	No CO	Part CO	No CO	Part CO
AT	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06
BE	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.22	0.23
BG	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04
CY	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
CZ	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	0.05	0.05
DE	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
DK	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03
EE	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
EL	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11	0.11
ES	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06
FI	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02
FR	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
HR	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12	0.12
HU	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
IE	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
IT	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
LT	0.62	0.62	0.61	0.61	0.61	0.61	0.60	0.61	0.60	0.61
LU	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.09	0.10	0.10
LV	0.42	0.42	0.42	0.42	0.41	0.42	0.41	0.42	0.39	0.42
MT	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13

35 Again, these results may differ to those from the PRIMES model reported in the EED Impact Assessment because they are based on economic sectors rather than physical energy quantities. The E3ME results also include rebound effects, as discussed in Section 1.

NL	0.21	0.21	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.21
PL	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.15
PT	0.09	0.09	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
RO	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
SI	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.08	0.07	0.07
SK	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.10	0.10
SW	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
UK	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07

Source(s): E3ME, Cambridge Econometrics

Table IV-9: Largest gas suppliers to selected Member States (% of total gas supply, 2016)

	Largest supplier	2nd largest supplier	3rd largest supplier
Czech Republic	Russian Federation	Norway	
	98.7	1.3	
Lithuania	Norway	Russian Federation	
	55.9	44.1	
Latvia	Russian Federation		
	100.0		
Poland	Russian Federation	Norway	The Netherlands
	90.5	5.8	3.7
Slovakia	Russian Federation	The UK	Norway
	56.1	13.5	11.7

Source(s): Cambridge Econometrics, based on COMEXT data and IEA publications (see Appendix G)

Figure IV.10 shows that, as the rates of energy efficiency improve at EU level there are also greater improvements in energy security, although they remain relatively small in scale. The chart confirms that at European level the energy savings result in lower import bills, rather than a substitution away from energy that is generated domestically.

Figure IV.10: EU28 energy imports as a share of GDP in 2030, % difference from EUCO27 scenario (no crowding out)

Source(s): E3ME, Cambridge Econometrics

2.8 The public finance variant

As a sensitivity, an alternative financing variant was tested in which all the additional investment in energy efficiency is paid for by the public sector, which increases VAT rates to cover the costs. The scenarios are otherwise identical to those assessed above, and include the same two alternative assumptions on the degree of crowding out.

As the amount of energy efficiency in the scenarios is the same, many of the impacts (for example on health or the environment) are the same, irrespective of the financing mechanism. The main differences are in the economic results and public finance results (see Section 6.3).

Table IV-10 compares the GDP impacts between the public financing and self-financing variants, and Table IV-11 compares impacts on employment. The results show that there is an additional stimulus effect when the investment is all publicly financed through an increase in VAT rates.

The main reason for these results is the impact of VAT receipts. In the public financing case, household expenditure on energy efficiency is not subject to VAT as it is purchased by the public sector, whereas if household self-finance then they must pay VAT. While lower VAT payments in the public finance variant mean that tax revenues are lower (see Section 6.3), it provides an additional stimulus, as less money is taken out of the economy. The impacts on GDP and public finances are thus reversed between the two variants.

The employment effects are slightly better in the self-financing case, however. This is due to endogenous, second round effects in the modelling, relating to changes in consumption rather than the investment in energy efficiency. In the public financing variant, VAT rates must increase by more to finance the additional public expenditure, which reduces the level of household expenditure (both compared to reference case and the self-financing case). As some of the most labour-intensive sectors (e.g. retail, hospitality) rely on household expenditure for their demand, the increase in total labour demand is less in the public financing variant than in the self-financing variant.

Table IV-10: GDP impacts in the public financing case (% from EUCO27)

Crowding out	Financing mechanism	EUCO30	EUCO33	EUCO35	EUCO40
None	Self	0.4	1.5	2.1	4.1
	Public	0.7	2.1	2.9	5.3
Partial	Self	0.4	1.3	1.6	2.2
	Public	0.5	1.9	2.6	4.2

Source(s): E3ME, Cambridge Econometrics

Table IV-11: Employment impacts in the public financing case (% from EUCO27)

Crowding out	Financing mechanism	EUCO30	EUCO33	EUCO35	EUCO40
None	Self	0.2	0.7	1.0	2.1
	Public	0.2	0.6	0.9	1.6
Partial	Self	0.2	0.6	0.9	1.4
	Public	0.2	0.6	0.8	1.3

Source(s): E3ME, Cambridge Econometrics

The results for the macro indicators in the public financing variant are shown in Table IV-12. The main difference to the self-financing results described in Section 2.2 relates to the definitions used in the scenario design. In the self-financing variant, investment in energy efficiency by households is counted as household consumption (i.e. consumer expenditure), whereas when paid for by government it is counted as investment. The results in Table IV-12 thus show higher investment and lower consumer expenditure than the results from the self-financing scenario variants. However, this does not reflect real differences in the scenarios; households still benefit from the same equipment being installed.

Aside from the GDP and employment differences described above, the other impacts are broadly in line with those in the self-financing variant.

Table IV-12: EU28 summary of macroeconomic impacts in public finance variant, 2030, % from EUCO27 scenario

	Degree of crowding out	EUCO30	EUCO33	EUCO35	EUCO40
GDP	No crowding out	0.7	2.1	2.9	5.3
	Partial crowding out	0.5	1.9	2.6	4.2
Employment	No crowding out	0.2	0.6	0.9	1.6
	Partial crowding out	0.2	0.6	0.8	1.3
Consumer expenditure	No crowding out	-0.1	0.0	-0.2	-0.3
	Partial crowding out	-0.4	-0.1	-0.2	-0.3

Investment	No crowding out	3.7	10.0	14.7	26.8
	Partial crowding out	3.6	9.6	13.3	21.2
Exports	No crowding out	0.0	0.2	0.3	0.8
	Partial crowding out	0.1	0.2	0.3	0.5
Imports	No crowding out	0.6	1.6	2.4	4.5
	Partial crowding out	0.5	1.5	2.1	3.4
Price index	No crowding out	1.0	1.9	3.0	5.3
	Partial crowding out	0.9	1.9	2.7	4.2

Source(s): E3ME, Cambridge Econometrics

3 Health

The following section summarises the results on health. It is based on the E3ME model results for levels of air pollutants. The first part of this section summarises the approach adopted to estimate the impacts. The second part presents the aggregated results.

The results in this section are presented as difference to the EUCO27 scenario. Part III, Section 3 describes the methodology that has been applied, including the key assumptions and limitations. It should be noted that there is a high degree of uncertainty about the results as they depend on specific contexts relating to for example the location of the air pollution and the characteristics of different healthcare systems across Europe.

3.1 Approach to estimate the health impacts

The E3ME model was used to estimate the reductions in emission of SO_2, NOx and PM_{10} at Member State level for each scenario, compared to the EUCO27 scenario. Section 4.3 presents the results for emissions levels for SO_2 and NOx.

Using the approach detailed below, the associated cost savings in terms of mortality and morbidity were estimated:

- For SO_2 and NOx, the third scenario of damages per tonne of emission of SO_2 and NOx, calculated by the CAFE[36] programme (which includes mortality, morbidity and crop damage), was used. This marginal cost per tonne was multiplied by the decrease in emissions in the E3ME results. Following the CAFE instructions, it was estimated that the crop damage represented, on average, 10% of the cost. This cost was deducted so that the figures only account for the health damage.
- According to results presented in Air quality in Europe (European Environment Agency, 2016), particulates are responsible for the biggest share of mortality and morbidity in the overall healthcare cost, accounting for around 84% of mortality (out of total related healthcare costs of between €330 billion and €940 billion). The data on damages provided by the CAFE programme could therefore not be used as they seemed largely underestimated.

A review of studies, some of which provide alternative estimates, is provided in Appendix D. The figures that have been used were chosen because they are specific to Europe.

The E3ME results suggest that PM_{10} emissions could be reduced by around 13.4% across Europe in the period up to 2030 in the EUCO40 scenario, compared to EUCO27. Assuming that 84% of the current mortality and morbidity cost is due to emissions of particulates, these emissions are currently responsible for losses of up to €790 billion (mid-range estimate €533 billion). Using a linear formula to apply the decrease in emissions to the cost, the results reveal estimated savings of up to €40 billion for EUCO30 scenario and up to €106 billion in the EUCO40 scenario (compared to EUCO27). However, in the analysis below we take mid-range, rather than maximum, values, so the amounts are €27 billion and €71 billion.

3.2 Aggregated results

The results for healthcare cost savings arising from mortality and morbidity costs savings are displayed in Table IV-13.

[36] Clean Air for Europe.

SO_2 and NOx results

Comparison of the EUCO30 to the EUCO27 scenario reveals health care cost savings of around €1.1bn from reduced levels of SO_2 and NOx emissions in the EU28 by 2030, as a result of improved energy efficiency. The savings increase further in the more ambitious scenarios, with a maximum additional decrease of €5.6bn in the EUCO40 scenario.

The SO_2 and NOx health costs savings were also calculated at country level. These more detailed results show that Germany, Italy and France account for 65% of the health-related cost savings from NOx reductions in the EUCO27 scenario and 70% in the EUCO30 scenario.

Particulate results

Using the methodology detailed above, the results reveal that reduced emissions of particulates could generate considerable cost savings from reduced mortality and morbidity. Compared to the EUCO27 scenario, improved energy efficiency could achieve savings of around €27 billion (EUCO30) to €71 billion (EUCO40). The particulate results were also calculated at country level.

All the aggregate results for EU28 are presented in Table IV-13 (below).

Table IV-13 EU28 Annual health cost impacts, difference from EUCO27

	Mortality & morbidity / cost savings, SOx in 2030	Mortality & morbidity / cost savings, NOx in 2030	Mortality & morbidity / cost savings, PM_{10} and $PM_{2.5}$ in 2030	Mortality & morbidity / cost savings NOx, SOx, PM_{10} and $PM_{2.5}$ in 2030
	m€ / year	m€ / year	m€ / year	m€ / year
EUCO30	-1,056	-62	-27,183	-28,301
EUCO33	-489	9	-54,366	-54,846
EUCO35	-1,365	247	-56,498	-57,616
EUCO40	-4,158	-1,467	-71,422	-77,047

The cost savings from the health benefits increase in line with the ambition in the different energy emission target scenarios, with the savings being greater in the more ambitious scenarios. Using this methodology, the total cost savings related to reduced SO_2, NOx and PM emissions are estimated to be between €41 billion (EUCO30) and €111 billion (EUCO40) each year by 2030 (compared to the EUCO27 scenario), depending on the level of ambition. The savings achieved in the most ambitious scenario (EUCO40) represent around 6% of the overall annual economic cost of health impacts and mortality from air pollution for the EU28 in 2010, as calculated by the OECD[37].

These figures include benefits relating to both reductions in indoor and outdoor air pollution, which partly explains why they are substantially higher than those reported in the EED Impact Assessment. However, there are several reasons to be cautious about the results presented in this report due to the assumptions involved. The first relates to the definition of particulates; E3ME reports only PM10 while much of the healthcare costs result from PM2.5. An extrapolation of proportional impacts to the smaller particular matter may lead to some bias in results. The second factor is the linear nature

[37] According to the *Cost of Air pollution, Health Impacts of Road Transportation* published by the OECD (2014), the cost of outdoor air pollution in OECD countries, both deaths and illness, was about USD 1.7 trillion in 2010.

of the approach applied, which does not reflect the non-linear 'dose-response' measures used in more complex modelling approaches. This may lead to differences in the less ambitious scenarios in particular; it is notable that the estimate in Table IV-13 is substantially above the result from GAINS for the EUCO30 scenario (€28 billion compared to a maximum of €8 billion), but for the EUCO40 scenario the results are much closer in relative terms (€77 billion compared to a maximum of €56 billion).

The final point to note from Table IV-13 is that it is possible for health costs to *increase* slightly due to NOx pollution in the scenarios. This relates in part to rebound effects and changes in the choice of fuel, but particularly to indirect effects due to changes in ETS prices. This is discussed in more detail in Section 4.

The health impacts at Member State level are shown in Table IV-14. Germany and France account for more than half the overall benefits from all the pollutants. Differences between Member States are mostly explained by how emissions of particulates in each country change in the scenarios. France sees the largest reduction in healthcare costs because it reduces emissions of particulates by around a third. Germany and Italy also have large reductions in healthcare costs, partly because of reductions in particulates (around 10-15% in the EUCO40 scenario) but also due to their relative sizes.

It is important to note that the Member State level impacts are quite dependent on what happens in the wider energy mix, which in turn is also affected by energy and climate policies, including the Emission Trading Scheme. In particular, many of the health impacts and the corresponding benefits depend strongly from the levels of consumption of coal in the power sector, fuel oil in industrial sectors and motor spirit in transport. Changes in any of these can lead to higher healthcare costs in some countries. This issue is discussed further in Section 4.3.

Table IV-14: Health impacts by Member State (m€ pa), % difference from EUCO27 in 2030

	EUCO30	EUCO33	EUCO35	EUCO40
AT	-1,838	-4,025	-5,097	-6,789
BE	-219	-438	-554	-238
BG	-1,064	-643	723	-461
CY	8	3	-15	-8
CZ	-811	-2,427	-3,537	-2,271
DE	-2,343	-8,077	-4,637	-10,220
DK	-459	-830	-1,061	-1,285
EL	-164	-255	-223	-505
EN	-156	-251	-291	-664
ES	2,370	520	-1,164	-4,939
FI	-581	-1,184	-1,248	-421
FR	-11,688	-19,844	-21,839	-22,230
HR	-185	283	-208	176
HU	691	255	439	233
IE	-337	-693	-714	-790
IT	-4,069	-4,444	-4,721	-6,597
LT	-339	-396	-556	-839
LV	-334	-554	-645	-790
LX	-7	-24	-26	-22

MT	0	1	1	1
NL	3	123	203	50
PL	-2,834	-5,876	-5,999	-11,533
PT	-850	-667	-742	-575
RO	-979	-1,520	-1,342	34
SI	-247	-374	-473	-744
SK	-41	-424	-959	-1,796
SW	-430	-845	-736	-1,027
UK	-1,398	-2,241	-2,194	-2,798
EU	-28,301	-54,846	-57,616	-77,047

4 Environmental impacts

4.1 Introduction

This section presents the results for environmental impacts from the modelling exercise with E3ME. It covers:

- Energy consumption
- Greenhouse gas and other air-borne emissions
- Material consumption
- Water consumption by the power sector

As in other sections, the time horizon for the analysis is 2030 and, unless otherwise stated, the results are compared to the EUCO27 scenario.

4.2 Sectoral impacts on energy consumption

Table IV-15 show the impacts on final energy demand by sector for the EU28 as percentage differences from the EUCO27 scenario. The figures are based on the PRIMES results (once converted to inputs for E3ME) but they also incorporate the rebound effects that are described in Section 1.1, plus some variations from indirect price effects that result from E3ME's econometric equations.

The buildings sector (a combination of households and commerce) sees the largest relative reduction in final energy consumption and there are also substantial reductions in some of the less energy intensive sectors. In contrast, the transport sectors show indirect rebound effects with modest increases in energy consumption recorded. These results follow the general pattern from PRIMES. Rebound effects can affect all sectors as expenditure increases across the economy but are particularly prevalent in construction and its supply chain (e.g. production of metals and minerals, plus transport).

The reductions in final energy consumption are driven by the level of investment in energy efficiency in the different scenarios. The impact on final energy consumption by households in the EU28 ranges from -20.8% (in EUCO30) to -41.6% (in EUCO40), while for the whole economy the range is from -7.1% (in EUCO30) to -17.8% (in EUCO40). The pattern of sectoral energy consumption does not change by much if partial crowding out is enforced, as the direct energy savings remain unchanged regardless of crowding out assumptions.

Table IV-15 EU28 Final energy demand by sector, 2030, % from EUCO27 scenario (no crowding out)

	EUCO27 (Mtoe)	EUCO30	EUCO33	EUCO35	EUCO40
Iron & steel	33.0	0.6	-0.1	-3.3	-5.3
Non-ferrous metals	9.4	-1.6	-2.3	-4.2	-11.5
Chemicals	54.1	-0.9	-7.2	-12.7	-17.6
Non-metallic minerals	34.8	0.3	-0.6	-2.4	-6.0
Ore-extraction	9.8	-0.3	-0.7	-1.2	-5.3
Food, drink & tobacco	26.7	-2.1	-10.2	-18.2	-30.3
Textiles & clothing	3.3	-1.8	-2.3	-6.7	-18.9
Paper & pulp	30.2	-1.1	-3.8	-8.5	1.5
Engineering	32.3	-3.1	-5.2	-6.9	-20.8
Other industry	33.0	0.0	-1.2	-4.4	-5.6
Construction	5.9	0.0	-2.9	-7.1	-15.1
Rail transport	9.0	-0.1	-0.3	-0.7	-1.2
Road transport	267.0	0.4	1.0	1.5	2.9
Air transport	58.5	0.9	2.3	3.0	5.0
Other transp. services	6.0	0.3	1.3	1.9	3.8
Households	221.5	-20.8	-35.5	-33.1	-41.6
Agriculture, forestry	22.9	0.0	0.1	0.2	0.3
Fishing	0.8	0.0	0.0	0.0	0.1
Commerce	135.5	-17.6	-31.4	-37.9	-46.1

Source(s): E3ME, Cambridge Econometrics

The magnitude of the impacts also varies considerably between countries (see Table IV-16), reflecting differences in the current quality of the building stock and the potential for energy efficiency improvements. The reductions in final energy consumption, most notably in the EUCO40 scenario, are highest in countries where the scope for further energy efficiency improvements remains the greatest.

Again, the results in Table IV-16 differ from those from PRIMES due to rebound and other indirect effects that are included in the modelling with E3ME.

Table IV-16 Final energy demand by Member State, 2030, % from EUCO27 scenario (no crowding out)

	EUCO27 (Mtoe)	EUCO30	EUCO33	EUCO35	EUCO40
AT	23.6	-7.5	-16.7	-21.3	-29.9
BE	36.6	-4.9	-10.6	-13.4	-13.7
BG	9.2	-4.4	-4.6	-7.1	-12.4
CY	1.7	-5.4	-12.4	-17.5	-14.2
CZ	22.5	-4.2	-10.8	-14.6	-8.9
DE	171.7	-6.1	-13.5	-10.5	-16.9
DK	13.5	-4.3	-8.0	-11.1	-11.9
EL	15.2	-5.6	-7.5	-7.7	-7.7
EN	3.0	-3.2	-6.2	-6.6	-11.4
ES	78.9	-3.9	-8.3	-11.1	-13.9
FI	21.2	-3.3	-6.6	-9.1	-7.3
FR	123.3	-12.5	-21.4	-23.6	-23.7
HR	5.7	-4.7	-6.8	-5.6	-9.6
HU	14.9	-5.7	-11.3	-12.7	-21.6
IE	10.3	-6.1	-12.7	-13.9	-15.9
IT	110.0	-5.7	-10.9	-14.2	-21.9
LT	4.3	-4.8	-7.7	-10.3	-14.3
LV	4.6	-2.0	-1.6	-1.5	3.1
LX	4.6	-4.4	-9.5	-10.7	-10.1
MT	0.5	-7.0	19.8	-1.4	-7.0
NL	42.6	-4.2	-8.5	-11.3	-17.9
PL	70.9	-4.0	-8.6	-10.1	-15.8
PT	15.7	-3.6	-2.9	-3.4	-1.3
RO	25.0	-2.0	-4.0	-4.8	-5.8
SI	4.8	-2.1	-4.4	-5.5	-6.9
SK	9.8	-4.5	-12.6	-14.8	-11.6
SW	31.2	-3.0	-5.5	-5.0	5.4
UK	118.4	-16.0	-22.4	-23.4	-30.8
EU	993.7	-7.1	-12.9	-14.1	-17.8

Source(s): E3ME, Cambridge Econometrics

4.3 Impacts on GHGs and other air-borne emissions

The levels of greenhouse gas emissions in each scenario are reported by the PRIMES and GAINS models in the Impact Assessment. These results are summarised in Table IV-17.

There is an important question as to whether the rebound effects described above could increase emissions in the scenarios, potentially meaning that the 40% GHG emission target for 2030 is not met. The E3ME results have been interrogated in more detail to assess what the impact of rebound effects on GHG emissions would be. The additional emissions attributed to the rebound effect are estimated by comparing the model inputs from PRIMES with final results from E3ME. In the E3ME analysis the ETS price is fixed to match the values from PRIMES and so additional emissions from rebound effects are counted both from the ETS and non-ETS sectors.

The results of this calculation are shown in Table IV-18. The figures show that rebound effects would have a very modest impact on GHG emissions in the EU and would not jeopardise the 40% emission reduction target for 2030.

Table IV-17: GHG emissions in the scenarios, excluding rebound effects (2030, % change from 1990 levels)

	EUCO30	EUCO33	EUCO35	EUCO40
Total GHGs	-40.8	-43.0	-43.9	-47.2

Source(s): PRIMES and GAINS models

Table IV-18: GHG emissions in the scenarios, including rebound and other secondary effects (2030, % change from 1990 levels)

	EUCO30	EUCO33	EUCO35	EUCO40
Total GHGs	-40.7	-42.7	-43.6	-46.6

Source(s): E3ME, Cambridge Econometrics

The E3ME model also provides estimates of impacts on SO_2 and NOx emissions, although the model does not go into the same level of detail as a specialised tool such as GAINS. The main impacts of these emissions are on human health and are described in the previous section, but there are also environmental impacts. Table IV-19 presents these results.

At EU level, there are modest reductions in both SO_2 and NOx emissions, which increase as the level of ambition in the scenarios increases. At Member State level, however, the results reported by the model are much more varied.

A closer inspection of the results from E3ME reveals that the impacts on both emission types are impacted strongly by changes in the use of coal-fired power generation, which are taken directly from PRIMES. Impacts on SO_2 in particular are very closely linked to the use of coal for energy purposes. While increased rates of energy efficiency allow for reductions in total power generation, the fuel mix used may vary in the period up to 2030, mainly because of the lower ETS prices in the scenarios modelled by PRIMES. Countries where coal-fired generation increases, including Austria, Spain, Hungary and Greece, may see higher levels of SO_2 and NOx emissions. Conversely, in countries where higher rates of energy efficiency lead to a reduction in coal-fired power there are larger reductions in these emissions.

Other factors that affect emissions of NOx and, to a lesser extent SO_2, include levels of activity in the transport sector (e.g. in response to rebound effects). Where countries see different impacts for SO_2 and NOx, transport-related emissions are often the reason. Agricultural emissions of NOx may also increase slightly if wider economic growth accelerates.

The pattern of results from E3ME is similar to that reported by GAINS at EU level[38]. The absolute impacts for SO_2 are larger in E3ME (up to 251 ktons, compared to 148 ktons in GAINS in the EUCO40 scenario). The differences are likely to reflect the more detailed modelling approach that is available in GAINS. The NOx impacts reported by E3ME are

[38] See Impact Assessment, page 59.

quite a lot smaller (up to 133 ktons reduction) than in GAINS (up to 487 ktons). Here the differences in modelling approach are also relevant, but the inclusion of rebound effects in the E3ME analysis also make a difference, as the E3ME results incorporate additional emissions from agriculture and transport that are linked to higher general rates of economic activity.

In summary, one can conclude that, whilst higher rates of energy efficiency provide the potential for reductions in emissions, to realise the full potential savings it is necessary to ensure that the energy mix is not changed in a way that limits emission reductions. In particular, benefits would be higher if measures were taken to ensure that coal does not become a bigger share of the power mix. The interaction of other policies (notably the EU ETS) is important here.

Table IV-19: SO_2 and NOx impacts in the scenarios (% change from EUCO27, no crowding out)

	EUCO30		EUCO33		EUCO35		EUCO40	
	SO_2	NOx	SO_2	NOx	SO_2	NOx	SO_2	NOx
AT	13.5	6.8	14.1	5.8	24.7	10.6	42.7	10.0
BE	-1.0	-2.1	-3.4	-4.5	-3.6	-4.5	1.4	-2.1
BG	-3.1	-1.1	-3.7	-0.6	14.9	9.4	9.0	11.5
CY	0.3	0.6	-3.0	0.0	-9.7	-1.8	-7.0	0.1
CZ	-0.4	-0.1	-5.1	-2.1	-8.8	-3.6	12.1	9.2
DE	0.4	2.0	-4.1	0.2	0.1	3.1	-4.6	0.5
DK	-5.9	-2.6	-15.9	-5.4	-11.4	-1.9	-15.5	-3.5
EE	1.8	1.7	-0.6	1.3	-2.2	1.1	-6.5	-1.9
EL	12.0	4.9	10.5	4.6	16.3	7.1	17.8	8.1
ES	12.0	7.7	4.2	5.4	0.6	4.7	-11.2	-1.2
FI	-3.1	-1.5	-6.7	-3.4	-3.1	-2.9	-1.6	0.0
FR	-4.1	-3.4	-9.5	-6.0	-11.6	-6.2	-14.5	-5.1
HR	1.3	0.1	15.7	3.0	1.0	0.6	20.5	4.9
HU	36.0	13.8	33.0	13.3	44.2	18.5	49.3	22.0
IE	-4.7	-1.3	-10.6	-3.1	-11.4	-3.0	-13.3	-2.9
IT	-18.7	-7.2	-19.4	-8.1	-17.2	-7.6	-22.7	-10.3
LT	-1.4	0.1	-5.8	0.8	-7.9	1.0	-9.8	2.9
LU	-4.1	-0.8	-10.9	-1.7	-14.1	-1.9	-13.8	-1.2
LV	0.5	0.6	-0.3	1.2	0.4	2.0	-4.1	1.9
MT	-7.0	-0.2	19.2	4.0	-1.7	2.5	-6.6	4.1
NL	1.5	-1.0	0.8	-2.4	2.8	-2.2	6.0	0.5
PL	1.4	2.5	-0.6	2.3	0.3	3.3	-4.6	0.9
PT	5.0	0.8	-8.7	2.3	-11.3	3.7	-18.7	10.0
RO	0.4	0.0	-0.3	0.3	-0.5	0.7	15.4	7.2
SI	-6.9	-2.2	-19.2	-6.0	-6.0	-0.1	-22.7	-4.0
SK	-1.1	-1.1	-12.7	-7.4	-21.9	-11.7	-35.8	-16.9
SW	0.7	0.1	-5.2	-1.3	-8.2	-0.7	-18.6	-5.0
UK	-2.6	-4.5	-8.7	-7.3	-8.8	-7.1	-12.0	-9.6
EU	-0.6	0.0	-4.3	-1.6	-2.5	-0.6	-5.1	-1.5

Source(s): E3ME, Cambridge Econometrics

4.4 Impacts on material consumption

The demand for materials in the E3ME materials sub-model is determined by rates of economic production, price and technology. Table IV-20 gives the results for the impact of energy efficiency on material consumption, measured as Domestic Material Consumption (DMC). Fuels are excluded from the measure to avoid double counting with the results in shown above.

The demand for materials in the EU28 increases in most Member States due to a combination of higher rates of economic activity (i.e. higher GDP) and a shift towards production in more material-intensive sectors. The DMC measure includes both biomass and mineral materials but tends to be dominated by the heavy bulk commodities, in particular aggregates that are used for construction minerals[39]. As the scenarios all involve an increase in construction activity, material consumption also increases, and the increases are larger in the more ambitious scenarios. When investment activity is crowded out, the increase in material use is lower.

The results also vary considerably between the Member States. Some countries, such as Portugal, Estonia and Sweden see a large increase in DMC; in most cases this reflects large investments being made (Sweden also benefits from trade effects, see below). Other countries, such as Belgium, Germany and Bulgaria see little change or even negative impacts. The relative impacts between Member States are caused principally by two factors:

- the increase in investment in each country
- the material intensity of the construction sector and its supply chain in each country

The model results also include secondary effects, including material consumption by other sectors. Countries that benefit from higher exports of energy efficient equipment will use materials in the manufacturing process, including Sweden.

The countries that show very small increases, or outright reductions in material consumption (compared to EUCO27) see increases in material efficiency in the scenarios. Germany and the UK both fall into this category; although they see initial increase in material consumption, improvements to efficiency mean that material consumption is back close to the values in the EUCO27 scenario by 2030.

Table IV-20 Impact on material consumption (excl fuels), 2030, % difference from EUCO27 scenario

	EUCO27	EUCO30		EUCO33		EUCO35		EUCO40	
	Baseline (Mt)	No CO	Part CO	No CO	Part CO	No CO	Part CO	No CO	Part CO
AT	243.7	0.1	0.1	0.6	0.5	0.9	0.7	1.7	0.8
BE	317.3	0.0	0.1	0.2	0.2	0.3	0.2	0.7	0.3
BG	618	-0.1	-0.1	0.3	0.2	1.2	0.9	3.3	2.5
CY	24.9	0.5	0.5	1.7	1.6	2.5	2.5	5.0	4.8
CZ	197.5	1.0	1.0	3.0	2.6	4.5	3.5	8.6	5.5
DE	1,294.5	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2
DK	201.5	0.8	0.8	2.2	2.0	4.1	3.3	10.1	6.9

[39] To avoid double counting of impacts, the measure of DMC used here also does not include energy materials, so reductions in coal consumption are excluded.

EE	54.3	1.5	1.5	5.4	5.2	8.6	8.0	17.6	14.6
EL	127.3	0.5	0.5	1.2	1.1	1.9	1.5	3.8	2.3
ES	805.1	1.5	1.5	3.4	3.4	5.1	5.0	10.0	9.6
FI	274.4	0.1	0.1	0.3	0.3	0.6	0.6	1.2	1.1
FR	969	0.5	0.5	1.1	1.0	1.6	1.4	3.0	2.3
HR	25.8	-0.1	-0.1	-0.5	-0.5	-0.6	-0.5	-0.7	-0.6
HU	112	0.4	0.3	1.6	0.9	2.3	1.1	4.1	1.1
IE	201.9	1.1	1.1	3.6	3.4	5.8	5.0	11.5	8.1
IT	966.5	1.2	1.2	4.1	4.1	6.3	5.6	12.3	9.0
LT	103.1	1.2	1.2	3.6	3.5	5.3	4.4	10.9	6.7
LU	13.2	1.6	1.6	4.7	4.5	7.3	6.6	14.8	11.4
LV	111.1	1.4	1.3	3.3	3.0	4.2	3.9	1.9	5.7
MT	6.5	0.4	0.4	1.2	1.2	1.8	1.7	3.7	2.9
NL	330	0.2	0.2	0.4	0.4	0.7	0.6	1.5	1.0
PL	946.4	1.0	1.0	3.0	2.9	5.1	4.3	10.1	7.1
PT	169.7	2.6	2.6	7.4	7.4	10.9	10.6	20.8	17.8
RO	485.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SI	26.2	1.1	1.1	3.3	3.2	5.0	4.4	9.6	7.1
SK	78.8	0.5	0.5	1.4	1.3	2.1	1.8	4.1	2.8
SW	243.8	1.5	1.5	4.5	4.4	6.7	6.1	15.4	11.5
UK	779.8	0.0	0.0	-0.1	0.0	-0.1	-0.1	-0.3	-0.2
EU	9,727.5	0.6	0.6	1.7	1.7	2.7	2.4	5.5	4.2

Source(s): E3ME, Cambridge Econometrics

4.5 Impacts on water used by the power sector

The power sector uses water mainly for cooling purposes. The available data from Eurostat make it difficult to assess the exact share of water consumption that the power sector accounts for but it is likely to be sizable. As the EU moves towards a more renewable energy mix, power sector water consumption is likely to fall, but a move towards more energy efficiency could make it fall at a faster rate.

In Table IV-21, water use refers to power sector water withdrawals only. The approach for deriving the figures is explained in Part III Section 4.4. It is noted that as water intensity varies on a plant-by-plant basis (and local geography), the figures are estimates based on available data by generation technology[40].

The results of the calculation show that water withdrawals from the power sector could be reduced by up to 13% in the scenarios that were modelled. This reflects both reductions in electricity demand and any changes in the power mix reported by PRIMES.

The impacts are in general largest in countries where there is a shift to renewables in addition to energy efficiency measures. In four of the countries where the largest impacts are observed (Belgium, Croatia, Luxembourg and Latvia), there is a shift towards renewable generation that displaces other CCGT generation. Without additional simulations from PRIMES that isolate the direct impacts of energy efficiency on the power sector fuel mix from other indirect changes, it is therefore difficult to estimate the reductions in water consumption that can be attributed to energy efficiency.

[40] The source for the coefficients is a report for the US National Renewable Energy Laboratory (Macknick et al, 2011). The coefficients are reproduced in Appendix D, Section 4.5.

However, the large reduction in the Netherlands is more closely related to reduced energy consumption, reducing generation from both biomass and natural gas.

In contrast, the countries that have potential increases in water consumption by the power sector (notably Spain and Austria) see renewable generation displaced in the PRIMES scenarios, with some increases in thermal generation in 2030 to compensate.

In summary, in line with some of the other environmental indicators, the impacts of greater energy efficiency must be considered in the context of the wider energy system. At EU level, there is a clear trend that more energy efficiency leads to less water consumption but, depending on how the power mix changes, this may not be the case in all Member States.

Table IV-21 Changes in water consumption by the power sector in 2030, % difference from EUCO27 scenario

	EUCO27 (Thousand m^3)	EUCO30	EUCO33	EUCO35	EUCO40
AT	6.1	13.7	12.3	21.8	-16.6
BE	10.1	-6.9	-12.3	-16.4	-28.4
BG	24.1	-5.3	-5.3	-1.7	-11.8
CY	0.7	-0.9	-1.1	-1.1	-1.1
CZ	60.5	-0.1	-1.9	-2.7	-8.3
DE	300.5	-0.2	-0.3	-2.6	-13.8
DK	8.6	-5.1	-7.9	-1.2	-4.5
EL	11.1	-8.7	-11.8	-4.6	-17.2
EN	6.8	2.1	1.4	-1.5	-12.7
ES	57.7	15.4	13.4	13.3	-5.4
FI	37.0	2.8	-2.6	-5.5	-10.9
FR	305.9	-0.4	-2.6	-5.0	-17.9
HR	1.4	-10.3	-18.5	-21.7	-46.3
HU	22.0	-7.8	-8.3	-11.9	-20.8
IE	6.8	-2.8	-4.5	-5.1	-10.9
IT	84.6	-14.1	-17.6	-16.7	-28.0
LT	6.0	1.3	0.3	-3.6	-9.7
LV	1.1	-8.4	-17.8	-21.3	-26.6
LX	0.7	-5.4	-12.0	-19.6	-30.9
MT	0.5	0.0	0.0	0.0	0.0
NL	40.1	0.7	0.1	-1.0	-2.3
PL	134.1	0.4	-0.6	-0.9	-7.1
PT	2.0	-1.0	-11.2	-17.8	-21.8
RO	25.6	1.6	-1.4	-2.7	-8.2
SI	8.9	-8.4	-14.8	-7.9	-16.6
SK	26.9	-2.6	-7.6	-10.8	-16.0
SW	58.4	2.1	0.4	-1.3	-7.0
UK	140.6	-2.5	-4.0	-4.9	-6.5
EU	1388.5	-0.8	-2.5	-3.8	-13.0

Source(s): E3ME, Cambridge Econometrics

5 Social impacts

This section summarises the household income distribution results for the EUCO30 policy scenario. Results for the other scenarios are provided in Appendix C. There is then a brief qualitative discussion on other social impacts, drawing on the results from the EPBD study.

Labour market and unemployment results are provided in the economic analysis in Section 2.

5.1 E3ME distributional results

The distributional impacts of energy efficiency measure vary by country (see Table IV-22, Table IV-23 and Table IV-25). The first quintile represents the poorest household while the fifth quintile represents the households with the highest incomes. In interpreting these results, it is important to note that it is assumed that the energy efficiency measures in buildings are not targeted at specific socio-economic groups but are instead spread evenly across all groups.

In most, but not all, countries, real incomes increase across all household groups. These results are derived from the E3ME modelling described in Section 2 and reflect a combination of factors:

- Higher employment rates
- Increases in wage rates
- Changes to taxation rates

The negative effects in some countries reflect increases in VAT rates, which reduce households' incomes in real terms. The VAT rates are increased in the scenarios to pay for public investment in energy efficiency.

Generally, in most Member States the results show that lower income groups appear to benefit the most from increased energy efficiency (and therefore lower heating bills). This reflects the different spending patterns across the groups, with the lower income households typically spending more on household heating. The results also reflect the changes in VAT rates which can impact on high-income households more, for example if food and other basic goods are not subject to VAT.

The exception is the UK, where secondary effects (principally through rents) mean that there is quite a different outcome. The effects in the UK reflect how prices and wage rates evolve and would be unlikely to occur in other countries.

However, the differences between groups are quite minor and the results also include secondary effects, including endogenous changes in wage rates, that will also impact on income distributions.

The key message to take from these results is that the scenarios do not appear to show negative distributional impacts and therefore distributional effects should not be seen as an obstacle to implementation of the energy efficiency measures. However, the final impacts on income distribution would be determined by the exact nature of the policies that are put in place to meet the energy efficiency targets, and the effects of targeting the measures at particular groups of households are likely to outweigh the impacts shown here.

The effects of crowding out reduce the income benefits to all households but do not in general change the overall pattern of income distribution.

Table IV-22: Real incomes by socio-economic group, 2030, EUCO30 (% difference from EUCO27 scenario) (no crowding out)

	All households	First quintile	Second quintile	Third quintile	Fourth quintile	Fifth quintile
AT	0.2	0.2	0.2	0.2	0.2	0.2
BE	0.3	0.3	0.2	0.3	0.3	0.3
BG	-0.3	-0.1	-0.2	-0.1	-0.2	-0.4
CY	-0.1	0.0	0.0	-0.1	-0.1	-0.1
CZ	0.3	0.4	0.4	0.4	0.2	0.0
DE	0.0	-0.1	0.0	0.0	0.0	0.0
DK	0.0	0.2	0.1	0.0	-0.1	-0.1
EE	-0.4	-0.2	-0.1	-0.3	-0.6	-0.6
EL	0.2	0.2	0.2	0.2	0.2	0.2
ES	0.0	0.1	0.0	0.0	-0.1	-0.1
FI	0.3	0.3	0.3	0.3	0.3	0.3
FR	1.0	1.0	1.1	1.0	1.0	0.9
HR	0.0	0.0	0.0	0.0	0.0	0.0
HU	0.7	1.2	1.0	0.9	0.6	0.2
IE	-0.1	0.1	0.1	-0.1	-0.2	-0.3
IT	0.1	0.2	0.2	0.2	0.1	-0.1
LT	0.5	0.9	0.8	0.7	0.5	0.2
LU	0.2	0.3	0.2	0.2	0.2	0.2
LV	0.9	1.5	1.6	1.4	1.0	0.6
MT	0.9	0.9	0.9	0.9	0.9	0.8
NL	0.0	0.0	0.0	0.0	0.0	0.1
PL	-0.7	-0.2	-0.3	-0.5	-0.7	-1.2
PT	0.4	0.4	0.5	0.4	0.4	0.4
RO	-0.8	-0.8	-0.8	-0.8	-0.8	-0.9
SI	-0.1	0.0	-0.1	-0.1	-0.2	-0.3
SK	-0.4	-0.5	-0.5	-0.5	-0.4	-0.4
SW	0.1	0.1	0.1	0.1	0.1	0.1
UK	0.0	-1.8	-1.3	-0.6	0.3	0.3
EU	0.1	0.2	0.2	0.2	0.1	0.0

Source(s): E3ME, Cambridge Econometrics

Table IV-23: Real incomes by socio-economic group, 2030, EUCO30 (% difference from EUCO27 scenario) (partial crowding out)

	All households	First quintile	Second quintile	Third quintile	Fourth quintile	Fifth quintile
AT	0.2	0.2	0.2	0.2	0.2	0.2
BE	0.3	0.3	0.2	0.3	0.3	0.3
BG	-0.3	-0.1	-0.2	-0.1	-0.2	-0.4
CY	-0.1	0.0	0.0	-0.1	-0.1	-0.1
CZ	0.3	0.4	0.4	0.4	0.2	0.0
DE	0.0	-0.1	0.0	0.0	0.0	0.0
DK	0.0	0.2	0.1	0.0	-0.1	-0.1
EE	-0.4	-0.2	-0.1	-0.3	-0.6	-0.6
EL	0.2	0.2	0.2	0.2	0.2	0.2
ES	0.0	0.1	0.0	0.0	-0.1	-0.1
FI	0.3	0.3	0.3	0.3	0.3	0.3
FR	1.0	1.0	1.1	1.0	1.0	0.9
HR	0.0	0.0	0.0	0.0	0.0	0.0
HU	0.7	1.2	1.0	0.8	0.6	0.3
IE	-0.1	0.1	0.1	-0.1	-0.2	-0.3
IT	0.1	0.2	0.2	0.2	0.1	-0.1
LT	0.5	0.9	0.8	0.7	0.5	0.2
LU	0.2	0.3	0.2	0.2	0.2	0.2
LV	0.8	1.3	1.4	1.3	0.9	0.5
MT	0.9	0.9	0.9	0.9	0.9	0.8
NL	0.0	0.0	0.0	0.0	0.0	0.1
PL	-0.7	-0.2	-0.3	-0.5	-0.7	-1.2
PT	0.4	0.4	0.5	0.4	0.4	0.4
RO	-0.8	-0.8	-0.8	-0.8	-0.8	-0.9
SI	-0.1	0.0	-0.1	-0.1	-0.2	-0.3
SK	-0.4	-0.5	-0.5	-0.5	-0.4	-0.4
SW	0.1	0.1	0.1	0.1	0.1	0.1
UK	0.0	-1.8	-1.3	-0.6	0.3	0.3
EU	0.1	0.2	0.2	0.2	0.1	0.0

Source(s): E3ME, Cambridge Econometrics

Table IV-24 shows how the differences change as the level of energy efficiency becomes more ambitious in the EUCO33 scenario. Although real incomes for all household groups increase as the level of ambition increases, the distributional patterns do not change. Results for the other scenarios at Member State level are presented in Appendix E.

Table IV-24: EU real incomes in EUCO30 and EUCO33 scenarios (% difference from EUCO27 scenario in 2030)

	Degree of crowding out	All h'holds	First quintile	Second quintile	Third quintile	Fourth quintile	Fifth quintile
EUCO30	None	0.1	0.2	0.2	0.2	0.1	0.0
EUCO33	None	0.7	1.1	1.0	0.9	0.7	0.4
EUCO30	Partial	0.1	0.2	0.2	0.2	0.1	0.0
EUCO33	Partial	0.6	0.9	0.9	0.8	0.6	0.4

Source(s): E3ME, Cambridge Econometrics

Looking in detail at the distributional results by employment status of head of households (Eurostat definitions, see Table IV-25), the extent of the impact varies considerably across the Member States, in line with the economic results from the E3ME model presented in Section 2. However, in most instances, there is no clear group that benefits or consistently sees the worst affects. In some countries, retired households appear to benefit the most from the energy efficiency improvements, while in some cases it is those who are unemployed or economically inactive. The differences relate to the different income patterns (e.g. in particular the relative balance between wages and pensions or other benefits) in these groups across the Member States, with some differences also due to variations in expenditure patterns (including the share of income spent on heating costs).

One important point to note, which has not been tested in these scenarios, is that the energy efficiency measures to some extent protect households from future increases in energy prices. As it is at present the vulnerable groups that are most exposed, the energy efficiency measures could alleviate future negative effects.

Table IV-25 Real incomes by socio-economic group, 2030, EUCO30 (% difference from EUCO27 scenario)

	Manual workers	Non-manual workers	Self-employed	Unemployed	Retired	Inactive
AT	0.2	0.2	0.2	0.1	0.2	0.2
BE	0.3	0.3	0.3	0.2	0.3	0.3
BG	-0.3	-0.3	-0.5	-0.3	-0.2	-0.2
CY	0.0	-0.1	-0.1	-0.1	0.0	0.1
CZ	0.2	0.1	0.2	0.6	0.7	0.2
DE	0.1	0.0	-0.1	-0.2	-0.1	-0.2
DK	0.0	-0.1	0.0	0.2	0.0	0.0
EE	-0.5	-0.5	-0.4	-0.3	-0.3	-0.7
EL	0.2	0.2	0.2	0.2	0.2	0.2
ES	0.0	-0.1	0.0	0.0	0.0	-0.1
FI	0.3	0.3	0.3	0.3	0.4	0.3
FR	1.0	0.8	1.0	1.0	1.1	1.0
HR	0.0	0.0	0.0	0.0	0.0	0.0
HU	0.8	0.3	0.2	0.9	1.1	0.7

IE	-0.1	-0.3	-0.1	0.1	0.1	0.0
IT	0.0	0.0	0.0	0.1	0.1	0.1
LT	0.5	0.3	0.7	0.6	1.0	0.4
LU	0.3	0.2	0.2	0.0	0.2	0.2
LV	1.1	0.7	0.7	2.7	3.4	1.8
MT	0.8	0.8	0.8	0.9	0.9	0.8
NL	0.0	0.0	0.1	0.0	0.0	0.0
PL	-0.6	-1.1	-0.8	-0.5	-0.4	-0.9
PT	0.4	0.3	0.4	0.4	0.4	0.4
RO	-0.7	-0.8	-0.8	-1.0	-0.9	-1.1
SI	-0.1	-0.2	-0.3	-0.2	0.0	-0.5
SK	-0.5	-0.4	-0.5	-0.6	-0.6	-0.7
SW	0.1	0.1	-0.3	0.0	0.2	-0.1
UK	-0.1	0.3	0.3	-0.3	-2.1	-0.4
EU	0.2	-0.1	0.0	0.1	0.2	0.1

Source(s): E3ME, Cambridge Econometrics

5.2 Insights from the EPBD study on energy poverty

In the absence of a shared and agreed definition (and common data source) across the EU, the occurrence / prevalence of energy poverty is measured using three separate proxy indicators for energy poverty in residential buildings from the EU-SILC database. These are:

- arrears on utility bills (AUB)
- presence of leaks, damp, rot (LDR)
- ability to keep home adequately warm (AKW)

Since energy poverty occurs mainly within old, non-refurbished buildings, only policy packages that comprise measures that target existing buildings (and preferably induce deep renovations) will have a strong impact in terms of energy poverty alleviation. The actual policy impact on energy poverty will depend on the extent to which energy poverty alleviation is included as a specific policy target (i.e. energy efficiency improvement measures are targeted at the low-income households and households in poor quality housing).

In the analysis carried out for the EPBD report, three policy options scenarios were considered (S1, S2 and S3, with S1 being the least ambitious in terms of energy savings and S3 being the most ambitious in terms of energy savings). Specific focus on energy poverty alleviation was indicated by the LOW/HIGH impact scenarios, with LOW impact scenarios focussing on overall reduction in energy consumption and HIGH impact scenarios including measures aiming to reduce energy poverty. The analysis covered the historical development of energy poverty levels measured over the three indicators by residential building type (i.e. Single Family (SFH) and Multi-Family Houses (MFH)) and country. These results, originally published in the EPBD report, are shown in Table IV-26.

Table IV-26: Total reduction in energy poverty (thousands of households)

	LOW variant			HIGH variant		
	S1	**S2**	**S3**	**S1**	**S2**	**S3**
AUB SFH	87.4	231.9	656.5	344.2	889.8	2,331.2
AUB MFH	106.5	282.6	799.9	419.5	1,084.3	2,840.1
AUB Total	193.9	514.5	1,456.4	763.7	1,974.1	5,171.3
LDR SFH	160.3	425.1	1203	630.9	1,630.4	4,267.2
LDR MFH	149.7	396.9	1,124.4	589.7	1,523.9	3,988.6
LDR Total	310	822	2,327.4	1,220.6	3,154.3	8,255.8
AKW SFH	105	278.5	788.1	413.3	1,068.2	2,796.1
AKW MFH	127.9	339.2	960.3	503.6	1,301.5	3,407.7
AKW Total	232.9	617.7	1,748.4	916.9	2,369.7	6,203.8

Source(s): Wuppertal Institut, EPBD report, Part IV, Section 5, pp. 54.

Note: AUB - arrears on utility bills; LDR: presence of leaks, damp, rot; AKW - ability to keep home adequately warm; SFH - Single Family Houses; MFH- Multi-Family Houses.

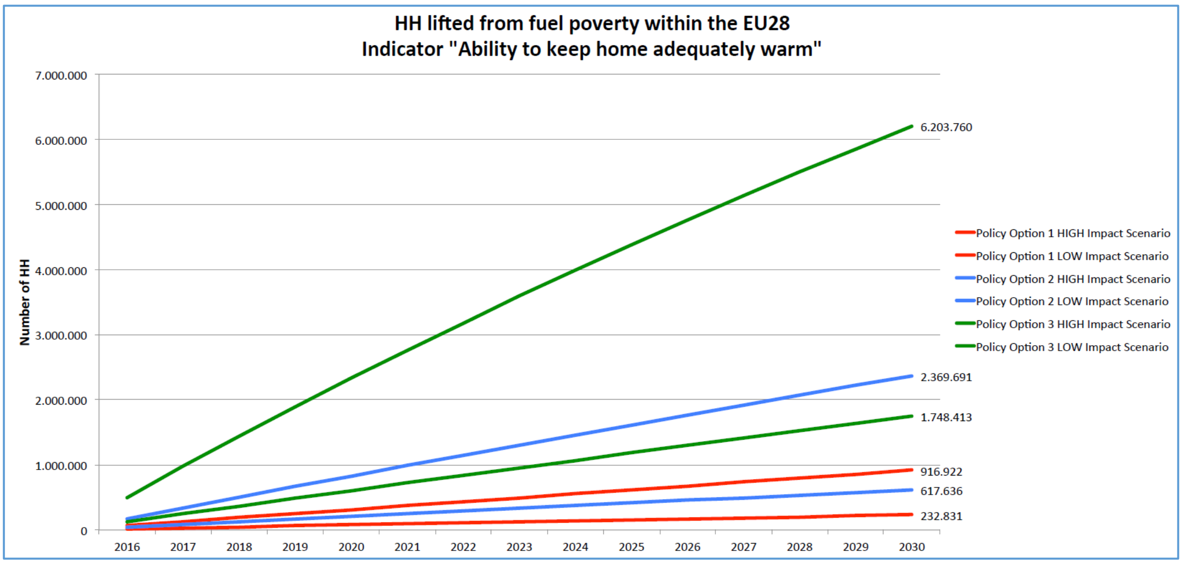
The results from the EPBD report suggest that the number of households that may be lifted from energy poverty (measured by arrears on utility bills) across the EU lies between 194,000 (LOW impact scenario/scenario S1) and 5.17m (HIGH impact scenario/scenario S3), depending on the degree to which policy is targeted towards fuel-poor households.

The potential of energy efficiency improvements in the residential stock to reduce the number of households who live in properties where leaks, damp or rot are present is considerable (indicator LDR), ranging from 310,000 (LOW impact scenario/scenario S1) to 8.26m (HIGH impact scenario/scenario S3) across the EU.

Ability to keep one's home adequately warm (AKW) has important implications for health and quality of life. According to the analysis presented in the EPBD report, improved energy efficiency can help between 233,000 (LOW impact scenario/scenario S1) and 6.2m (HIGH impact scenario/scenario S3) households across Europe to increase their indoor temperature to comfortable levels.

Unsurprisingly, the results are consistently higher in the more ambitious policy scenarios (S2 and S3), and the HIGH impact scenarios (where interventions are targeted at energy-poor households). This is clearly illustrated in Figure IV.11, which gives a graphical illustration of the differences in the level of impacts on ability to keep warm (AKW) between the various policy scenarios for both HIGH and LOW impact scenarios.

Figure IV.11: Energy poverty alleviation impact of the different policy options in residential buildings using AKW as indicator



Source(s): Wuppertal Institut, EPBD report, Part IV, Section 5, pp. 60.

At the Member State level, the results differ by energy poverty indicator and share of dwelling type (SFH/MFH) within the building stock. National results also depend on the size of the building stock and the share of energy-poor households according to the different indicators[41].

In order to get a more precise picture of the extent, level and distribution of energy poverty across the EU and to design and implement targeted action to alleviate it, a harmonised definition is required on which base the respective data can be collected.

6 Public budgets

6.1 Impacts at European level

The estimated impacts of energy efficiency on public budgets are shown in Table IV-27 (no crowding out) and Table IV-28 (partial crowding out). The data in these tables are based on the results from E3ME together with expansion of the model results to take into account certain specific factors, such as corporate taxation (see description in Part III, Section 6). The key figures in the tables are the bottom rows, which show how budget deficits change in relation to GDP levels. This is an important metric for governments and the EU's Stability and Growth Pact (SGP) places a 3% limit on the size of the deficit that any Member State government can run. The positive figures in the tables mean that government deficits are reduced overall and it is therefore easier for Member States to stay inside the limit set by the SGP.

The results in the tables are displayed in current prices as this is the important metric for governments. Consequently, some of the differences in levels can be explained by changes in price levels and inflation rates that are caused by higher VAT rates in the scenarios (see results in Section 2.1).

[41] For detailed results for the three policy scenarios at country level for each policy scenario, see the EPBD report https://ec.europa.eu/energy/sites/ener/files/documents/final_report_v4_final.pdf (Part IV, Section 5, pp. 53-60.

Looking first at government revenues, there is an increase overall in the scenarios (compared to EUCO27), although not in every category. Much of the increase in revenues can be explained by a combination of higher rates of GDP growth, higher employment levels and higher inflation rates. For example, if employment levels are higher, then receipts of income taxes and social security contributions (from both employees and employers) will also be higher. If wages increase in response to higher rates of inflation then income tax receipts and social contributions will increase further.

Corporation taxes increase in the scenarios primarily as a result of higher rates of economic growth, which boost company profitability and therefore the taxes levied on profits. Again, if higher inflation and price levels boost profits this will be reflected in taxation receipts.

There is an especially large increase in VAT receipts in the scenarios. This in part reflects the modelling assumptions that VAT rates automatically increase to fund the public investment in energy efficiency, as well as any loss of revenues from auctioned ETS allowances (see below). However, rising household incomes and higher product prices also lead to higher VAT receipts. In addition, it should be noted that spending on energy efficient goods by households is subject to VAT.

The other two categories of revenue that are assessed show falls overall; there is a reduction in energy excise duties in the scenarios that results from lower levels of energy consumption. Government revenues from auctioned EU ETS allowances are also lower because ETS prices are lower in the scenarios according to the results from the PRIMES model.

Government expenditure increases overall in the scenarios, but by less than revenues. One of the main increases is the public expenditure on energy efficiency measures within the public sector. This is partially compensated by reduced public spending on energy but the payback on these investments is not complete by 2030 and so there is an increase in energy-related spending overall.

Other costs to government increase due to higher inflation rates. These include social benefit payments, as the higher inflation rates offset the reduction in unemployed workers (essentially higher rates of inflation mean paying higher pension costs). The largest increase in expenditure, however, is on health and education. It is assumed that the quality of services is maintained and, in real terms, expenditure remains unchanged[42]. Due to higher inflation rates, nominal spending on services therefore increases.

The overall budget change at EU level is positive for all the policy scenarios, ranging from €19,824m in EUCO30 to €511,570m in EUCO40 (€295,029m with partial crowding out, see below) in monetary terms. However, as many of the figures reflect price changes, it is better to look at budget impacts as a percentage of GDP. These figures show an estimated budget change of around 0.1% of GDP in EUCO30, ranging to up to 2.0% of GDP in EUCO40 at EU level. In the context of current European budget deficits and SGP targets, this is potentially a substantial change.

[42] The impact of energy efficiency on healthcare costs, mortality, morbidity and health-related productivity gains are covered separately in Section 3 of this chapter and are thus not included in the 'other expenditure' category here to avoid double counting.

Table IV-27: EU28 impact on public budgets, €m difference from EUCO27 scenario, 2030 (current prices) (no crowding out)

	EUCO30	EUCO33	EUCO35	EUCO40
Taxation				
Income taxes	22,554	57,346	86,884	166,153
Employees' social	9,393	24,913	37,902	73,178
Employers' social	14,069	36,426	55,007	105,078
Corporation tax	-8,908	4,615	15,592	45,929
VAT	59,966	131,610	202,351	365,065
Energy excise duties	-20,431	-39,060	-38,400	-51,733
Auctioned ETS allowances	-24,232	-26,506	-36,488	-46,861
Expenditure				
Energy purchases	-4,019	-9,895	-13,068	-16,460
Social benefits	515	1,920	2,529	5,099
EE investment	-143	-267	-246	-323
Other expenditure	36,232	52,771	86,618	156,922
Overall budget change	19,824	144,814	247,016	511,570
Budget impacts as % of GDP	0.1%	0.6%	1.0%	2.0%

Source(s): Cambridge Econometrics

Regarding the effects of crowding out on public budgets, the pattern is similar to that seen in the economic results. Crowding out has almost no impact in the EUCO30 case, but the impact of crowding out becomes much bigger as the level of ambition grows in the scenarios. In the EUCO40 scenario, partial crowding out reduces the budget surplus from 2.0% of GDP to 1.2% of GDP.

Table IV-28 Impact on public budgets, €m difference from EUCO27 scenario at EU level, 2030 (current prices) (partial crowding out)

	EUCO30	EUCO33	EUCO35	EUCO40
Taxation				
Income taxes	22,560	53,102	72,773	112,978
Employees' social	9,400	22,726	30,853	47,346
Employers' social	14,072	33,559	45,718	70,686
Corporation tax	-8,925	2,648	9,237	22,525
VAT	59,949	123,256	173,391	253,894
Energy excise duties	-20,437	-39,380	-39,195	-54,741
Auctioned ETS allowances	-24,232	-26,512	-36,505	-46,900
Expenditure				
Energy purchases	-4,019	-9,874	-13,043	-16,063
Social benefits	517	1,818	2,175	3,881
EE investment	-118	-220	-206	-279
Other expenditure	36,265	50,056	77,978	123,220
Overall budget change	19,743	127,618	189,367	295,029
Budget impacts as % of GDP	0.1%	0.5%	0.8%	1.2%

Source(s): Cambridge Econometrics

6.2 Impacts at Member State level

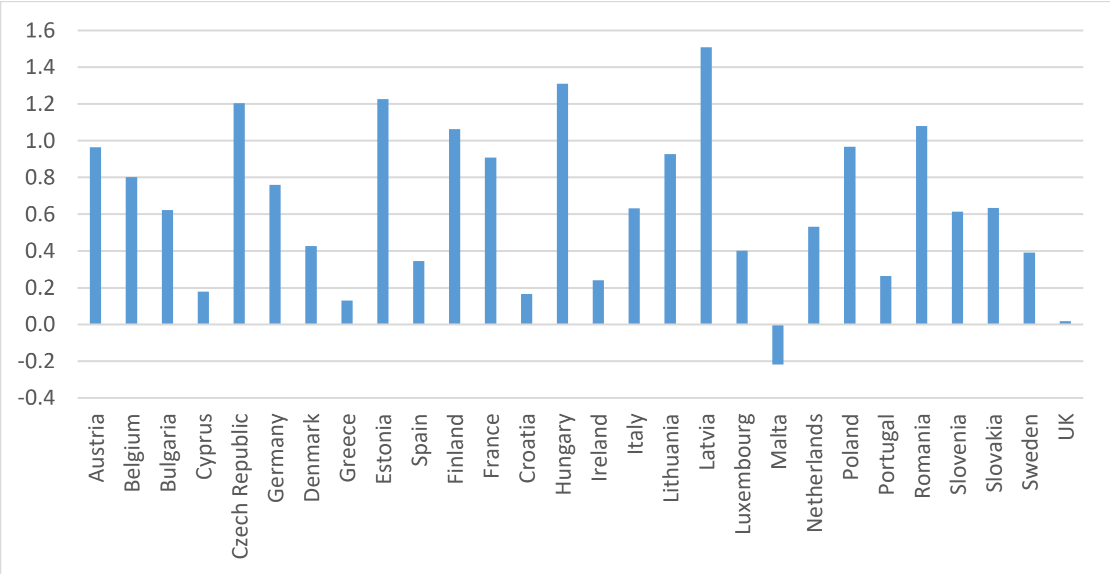
Figure IV.12 shows the estimated public budget impacts at Member State level for the EUCO33 scenario (compared to EUCO27). The results in this scenario are typical and the trends are quite consistent with the other scenarios. Charts of the results in the other scenarios are provided in Appendix E.

For most Member States, the budget position improves due to higher levels of energy efficiency, although the extent of these impacts varies. The extent of the impact is usually linked fairly closely to the level of investment in the different policy scenarios.

Labour market responses are also quite important in determining results on public balances because labour taxation still makes up a large proportion of overall taxation receipts in Europe. The responses of prices and inflation rates can additionally affect the calculation, although this affects both taxation receipts and public expenditures.

Finally, the different tax rates across the Member States affects the relative sizes of the impacts. For example, if a country levies low rates of excise duty on energy consumption, then reductions in energy consumption have a smaller impact on government revenues than they might do otherwise. Similarly, variations in income tax rates and social contribution rates mean that the link between higher employment rates and government revenues can vary considerably between countries.

Figure IV.12: Change in public budget balance by Member State in 2030, as a % of GDP for EUCO33 compared to EUCO27 (no crowding out)



Source(s): Cambridge Econometrics

6.3 The public financing variant

Table IV-29 compares the impacts on public budgets in the public financing variant to the main self-financing scenarios. It is clear that the impacts on public budgets, while still positive at EU level, are much smaller overall.

The reason for the difference is the different treatment of VAT between the scenario variants (see also discussion in Section 2.8). In the public financing variant, VAT receipts are lower because household energy efficiency improvements are not paid by households and therefore are not subject to VAT. The 1-2% difference in outcomes counterbalances a change of similar magnitude, but in the opposite direction, to the differences in economic results presented in Section 2.8.

In summary, the financing approach does not change much the potential of energy efficiency to improve the economy but it can have important redistributional impacts between the public and private sectors that need to be considered carefully in the context of wider fiscal policy.

Table IV-29: Impacts of the public financing variant on public budgets, % of GDP from EUCO27 in 2030

	EUCO30	EUCO33	EUCO35	EUCO40
Self-financing				
No crowding	0.1%	0.6%	1.0%	2.0%
Partial crowding	0.1%	0.5%	0.8%	1.2%
Public financing				
No crowding	0.0%	0.1%	0.1%	0.4%
Partial crowding	0.0%	0.1%	0.1%	0.2%

Source(s): E3ME, Cambridge Econometrics

7 Industrial competitiveness

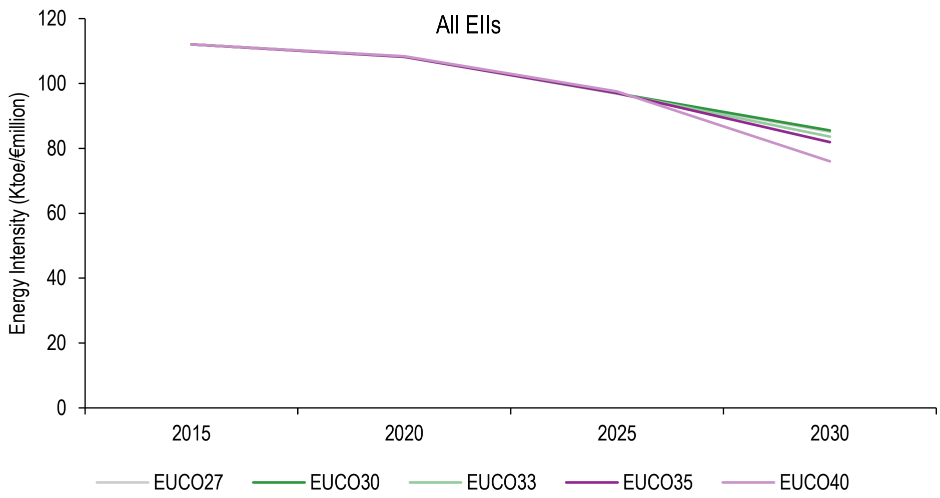
7.1 Introduction

This section reports the results on competitiveness, mainly focusing on Energy Intensive Industries (EIIs). The analysis is carried out at a more detailed level than that offered by the E3ME model but is covered through the aggregation and streamlining of qualitative and quantitative information on the cost and non-cost factors of competitiveness. The approach used considers energy intensive industries and industries for energy efficiency products and services. However, it needs to be noted that capturing the extent of the energy efficiency industry is complex endeavour, especially as energy efficiency is a design aspect of many manufacturing processes.

7.2 Energy consumption by Energy Intensive Industries

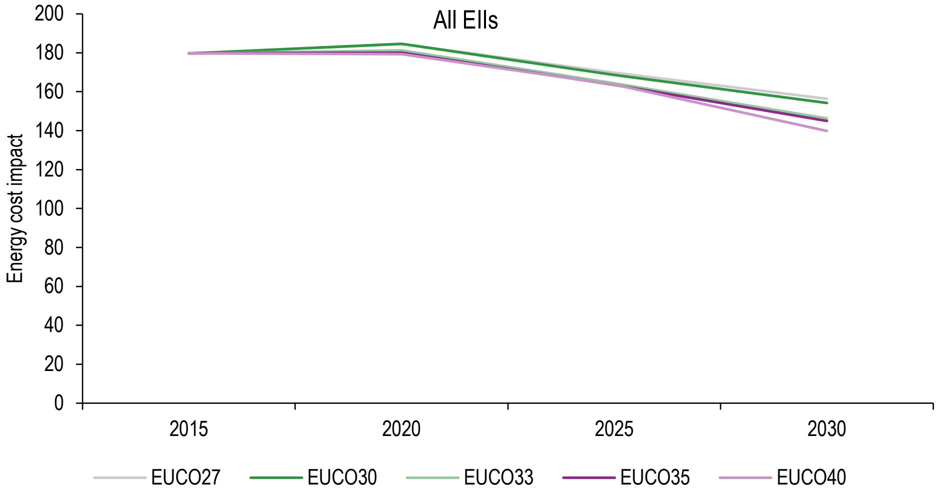
Figure IV.13 and Figure IV.14 show the two main competitiveness indicators, the energy intensity, and the cost per value added across all the industry-subsectors at EU level for the different energy efficiency scenarios. Further in this section, the energy intensity indicator results are presented in graphs for each industry sector, while both the energy intensity and the cost per value added are presented in Table IV-30 and Table IV-31.

Figure IV.13: EU28 Average energy intensity, 2015-2030



Source(s): EY, based on data from E3ME and PRIMES

Figure IV.14: EU28 Energy cost impact, 2015-2030



Source(s): EY, based on data from E3ME and PRIMES

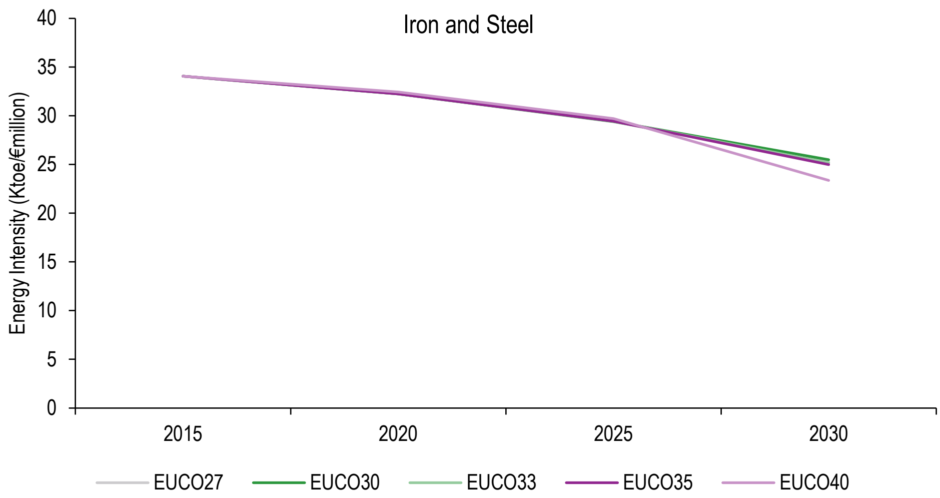
In each scenario, the energy consumption (in ktoe) per unit of value added and energy cost (in euros) per unit of value added decreases significantly from 2015 until 2030. In this period, total energy consumption in ktoe decrease by about 10% on average in the EUCO40 scenario compared to EUCO27. In the period 2015 to 2020, the effects on efficiency are relatively small, due to the slow response of EIIs, and improvements are observed after 2020 where the energy consumption per unit of value added starts to decrease. This decrease intensifies after 2025, when more energy efficiency measures are adopted in these industries.

In comparing the five scenarios against each other, it is noticeable that, in the short term, the energy efficiency improvement in all scenarios is marginal. Their differentiation is observed after 2025, with the corresponding levels of adoption of energy efficiency measures. As expected, the EUCO40 scenario provides the highest improvement in energy efficiency, with a total reduction in energy intensity of 10% by 2030 compared to EUCO27 projections.

Both indicators presented in Figure IV.13 and Figure IV.14 evolve in a similar manner, which is a direct outcome of efficiency improvements and the associated benefits provided by equipment upgrades and lower energy expenditure.

The following graphs focus on the energy intensity indicator and its variation between the different industries.

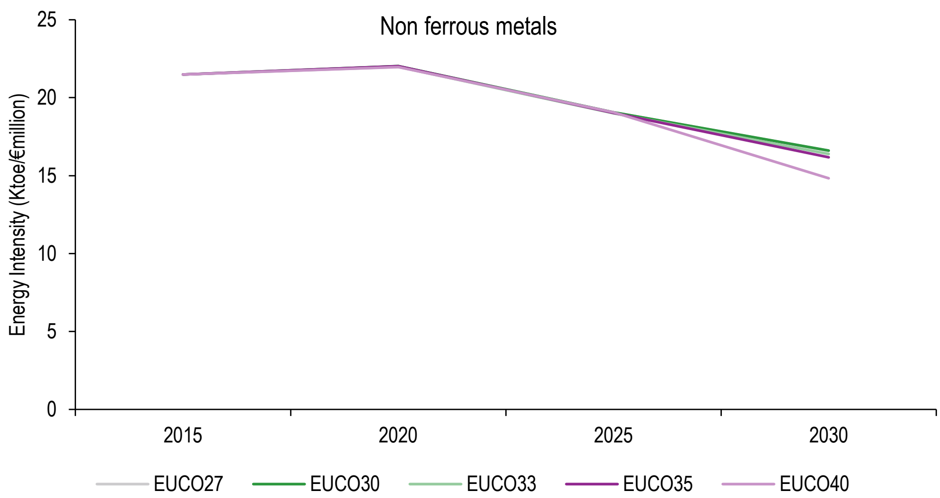
Figure IV.15: EU28 Energy intensity (Iron and Steel), 2015-2030



Source(s): EY, based on data from E3ME and PRIMES

Because the iron and steel industry accounts for almost one third of the total EIIs' energy consumption, it has a large effect on EII total energy consumption per value added and the analysis for the iron and steel industry's position is closely in line with the general one made above. Over time, energy consumption per unit of value added decreases by approximately 8% in the EUCO40 scenario compared to the EUCO27 scenario. Again, the change in energy consumption relative to EUCO27 is significantly smaller in the short and medium term, while it is much larger in the medium term for the EUCO40 scenario.

Figure IV.16: EU28 Energy intensity (non-ferrous metals), 2015-2030

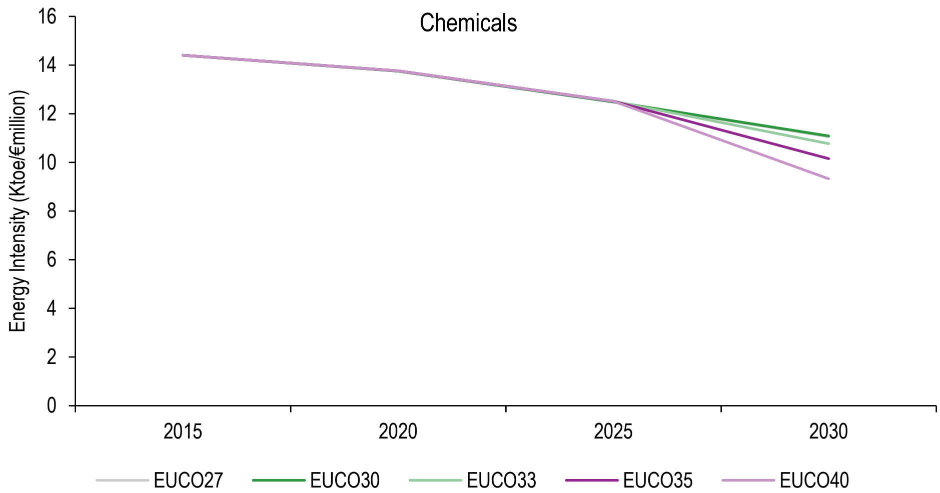


Source(s): EY, based on data from E3ME and PRIMES

The differences between the five scenarios for the non-ferrous metals industry (Figure IV.16) are much smaller than the differences in the iron and steel sector (Figure IV.15). For both sectors, energy intensity decreases by 7 and 10%. This decrease for the non-ferrous metals industry represents the lowest improvement out of all the energy intensive industries. The three periods in which the effects differ are also more evident for the non-ferrous metals industry. However, the EUCO40 scenario deviates in the medium to long term by having significantly lower energy intensity from 2025 to 2030.

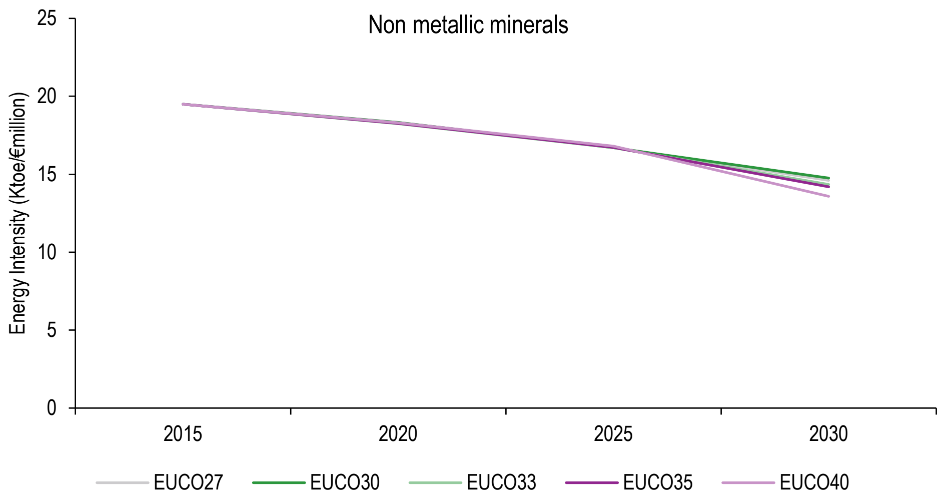
The chemicals industry (see Figure IV.17) displays the largest reduction in energy consumption per unit of value added out of all the energy intensive industries. Over the projection period, total energy consumption per unit of value added decreases by 15%. In both the short and long terms, there are no noticeable differences between the five scenarios. However, the percentage decline in energy consumption per unit of value added in the EUCO27 and EUCO30 scenarios does not differ in the medium and long terms, while the EUCO40 scenario displays larger energy efficiency improvements in both the medium to long terms.

Figure IV.17 EU28 Energy intensity (chemicals), 2015-2030



Source(s): EY, based on data from E3ME and PRIMES

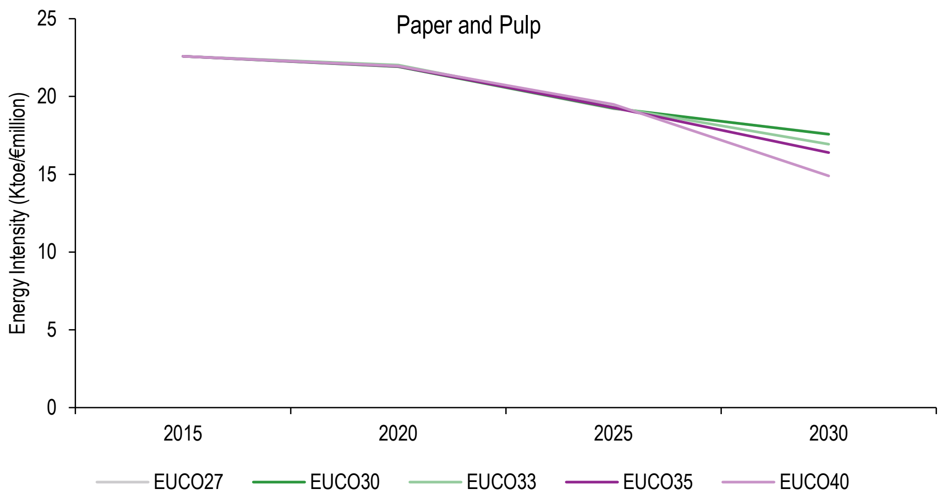
Figure IV.18 EU28 Energy intensity (non-metallic minerals), 2015-2030



Source(s): EY, based on data from E3ME and PRIMES

Similarly, the rate at which energy intensity declines in the non-metallic minerals sector does not significantly differ in the short and medium terms. Overall, it can be observed that energy intensity decreases by 15% in the period up to 2030 for the EUCO40 scenario compared to EUCO27.

Figure IV.19 EU28 Energy intensity (paper and pulp), 2015-2030



Source(s): EY, based on data from E3ME and PRIMES

For the paper and pulp industry there is a relatively stable rate of decline in all scenarios, which results in a total reduction in energy consumed per unit of value added by about 15%. Consequently, the effects for the paper and pulp industry are the largest among all the energy intensive industries. Here again, the EUCO27 and EUCO30 scenarios have lagging efficiency improvements in the medium and long terms while the EUCO40 scenario displays larger energy efficiency improvements in the medium to long term.

When comparing the effects of the scenarios at Member State level for each industry a recurring pattern can be observed. The most energy intensive countries in 2015 are those realising a bigger energy efficiency potential over the projection period, while the less energy intensive countries do not experience a significant increase in competitiveness due to the energy efficiency gains.

The tables below show total energy consumption and total energy cost per unit of value added, for each industry subsector and in total.

Table IV-30 Total energy consumption (ktoe) / value added (millions of euros)

		2015	2020	2025	2030
All EIIs	EUCO27	112.05	108.23	96.86	85.13
	EUCO30	0.0%	0.0%	0.0%	0.5%
	EUCO33	0.0%	0.0%	0.1%	-1.8%
	EUCO35	0.0%	0.0%	0.2%	-3.8%
	EUCO40	0.0%	0.2%	0.7%	-10.7%
Chemicals	EUCO27	14.40	13.75	12.48	11.06
	EUCO30	0.0%	0.0%	0.1%	0.3%
	EUCO33	0.0%	0.1%	0.3%	-2.6%
	EUCO35	0.0%	0.1%	0.3%	-8.2%
	EUCO40	0.0%	0.1%	0.3%	-15.6%
Iron and steel	EUCO27	34.07	32.23	29.38	25.27
	EUCO30	0.0%	0.0%	0.1%	0.9%
	EUCO33	0.0%	0.1%	0.2%	-0.4%
	EUCO35	0.0%	0.1%	0.3%	-1.1%
	EUCO40	0.0%	0.6%	1.1%	-7.5%
Non-ferrous metals	EUCO27	21.50	22.02	19.07	16.60
	EUCO30	0.0%	0.0%	0.0%	0.1%
	EUCO33	0.0%	-0.2%	-0.3%	-1.2%
	EUCO35	0.0%	0.0%	-0.2%	-2.5%
	EUCO40	0.0%	-0.3%	-0.1%	-10.6%
Non-metallic minerals	EUCO27	19.49	18.32	16.73	14.61
	EUCO30	0.0%	0.0%	-0.2%	1.0%
	EUCO33	0.0%	-0.4%	-0.2%	-1.8%
	EUCO35	0.0%	-0.3%	-0.1%	-2.8%
	EUCO40	0.0%	-0.1%	0.5%	-7.0%
Paper and pulp	EUCO27	22.58	21.91	19.21	17.59
	EUCO30	0.0%	0.0%	0.2%	-0.1%
	EUCO33	0.0%	0.5%	0.5%	-3.7%
	EUCO35	0.0%	0.1%	0.4%	-6.8%
	EUCO40	0.0%	0.3%	1.5%	-15.3%

Source(s): EY, based on data from E3ME and PRIMES

Table IV-31 Total energy cost (millions of euros) / value added (millions of euros), *Cambridge Econometrics, PRIMES*

Industry	Scenario	2015	2020	2025	2030
All EIIs	EUCO27	179.70	184.56	169.84	156.37
	EUCO30	0%	0%	-1%	-1%
	EUCO33	0%	-2%	-3%	-6%
	EUCO35	0%	-2%	-4%	-7%
	EUCO40	0%	-3%	-4%	-11%
chemicals	EUCO27	18.47	18.89	18.00	16.79
	EUCO30	0%	0%	-1%	-2%
	EUCO33	0%	-2%	-3%	-8%
	EUCO35	0%	-3%	-4%	-13%
	EUCO40	0%	-3%	-4%	-16%
Iron and steel	EUCO27	55.94	56.25	53.39	48.64
	EUCO30	0%	0%	-1%	-1%
	EUCO33	0%	-2%	-3%	-5%
	EUCO35	0%	-2%	-3%	-5%
	EUCO40	0%	-2%	-3%	-7%
Non-ferrous metals	EUCO27	40.52	43.13	37.47	34.19
	EUCO30	0%	0%	-1%	-2%
	EUCO33	0%	-2%	-4%	-7%
	EUCO35	0%	-2%	-4%	-6%
	EUCO40	0%	-3%	-4%	-11%
Non-metallic minerals	EUCO27	29.93	29.95	28.07	25.49
	EUCO30	0%	0%	-1%	-1%
	EUCO33	0%	-2%	-3%	-5%
	EUCO35	0%	-3%	-4%	-6%
	EUCO40	0%	-3%	-4%	-6%
Paper and pulp	EUCO27	34.83	36.34	32.92	31.27
	EUCO30	0%	0%	-1%	-2%
	EUCO33	0%	-1%	-3%	-8%
	EUCO35	0%	-3%	-4%	-11%
	EUCO40	0%	-3%	-3%	-15%

Source(s): EY, based on data from E3ME and PRIMES

7.3 The importance of SMEs in the EIIs

This section describes a less known aspect of EIIs, which is that an important share of these industries' turnover is from SMEs. The importance of EII SMEs for the European economy should not be understated, since, they constitute the majority of companies in the sectors, employ between 30% and 60% of EII employees, and return between 10% and 34% of total value added, depending on the industry sub-sector.

Table IV-32 Data on SMEs in the EIIs, 2013

Sector	Pulp & Paper	Chemicals	Aluminium	Cement	Steel	Glass
Sector description	Manufact. of pulp, paper and paperboard	Manufact. of basic chemicals, fertilisers and nitrogen compounds, plastics and synthetic rubber in primary forms	Manufact. of basic precious and other non-ferrous metals	Manufact. of cement, lime and plaster	Manufact. of basic iron and steel and of ferro-alloys	Manufact. of Glass and Glass products
NACE 2 Code	C171	C201	C244	C235	C241	C231
% SMEs in total Value Added - 2013	24%	25%	30%	30%	10%	34%
% SMEs in total Turnover - 2013	30%	27%	38%	31%	10%	36%
% SMEs in total no. of companies - 2013	91%	96%	95%	93%	93%	99%
% SMEs in total no. of employees - 2013	45%	35%	36%	60%	31%	52%
Value added per enterprise (SME) – 2013 (k€ / enterprise)	1.0934	1.0831	1.0357	1.0899	829	308
Value added per Employee (SME) – 2013 (k€ / enterprise)	54	81	73	50	20	31
Turnover per enterprise (SME) (k€ / enterprise)	12,457	11,141	12, 648	6,378	6,166	1,048
Turnover per Employee (SME) (k€ / enterprise)	346	496	681	168	149	107

Source(s): EY, based on Eurostat data

According to Eurostat figures for 2013, SMEs[43] accounted for more than 90% of enterprises in energy intensive industrial sectors (up to 99% for the Glass industry). On average, they represent 30% of the total value added of their respective sectors (except

[43] SME = small and medium sized enterprises (SMEs) definition according to EUROSTAT: with 1-249 persons employed

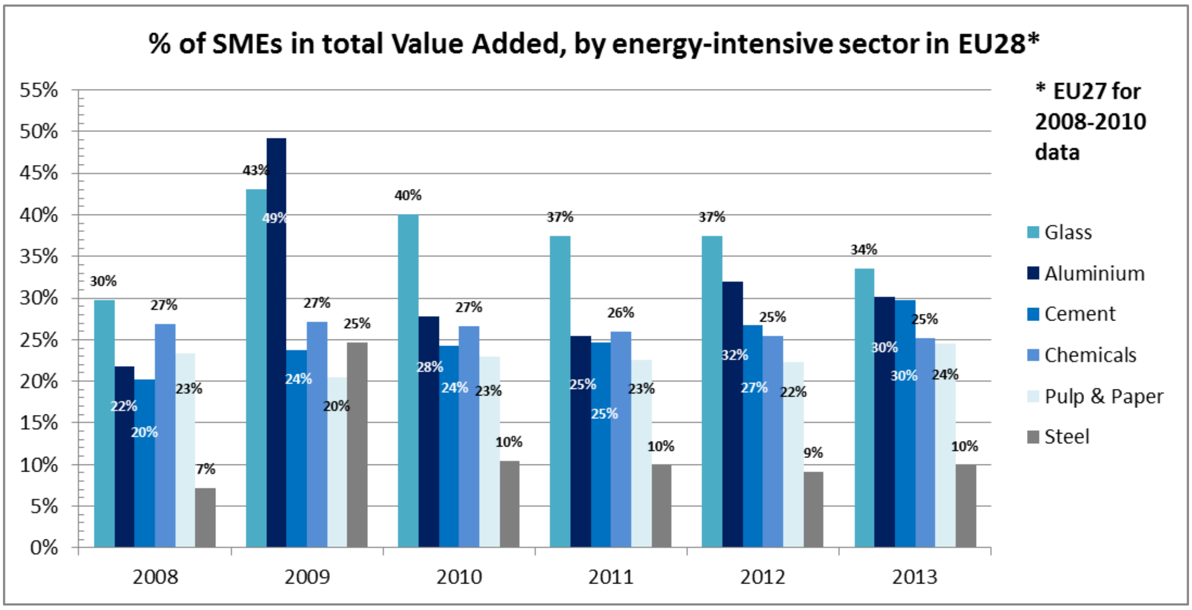
for the steel industry, for which SMEs only account for 10% of the total value added, despite accounting for 93% of the total number of enterprises).

SMEs in the glass industry are particularly small, with an average value added per enterprise of around €308,000 in 2013, and an average number of ten employees per enterprise (compared to 20-40 employees for SMEs in other sectors).

For most energy intensive sectors, the share of SMEs in total value added has remained relatively flat over time (at least for the 2008-2013 period). The economic crisis of 2008 that impacted industry as a whole and in 2009 there was a in a one-off increase in the share of SMEs in the value added for aluminium, steel and glass sectors. These three sectors have been particularly impacted by the economic crisis, and large enterprises (>250 employees) were the first to be affected.

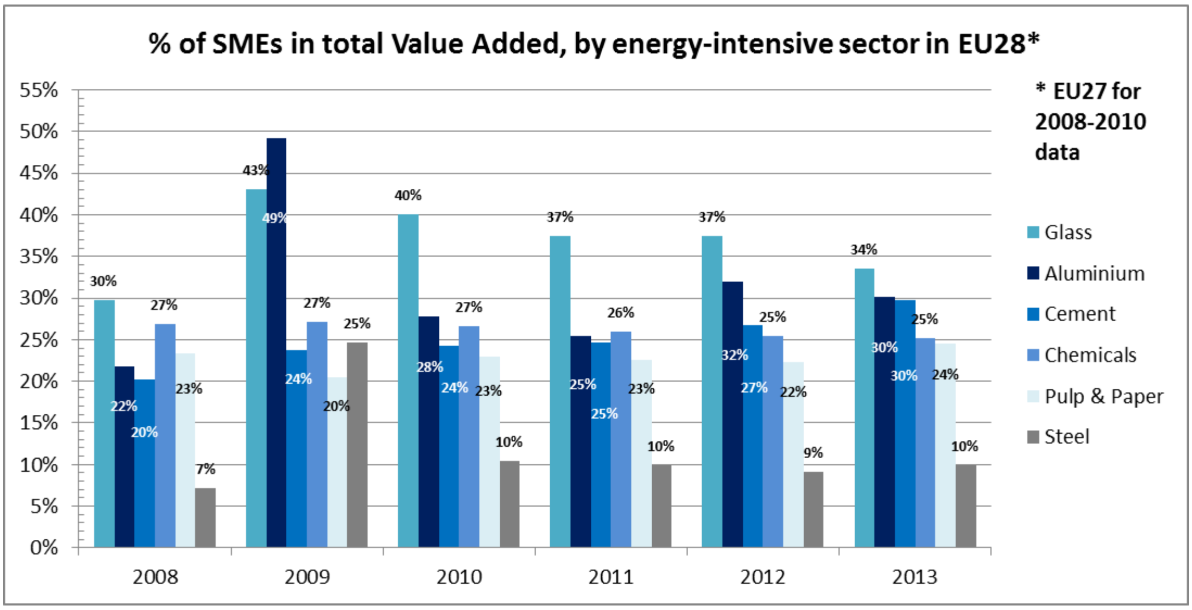
The share of SMEs in the cement sector has been constantly increasing since 2008, from 20% in 2008 to 30% in 2013. This tendency, driven by a decrease in large enterprises' value added rather than an increase in SMEs', could continue into the projection period, making cement an important sector for SMEs.

Figure IV.20 % of SMEs in total value added, by energy-intensive sector in EU 28



Source(s): EY analysis based on Eurostat data

Figure IV.21 % of SMEs in total value added, by energy-intensive sector in EU 28



Source(s): EY analysis based on Eurostat data

7.4 International competitiveness of EIIs

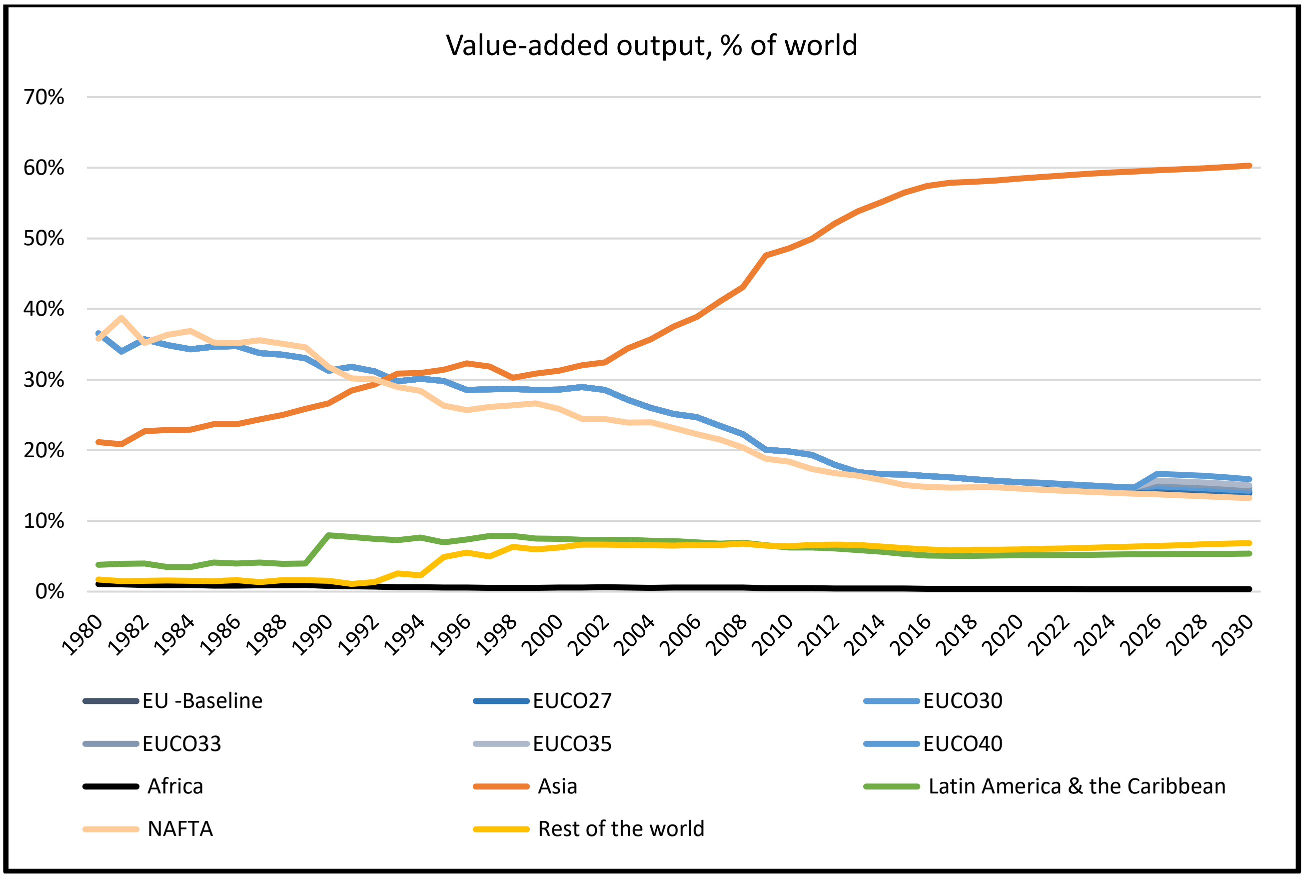
This section assesses the international competitiveness of European EIIs. The aggregated value added of all EIIs[44] is used as an indicator and expressed as a share of worldwide value added. The geographical scope is worldwide and for ease of presentation, it is aggregated in five key regions: EU28, Asia, NAFTA[45], Africa, Latin America & the Caribbean, and the rest of the world. There are projections of value added for international competitors and for the EU, which is represented in the five EUCO scenarios that improve the energy efficiency of EIIs in 2030.

Figure IV.22 shows that Asian EIIs overtook Europe and North America in the 1990's, after a period of intense growth, which is expected to continue to 2030. Contrary to Asia, Europe and North America are in a continuous decline in their share of global value added. It should be noted that these figures are shares of world value added, and thus relative to each other. EU value added among EIIs has grown by about 80% since 1980, but the strong growth of Asian economies has caused a decline in overall global market share.

The results suggest that energy efficiency could increase the international market competitiveness of European EIIs in 2030 by about 5% above currently projected trends. While not a negligible impact, it would not reverse the loss of global market share since 2000.

[44] Pulp & paper, Basic chemicals & fertilisers, Non-metallic minerals, Cement, Iron & steel, Non-ferrous metals
[45] North American Free Trade Agreement, comprising of the USA, Canada and Mexico

Figure IV.22: Value added shares of the EU and other world regions



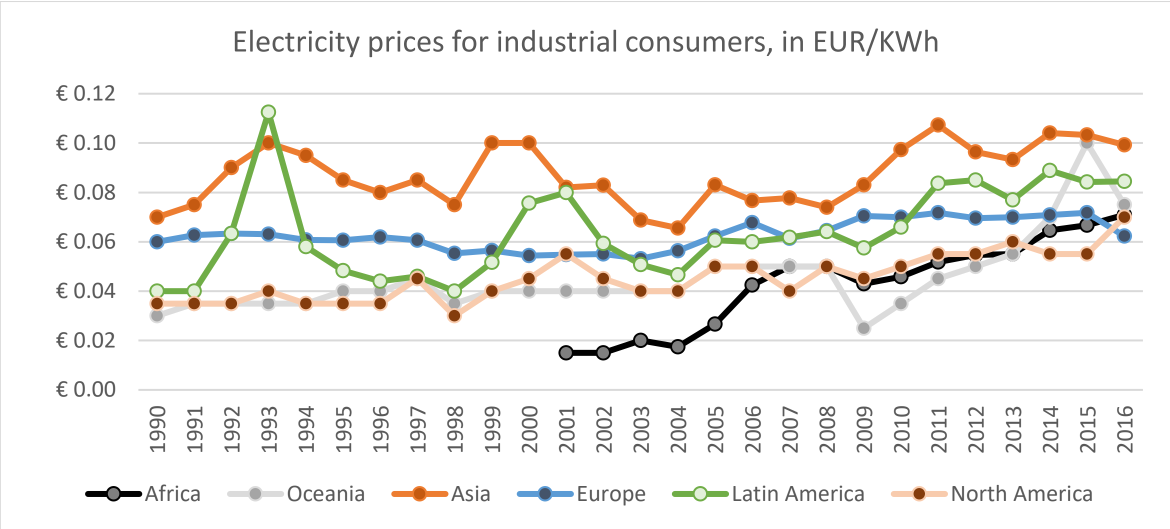
Source: Oxford Economics, Using data from National Statistical Offices, 2017

7.5 Energy costs for energy intensive industries

The previous section offered insight on the competitiveness levels of European industry, and how it has evolved since 1980. This section discusses the impact of energy prices on competitiveness within the global market. Energy costs is a key issue for companies in the energy-intensive sectors and the European Commission has published specific analysis on this issue (European Commission, 2014; 2016b).

Prices for fossil fuels, mainly oil and coal, are market determined by global supply and demand, and therefore do not vary significantly between regions. Local circumstances and specific contracts can offer highly competitive energy prices to individual customers, but that level of disaggregation cannot be considered here. The energy source for EIIs that is highly region-depended, is electricity which, even within the EU, varies significantly. Figure IV.23 shows the evolution of electricity prices for industrial consumers in the six world regions since 1990.

Figure IV.23 Electricity costs for global EIIs since 1990



Source: BMI research, 2017

Electricity costs for industry in the EU have historically been higher than most regions, other than Asia, but energy costs are not the only determinant of effective business, and could in comparison be regarded as a relatively marginal aspect of competitiveness. Our results suggest that energy costs may not be the most important determining factor of competitiveness, as there is little correlation between electricity prices and EII value added, as seen in Table IV-22. We therefore examine the share of energy costs to the gross output of various EIIs in the EU and in three major competitors: the US, China and Japan. The following table indicates that in the EU, energy costs as a share of industry expenditure are lower than major international competitors.

Table IV-33: Energy cost shares by manufacturing industry in basic prices (in % of gross output)

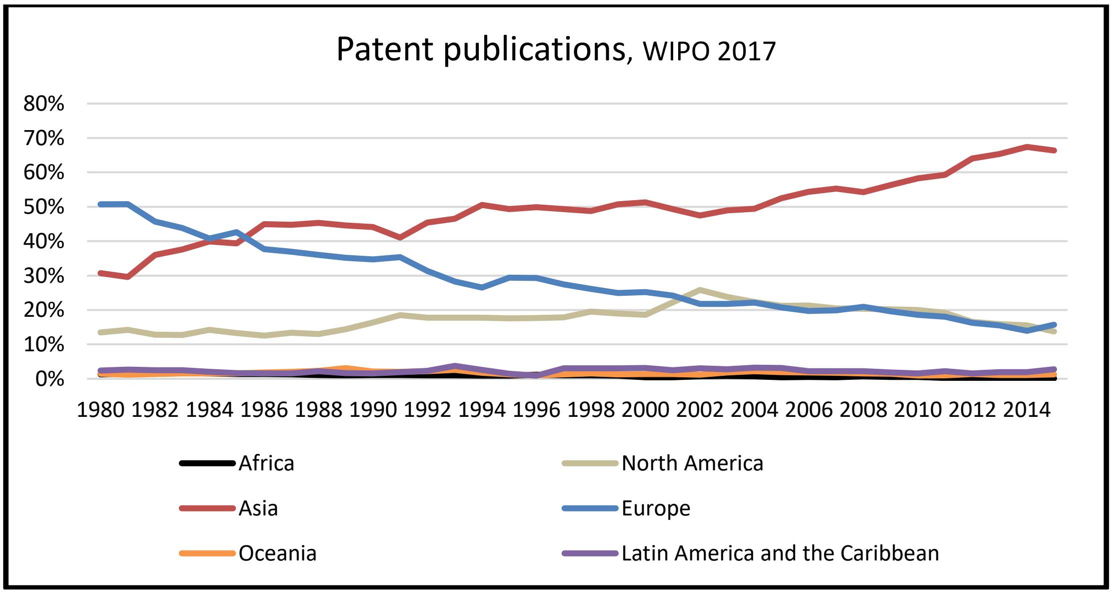
	EU-27	China	Japan	US
Pulp, paper, printing and publishing	3.2	3.6	4.8	3.2
Chemicals and chemical products	7.4	18.9	13.1	7.8
Other non-metallic mineral products	7.4	15.5	16.8	5.8
Basic metals and fabricated metal	4.1	9.8	10.2	4.2

Source(s): WIOD, 2016

Other aspects that define the competitiveness of an industry are product quality, differentiation, innovation, and in general, aspects that relate more to the skills and training of the workforce. Moreover, the proximity to consumers, geographical factors, and the trade network of intermediaries are significant in determining competitiveness. Innovation is assessed further here as a key determinant of competitiveness.

Innovation can offer insights into the competitiveness of European EIIs. Figure IV.24 traces all patents submitted in the EII-relevant fields[46] since 1980. It is evident that the R&D interest of European industries has been steadily decreasing since 1980, when Europe was submitting 50% of all patents in the EII-relevant fields. The equivalent figure now is about 15%. In 1985, Asian economies had already overtaken Europe in innovation by submitting more patents. Comparing to the previous figures, it becomes evident that innovation offers some justification why, only five years later, Asia was already starting to overtake the EU and the US in terms of value added, despite the higher unit energy costs shown in Table IV-33. In summary, while lower unit energy costs boost competitiveness of the EIIs, other factors like innovation are also important.

Figure IV.24 Patent applications for EIIs, by world regions



Source(s): EY

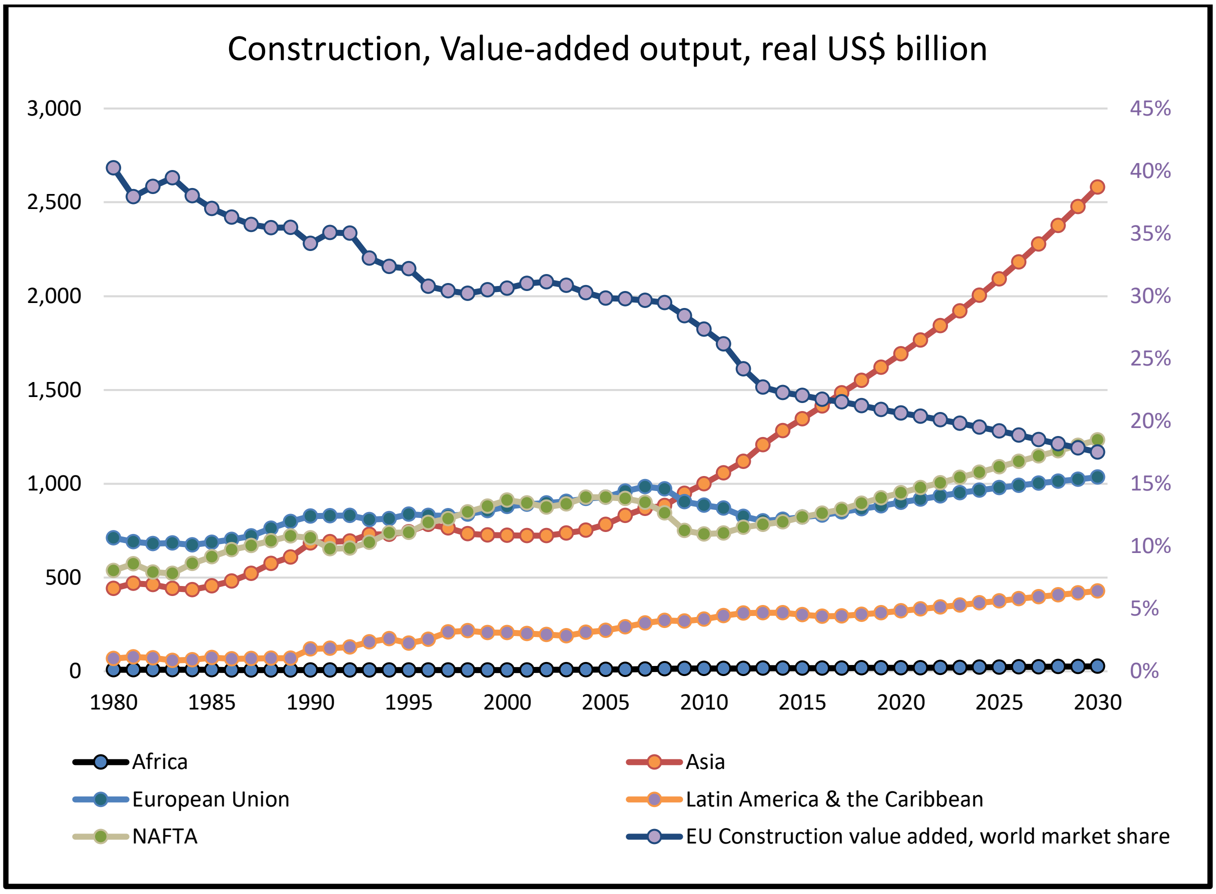
7.6 The construction sector and its potential for energy efficiency

The EU's construction sector value added, as a world market share, has been declining over the past 37 years, due to increases in output by other world regions, most notably Asia. It is projected that this gap will widen in the decades to come, with the construction sector's value added in the EU hardly reaching above the levels of the pre-2008 crisis levels.

Furthermore, recent innovations in construction (such as prefabrication, 3D printing and building information modeling) seem to be taken up mostly in Asia and emerging markets, as they exploit the best available technologies and drive innovation to meet the demands of their growing economies.

[46] Electrical machinery, apparatus, energy; Basic materials chemistry; Materials, metallurgy; Chemical engineering; Environmental technology; Textile and paper machines

Figure IV.25: Construction value added, global market shares



Source(s): EY

Figure IV.25 identifies development opportunities for the construction sector, which, in contrast to previous decades, do not need to be in the field of new construction. More benefits are to be found now in new business models that improve buildings operation and reap the benefits of energy efficiency. In the construction industry, there are multiple examples why energy efficient buildings offer benefits. For example, the literature identifies that the presence of an energy efficient label increases the value of properties[47]. Other benefits such as improved cognitive functioning for office employees, accelerated recovery of hospital patients and improved learning in schools are also increasingly realised (Allen et al, 2017; MacNaughton et al, 2017).

7.7 The market for energy efficiency services

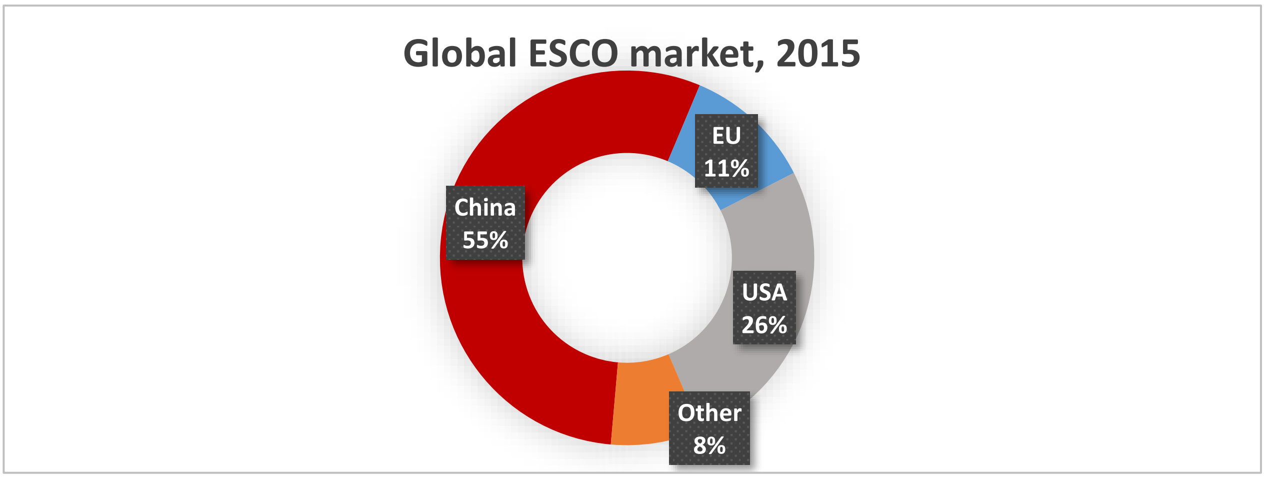
The market for energy efficiency services is comprised of companies (mostly SMEs) that offer technical and financing solutions for improving the energy efficiency of their customers' operations with the aim of reducing energy consumption. These companies guarantee payback period in accordance with their client's investment hurdle rates. They are also referred to as Energy Service Companies (ESCOs) and offer their services through energy performance contracts (EPCs) that are usually repaid by harvesting the

[47] See the EPBD report, also Brounen & Kok, 2011; Bloom, 2011; Kok & Kahn, 2012; Zheng, 2011; Fuerst, 2013.

reduction in energy utility bills. The targets of ESCOs are characterised by large assets with corresponding energy consumption patterns (therefore mostly industrial clients) in order to capitalise on the savings scale. ESCOs are also active in the residential market through the aggregation of projects, often as a response to public procurement. The achieved savings may link to energy efficiency obligations, or white certificates, or be monetised in carbon markets.

The worldwide market for energy efficiency services has been valued at close to $24 billion in 2015, with China holding the world's largest share, and achieving 7% growth during the same year. In the EU, for 2015, the ESCO market was worth $ 2.7 billion in gross output (IEA, 2016).

Figure IV.26: Global ESCO market, 2015



Sources: EMCA, JRC, Navigant Research in IEA, 2016

ESCO is a growing market, which is driven by energy prices and government procurement and regulation (i.e. energy efficiency obligations schemes in Europe). In order to ensure that the multiple benefits arising from the expansion of the market for energy efficiency services are realised, regulatory standards and obligations could provide effective solutions, and allow this growing sector to tap into large markets. Considering the increasing constraint on carbon emissions, and the effective role of energy efficiency to mitigate energy demand, business models and experience developed in the EU could be replicated globally. The competitiveness of EU firms in global ESCO markets depends on the quality and cost of their services, which they can develop through responding to tight regulatory constraints.

Part V. Conclusions

1 Overview of the study

The IEA (2014) has identified a range of multiple benefits that may result across the all economy and society from improved energy efficiency. There are also costs associated with energy efficiency, notably in financing the initial investment, which may take resources away from other parts of the economy. This report has aimed to estimate both the benefits and the costs of enhanced energy efficiency in Europe, using a broad assessment framework. Our approach is primarily model-based, using the E3ME macro-econometric model, with supplementary analysis for impact areas that the model cannot cover. Wherever possible, results are quantified.

The methodologies and results used in this report build on a recent assessment of the EPBD, extending the analysis to cover other economic sectors. Based on different policy options, five possible future energy efficiency target scenarios were assessed. The five energy efficiency target scenarios were:

- EUCO27: 27% the minimum energy efficiency target, politically agreed in 2014
- EUCO30: 30% Energy efficiency target
- EUCO33: 33% Energy efficiency target
- EUCO35: 35% Energy efficiency target
- EUCO40: 40% Energy efficiency target

All the targets are defined against a 2007 baseline case (European Commission, 2008). For each scenario, the inputs have been derived from PRIMES model results, providing consistency with the full EED Impact Assessment (European Commission, 2016). The scenarios have been compared to a reference option (derived from the 2016 PRIMES Reference scenario) in which there is no policy change and presented, in most cases, as a comparison to the EUCO27 scenario. Six impact areas have been covered:

- Economy and labour market
- Health
- The environment
- Social aspects
- Public budgets
- Industrial competitiveness

It should be noted that there is potentially considerable cross-over and interaction between the different categories, some of which is captured in the assessment framework. However, most important is to note that we avoid double counting of impacts between the different categories[48].

Table V-1 summarises the key findings in each impact area. The following sections describe the key findings in each area.

[48] An exception is the results for GDP and competitiveness; the increase in output for the insulation and glass sectors also makes a small contribution towards the GDP increases. There is also a slight increase in material consumption.

Table V-1 Key results from the analysis (EU28, difference to EUCO27 in 2030)

	Direction of impact	Key results in 2030
Economy and labour market	Positive	GDP increases by 0.4 to 4.1% Employment increases by 0.2 to 2.1% There are modest improvements in energy security, more significant in vulnerable countries
Health and well-being	Positive	Annual healthcare cost savings of up to €77 billion
Environmental impact	Mostly positive	Final energy consumption reduced by 7.1% to 17.8% GHG emissions reduced by more than 40% compared to 1990 levels, potentially by 47% Material consumption increased by 0.7-2.7%
Social aspects	Positive	Potentially up to 8.3m households removed from fuel poverty Slightly reduced income distribution inequality Unemployment reduced by between 0.3 and 3.0 million
Public budgets[49]	Slightly positive	Increase in annual public balances of between 0.1 and 2.0% of GDP
Industrial competitiveness	Slightly positive	Potential long-run benefits to European firms from reduced energy costs

2 Conclusions in each impact area

2.1 Economy and labour market

The model results show that ambitious investment programmes in energy efficiency could have benefits for Europe's economy. GDP impacts in 2030 are positive at EU level in all the scenarios compared to EUCO27. The positive results are obtained even if some of the additional investment activity 'crowds out' investment elsewhere in the economy (see Section 4.2 below).

Investment demand could increase substantially in the scenarios, reflecting the investment-intensive nature of energy efficiency. The construction sector is likely to see the largest increase in production as it plays a key role in installing new energy efficiency equipment. However, apart from the energy supply and utilities sectors, there are increases in output across all parts of the economy.

A large part of the overall increase in GDP is driven by reductions in fuel imports. Spending by households and businesses in the EU is diverted from imported fuels to other goods and services that may be produced domestically. This leads to an overall increase in rates of activity in the EU's economy, and higher GDP. Reduced imports of

[49] From this area, the positive effects of reduced health costs on public budgets is not included.

fuels would also have energy security benefits, including in several central and Eastern European Member States that are currently exposed to a single non-EU supplier.

Household expenditure also increases in the scenarios. Combined with the non-financial benefits of having warmer homes, it can be inferred that welfare would also increase.

Table V-2: Impacts on EU GDP and employment in 2030, % difference from EUCO27

	Degree of crowding out	EUCO30	EUCO33	EUCO35	EUCO40
GDP (€2013bn)	No crowding out	0.4	1.5	2.1	4.1
	Partial crowding out	0.4	1.3	1.6	2.2
Employment (m)	No crowding out	0.2	0.7	1.0	2.1
	Partial crowding out	0.2	0.6	0.9	1.4

Source(s): E3ME, Cambridge Econometrics

The modelling results also show that an increase in energy efficiency would lead to higher rates of employment and lower rates of unemployment in the EU in 2030. Employment could increase by up to 2.1% compared to the EUCO27 scenario. Many of the additional jobs created relate to the manufacturing and installation of energy efficient equipment (e.g. in the construction and engineering sectors) but due to multiplier effects there are also jobs created in the wider economy, including in service sectors. In the EUCO35 and EUCO40 scenarios, a rapid increase in employment in key sectors after 2025 may lead to skills shortages but these could be alleviated by further increases in training in STEM[50] subjects and active labour market monitoring.

2.2 Health

Improved energy efficiency can have health benefits for several different reasons but the largest impacts arise from a combination of reductions in indoor and outdoor air pollution. The scenarios that were assessed show large potential health benefits in monetary terms, particularly due to changes in the indoor environment. The scale of the changes (€100bn pa) is roughly equivalent to 0.5% of EU GDP in 2030.

Table V-3: Potential health benefits in 2030, EU28, difference from EUCO27 scenario

	Mortality & morbidity / cost savings, SOx in 2030	Mortality & morbidity / cost savings, NOx in 2030	Mortality & morbidity / cost savings, PM_{10} and $PM_{2.5}$ in 2030	Mortality & morbidity / cost savings NOx, SOx, PM_{10} and $PM_{2.5}$ in 2030
	m€ / year	**m€ / year**	**m€ / year**	**m€ / year**
EUCO30	-1,056	-62	-27,183	-28,301
EUCO33	-489	9	-54,366	-54,846
EUCO35	-1,365	247	-56,498	-57,616
EUCO40	-4,158	-1,467	-71,422	-77,047

50 Science, technology, engineering and mathematics.

Although the uncertainties and limitations of such assessment are high, clearly the potential benefits involved are substantial. The EPBD and other legislation relating to residential dwellings will play a key role in capturing these benefits.

2.3 Environmental impacts

Energy efficiency could impact on the environment in several different ways. Reducing energy consumption is, in itself, an environmental benefit, as energy extraction and electricity generation can have adverse impacts on local environments and, in particular, on air pollution. The results presented in this report show that, despite rebound effects (see Section 4.1 below), there are substantial falls in final energy consumption in the EU in the scenarios.

Reductions in energy consumption are matched by falls in greenhouse gas emissions. The results in this report, which follow those from PRIMES but include rebound and other indirect effects, confirm that in all the scenarios the EU 40% emission reduction target for 2030 is met. Further emission reductions in the more ambitious scenarios suggest that the target could be exceeded by some distance.

Table V-4: Summary of environmental impacts, % difference from EUCO27 scenario

	Units	EUCO30	EUCO33	EUCO35	EUCO40
Final energy demand[51]	% from EUCO27	-7.1	-12.9	-14.1	-17.8
GHG emissions	% from 1990	-40.8	-43.0	-43.9	-47.2
SO_2 emissions	% from EUCO27	-0.6	-4.3	-2.5	-5.1
NOx emissions	% from EUCO27	0.0	-1.6	-0.6	-1.5
Material consump.[52]	% from EUCO27	0.6	1.7	2.7	2.5

Source(s): E3ME, Cambridge Econometrics

The impacts on local air pollutants, such as SO_2 and NOx, which can cause harm to human health are also reduced at European level in the scenarios. The E3ME model does not go into the same level of detail as the more specialised GAINS model that was used in the EED Impact Assessment, but does include impacts that arise from rebound and other direct economic effects. However, a further disaggregation of results shows that a large share of the impacts on emissions of these pollutants depends on the scale of coal-fired electricity generation, which in turn depends on EU ETS prices (which fall in the scenarios with more energy efficiency, as modelled by PRIMES). The conclusion is that to realise the full benefits of reduced local air pollution, other measures are required alongside the energy efficiency programmes.

Rates of material consumption (DMC) could increase in scenarios that have more energy efficiency. The reason for this is that the investment sectors, in particular construction, are intensive users of materials. In order to produce the additional energy efficient equipment, additional resources are required. Slightly higher rates of economic growth (Section 2.1) also lead to higher material demands.

[51] Primary Energy Consumption has not been fully estimated in the current E3ME results but the trends follow those for Final Energy Demand.
[52] Domestic Material Consumption, DMC

2.4 Social impacts

The social impacts of energy efficiency arise mostly from energy efficiency in residential dwellings. The analysis in this report suggests that large numbers of households across Europe could be removed from energy poverty if ambitious energy efficiency programmes were implemented. Because at this stage it is not possible to say what types of households would be affected by the energy efficiency measures (e.g. whether they could be targeted at low-income households) it is only possible to provide a range of results. Table V-5 shows three indicators of potential energy poverty; the results suggest that up to 8.3 million households could be removed from energy poverty if the measures were carefully targeted.

Table V-5: Potential reductions in energy poverty by 2030 compared to reference (thousands of households in the EU, ambitious scenario)

	LOW variant	HIGH variant
Arrears on utility bills	1,456.4	5,171.3
Leaks, damp, rot	2,327.4	8,255.8
Ability to keep home warm	1,748.4	6,203.8

Source(s): Wuppertal Institut, EPBD report, Part IV, Section 5, pp. 54.

There are other potential social impacts from energy efficiency. An increase in employment in the scenario results is matched by a decrease in unemployment. The modelling results from E3ME suggest that income distribution will not get worse under the energy efficiency scenarios and could improve. In summary, there are potentially quite substantial social benefits if the policies are implemented appropriately.

2.5 Public budgets

Public sector budgets can be affected by energy efficiency in several different ways. The public sector will be impacted directly through its own investment in energy efficiency and any savings in energy bills that arise. There may also be a loss of revenue from fuel excise duties if energy consumption falls, and ETS auction revenues if the ETS price falls.

However, the larger impacts are likely to arise from other activities in the economy. For example, if employment levels increase then revenues from income taxes and social contributions will also increase; expenditure on social benefits and welfare payments will likely decrease.

Overall, the impacts on public budgets in all the scenarios are positive. The maximum impact on the public sector is in the EUCO40 scenario is 2% of GDP, potentially a substantial amount that could help Member States stay within their 3% budget deficit ceiling under the EU's Sustainability and Growth Pact.

One consideration that is important regarding public budgets is how the energy efficiency measures are financed. In this report, one variant to the main scenarios is tested, where the measures are financed through taxation rather than private investment (see Section 4.3 below). Despite assumptions about adjusting tax rates to compensate for the additional public expenditure in this scenario, the impacts on public budgets are quite different, because VAT that accrues from household spending on energy efficiency is lost if the government funds it.

Table V-6: Impact on public budgets, as % of EU GDP in 2030 (difference from EUCO27)

	EUCO30	EUCO33	EUCO35	EUCO40
Self-financing				
No crowding	0.1%	0.6%	1.0%	2.0%
Partial crowding	0.1%	0.5%	0.8%	1.2%
Public financing				
No crowding	0.0%	0.1%	0.1%	0.4%
Partial crowding	0.0%	0.1%	0.1%	0.2%

Source(s): E3ME, Cambridge Econometrics

2.6 Competitiveness

Competitiveness is the result of a combination of factors. Unit energy costs could be important for the Energy Intensive Industries (EIIs) but is unlikely to have much impact on other sectors. Within the EIIs, the scenarios show reductions in energy costs in addition to what could be expected anyway. This could provide some assistance to European industry but is unlikely to reverse the long-term trends of shifts in market share towards Asia.

The role of innovation is also important to EIIs. It has not been assessed specifically in this report but there is a correlation between patents and increasing market share. If the innovation relates to increasing energy efficiency then there is a potential link to future prospects.

Other sectors, such as construction and ESCOs, could benefit from the development of large-scale energy efficiency programmes in Europe. If these firms are able to develop expertise in their domestic market then there is the potential to export to other parts of the world in future.

3 Allocation of impacts to EU policies

The scenarios considered in this report do not represent specific policies but instead consider ranges of policies that are designed to meet specified targets for energy efficiency. This is in part due to the way that energy efficiency has been modelled in PRIMES, for example through the effects on agents' behaviour of economic incentives that represent policies but not always in an explicit manner. The policies that are included in the different scenarios are described in Annex 4 of the Impact Assessment and in E3MLab and IIASA (2016). They are summarised here:

- Compared to the EUCO27 scenario, EUCO30 includes higher rates of residential energy efficiency through the EPBD and EED (including financing), more stringent ecodesign standards and measures to promote heat pumps. There are some additional measures in the transport sector.
- The EUCO33 scenario then includes further measures to renovate buildings linked to the EPBD and EED and additional financing options. Best available technologies are used in industry and there are several transport measures.

- The EUCO35 scenario includes further energy efficiency in buildings and adoption of heat pumps. There are further standards and advanced technology uptake in industry and tighter fuel standards in transport.
- The EUCO40 scenario includes upgraded versions of the same policies.

It is possible to draw the following tentative conclusions from the analysis:

- Almost all the social benefits that have been outlined in this report can be attributed to the combined effect of the EPBD and EED on residential buildings[53]. Based purely on a ratio of energy savings, around one quarter of the environmental benefits that are obtained in the EUCO30 and EUCO33 scenarios could be attributed to the EPBD. However, it should be stressed that the energy savings in the EPBD scenarios are to some extent dependent on other regulation (e.g. the Ecodesign Directive) so policy interaction is important.
- Labelling and Ecodesign options also feature in the EUCO30 and EUCO33 scenarios. These policies affect both households and businesses and so it is difficult to separate their impacts from EED and financing policies, as well as the EPBD.
- Leaving aside transport, a combination of financing measures and the EED account for the rest of the benefits. It is not possible to separate these two policy instruments because they are closely interlinked; without both operating in tandem some of the efficiency gains would not be realised. These measures together are likely to account for most of the benefits in the EUCO35 and EUCO40 scenarios as they stimulate the large amounts of investment that drives the positive results in the modelling.

In addition, it is noted that the policies each already make contributions to the EUCO27 scenario, to which the results are compared in this report, and that other policies (e.g. carbon pricing) can have an important impact.

Although the disaggregation described above is rather coarse in nature, it highlights the importance of having a portfolio of policies working together to meet the requirements of different sectors. Without any one of the policies the degree of energy efficiency realised, and therefore level of benefits, would be diminished.

4 Key issues to consider

4.1 Rebound effects

Rebound effects are an important issue in any assessment of energy efficiency impacts. They describe how the initial energy savings may not be fully realised because of secondary effects. Usually they are split into:

- Direct effects – for example, if insulation makes heating cheaper, then people have warmer homes)
- Indirect effects – for example, if lower heating bills mean more money to spend on other things, then consumers will purchase more goods, some of which require energy to produce.

In this report, the direct effects are included in the inputs received from the PRIMES model. The modelling with E3ME then estimates indirect effects.

[53] The impacts of the EPBD are reported separately. Scenario 3 in the EPBD report could be embedded in the EUCO33 scenario. There are positive impacts on GDP (up to 0.6% in 2030) and measures linked to the EPBD could also be expected to lead to large health benefits and a small improvement in public budgets.

Table V-7 shows the scale of the indirect rebound effect. In the less ambitious scenarios the extent of the rebound effect is quite limited and in the EUCO30 scenario is too small to stand out amongst other indirect effects (e.g. price changes). However, as the level of ambition increases the size of the rebound effect also increases (both in relative and absolute terms). In the EUCO40 scenario more than a quarter of the initial energy savings could be lost to the indirect rebound effect.

The reason that the rebound effect increases in size with the level of ambition is the relationship between economic production and energy consumption. In the EUCO40 scenario the level of investment required is much higher than in the other cases because the energy efficiency measures become more expensive. The more expensive measures require more energy to produce. They also provide higher incomes to the companies and workers that manufacture and install them, leading to induced effects. Thus, the size of the rebound effect is very closely linked to the economic impacts described in Section 2.1.

In this light, it should be stressed that the rebound effect is not necessarily a negative outcome. The positive impacts on the economy and labour market, social welfare and public budgets all depend on the same mechanism. If the primary aim is to reduce energy consumption, however, additional policy may be required.

Table V-7: The scale of indirect rebound effects and implications on energy savings achieved (compared to 2007 baseline), EU28 in 2030

	No Crowding out		Partial crowding out	
	Rebound effect	EE savings in 2030	Rebound effect	EE savings in 2030
EUCO30	0.0%	30.0%	0.0%	30.0%
EUCO33	6.1%	32.6%	6.1%	32.6%
EUCO35	9.4%	34.2%	8.7%	34.3%
EUCO40	27.4%	36.4%	25.6%	36.7%

Source(s): E3ME, Cambridge Econometrics

4.2 Crowding out

Crowding out is a term that is used in this report to refer to capacity constraints on the levels of production that can be achieved. The issue has been recognised as a key determinant of the differences in results between macro-econometric models such as E3ME and the more common Computable General Equilibrium (CGE) approach (e.g. see European Commission, 2015).

In summary, the difference arises because of the ways the models treat economic production. In a CGE model, it is assumed that agents optimise and that resources are never left unemployed involuntarily.; this means it is not possible to increase production without displacing, or 'crowding out', production from elsewhere. E3ME does not impose this assumption, and so higher levels of production are possible. The result is that E3ME often suggests better results than other models for scenarios that involve large investment stimuli.

To aid comparability, there are two sets of results produced:

- A set with no crowding out, which is a standard E3ME assessment (no crowding out)
- A set with an additional constraint imposed to limit how much production can increase (partial crowding out)

The limit in the partial crowding out case was determined by assessing how much it was possible for the construction sector to increase output in a short period of time, given available Eurostat data. Any attempt to increase production above this level led to displacement of other activity.

The impact on results of imposing partial crowding out, shown in Table V-8, is to reduce economic, labour market benefits and public budget benefits by almost half. The differences become larger as the scenarios become more ambitious, because more Member States hit the constraint.

There is no consensus among economists about whether crowding out would occur in reality. There are, however, some ways that the effects of it could be reduced. Most importantly would be to signal to firms in advance about potential future increases in production, so that they can invest in sufficient capacity. Labour market capacity could also be important as skills shortages can be an important constraint on production. Previous analysis of energy efficiency policy has highlighted the need to encourage training of more workers with basic STEM skills who are able to adapt to the new types of jobs that would be created.

Table V-8: Impacts on EU GDP and employment in 2030, % difference from EUCO27

	Degree of crowding out	EUCO30	EUCO33	EUCO35	EUCO40
GDP (€2013bn)	No crowding out	0.4	1.5	2.1	4.1
	Partial crowding out	0.4	1.3	1.6	2.2
Employment (m)	No crowding out	0.2	0.7	1.0	2.1
	Partial crowding out	0.2	0.6	0.9	1.4
Public budgets (% of GDP)	No crowding out	0.1	0.6	1.0	2.0
	Partial crowding out	0.1	0.5	0.8	1.2

Source(s): E3ME, Cambridge Econometrics

4.3 Financing the energy efficiency measures

The final key issue to consider is the way in which the energy efficiency measures are financed. As the levels of energy efficiency in the scenarios are given by the results from the PRIMES model, this report is not able to assess how different financial arrangements can affect the take-up of efficiency measures. However, there is some scope for assessing how the financing arrangements might affect the six impact areas.

In the main scenarios in this report, a 'self-financing' approach is assumed. Under this approach the agents the benefit from the energy efficiency pay for it. This means that:

- Businesses pay for their own equipment and increase prices to recoup costs
- Households divert spending from other things towards energy efficient goods
- Government pays for its own equipment and increases VAT rates to cover costs

One alternative approach, where the whole investment is paid for through public budgets, was also tested. This variant is similar to the approach used in European Commission (2015).

Some of the impact areas are not affected by the financing method (e.g. the environmental benefits accrue either way) but the results do impact on the economic and public budget results. Table V-9 shows that the GDP impacts are better under the public financing scheme but the public budgets are worse under the public financing scheme by about the same amount.

The reason for the differences is to do with VAT receipts from purchases of the energy efficient equipment. In the self-financing case, households must pay VAT on their purchases. This takes money out of the economy but it accrues to national governments. The impacts on GDP and public budget results are thus close to being opposite and equal.

The conclusion from this analysis is that investment in energy efficiency will yield benefits that can be split between the public sector and the wider economy. The financing method could be important in determining exactly what that split is.

Table V-9: Impacts of changing the financing method, EU28, 2030 (no crowding out)

	EUCO30	EUCO33	EUCO35	EUCO40
GDP (% from EUCO27)				
Self-financing	0.4	1.5	2.1	4.1
Public-financing	0.7	2.1	2.9	5.3
Public budgets (%GDP from EUCO27)				
Self-financing	0.1	0.6	1.0	2.0
Public-financing	0.0	0.1	0.1	0.4

Source(s): E3ME, Cambridge Econometrics

5 Closing remarks and policy interactions

This report has shown that across six impact areas, the effects of ambitious programmes of investment in energy efficiency could be positive, sometimes highly so.

It should be noted, however, that there are some key conditions that must be met for the full benefits to be realised. These are summarised below:

- The EED and related policies must be implemented fully and properly enforced; otherwise results will be weaker across all impact areas. The modelling results show that the higher degree of energy efficiency that is achieved, the more positive the results.
- There is an important question about how energy efficiency investment will be financed. This report does not assess the crucial question of how to incentivise energy efficiency but shows that how the benefits of energy efficiency are shared will depend on the financing mechanism.
- Competitiveness and economic benefits will be maximised if the energy efficient equipment and materials are manufactured domestically (within the EU). Many of the economic benefits accrue because spending on imported fuels is diverted towards more domestic production. Although not assessed in this report, in the more ambitious scenarios it is possible that a larger domestic market would incentivise more firms to locate production in the EU, enhancing these benefits. Incentives to attract firms and provide a suitably trained labour force could encourage domestic production.
- The potential 'crowding out' of economic activities remains a key concern in the more ambitious scenarios. If ambitious targets were to be met, firms that manufacture and install energy efficient equipment would need to ensure that they had adequate

capacity to meet market demands. Signalling the ambition clearly to companies in advance so that they can take a view on the prospective increases in demand, and ensuring a suitably skilled workforce, will assist in the process.

- The impacts on social welfare and income distribution could be enhanced if there were specific measures to target energy efficiency improvements in buildings that house low income households. Such measures could also reduce fuel poverty rates across the EU by up to 8.3 million households.
- The environmental impacts depend not only on the amount of energy efficiency that is implemented but also what happens in the wider energy system, and especially in the fuel mix of the power generation sector. Other policies and their synergies have an impact on that, notably EU ETS and the level of the carbon price.

In conclusion, the results in this report outline many potential benefits of improving energy efficiency in Europe over the period up to 2030. There are potential economic, social and environmental benefits, that increase in line with the degree of energy savings that is achieved. The targets for energy efficiency across Europe have now been set and it is up to policy makers to ensure that these targets are met in a way that enables society to realise these benefits.

Appendices

Appendix A Short Description of E3ME

1 Introduction

1.1 General overview of the model

E3ME is a computer-based model of the world's economic and energy systems and the environment. It was originally developed through the European Commission's research framework programmes and is now widely used in Europe and beyond for policy assessment, for forecasting and for research purposes. It was applied in the recent study for DG ENER that provided inputs to the assessment of 2030 climate and energy framework and was also used in the previous Impact Assessment of the Energy Efficiency Directive.

1.2 E3ME's basic structure

The economic structure of E3ME is based on the system of national accounts, with further linkages to energy demand and environmental emissions. The labour market is also covered in detail, including both voluntary and involuntary unemployment. In total, there are 33 sets of econometrically estimated equations, including the components of GDP (consumption, investment, international trade), the labour market, prices, energy demand and materials demand. Each equation set is disaggregated by country and by sector. Each EU Member State is disaggregated and broken down to 69 economic sectors, although for presentational purposes the sectors are aggregated to show key impacts more clearly.

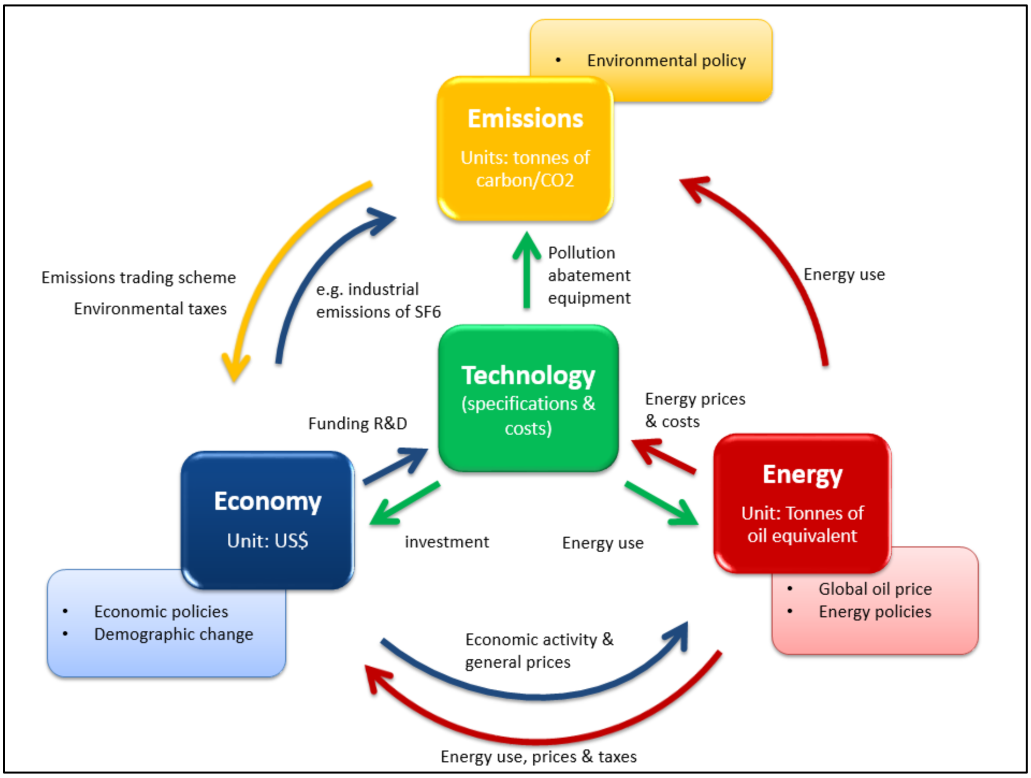
E3ME's historical database covers the period 1970-2014 and the model projects forward annually to 2050. The main data sources for European countries are Eurostat and the IEA, supplemented by the OECD's STAN database and other sources where appropriate.

1.3 The different modules in E3ME

Figure 0.1 shows how the three E's or components (modules) of the model - energy, environment and economy - fit together. Each component is shown in its own box. Each data set has been constructed to conform with accounting conventions. Exogenous factors coming from outside the modelling framework are shown on the outside edge of the chart as inputs into each component. For each region's economy, the exogenous factors are economic policies (including tax rates, growth in government expenditures, interest rates and exchange rates). For the energy system, the outside factors include energy policy[54] (including regulation of the energy industries and public energy efficiency programmes). For the environment component, exogenous factors include policies such as reduction in SO_2 emissions by means of end-of-pipe filters from large combustion plants. The linkages between the components of the model are shown explicitly by the arrows that indicate which values are transmitted between components.

[54] Existing policy will already be included implicitly in the historical data. Additional regulations limiting energy usage can be added by the model user; pricing instruments can also be added separately.

Figure 0.1 E3ME's modules



Source(s): Cambridge Econometrics

1.4 Standard model outputs

As a general model of the economy, based on the full structure of the national accounts, E3ME is capable of producing a broad range of economic indicators. In addition, there is range of energy and environment indicators. The following list provides a summary of the most common model outputs:

- GDP and the aggregate components of GDP (household expenditure, investment, government expenditure and international trade)
- sectoral output and GVA, prices, trade and competitiveness effects
- international trade by sector, origin and destination
- consumer prices and expenditures
- sectoral employment, unemployment, sectoral wage rates and labour supply
- energy demand, by sector and by fuel, energy prices
- CO_2 emissions by sector and by fuel
- other air-borne emissions
- material demands

In addition to the sectoral dimension mentioned in the list, all indicators are produced at the national level and annually up to 2050, although the analysis in this report focuses on the period up to 2030.

2 How energy efficiency is modelled in E3ME

The modelling approach that is applied in this study broadly matches the methodology that was used in the 2015 assessment of the Energy Efficiency Directive. The inputs to the model are:

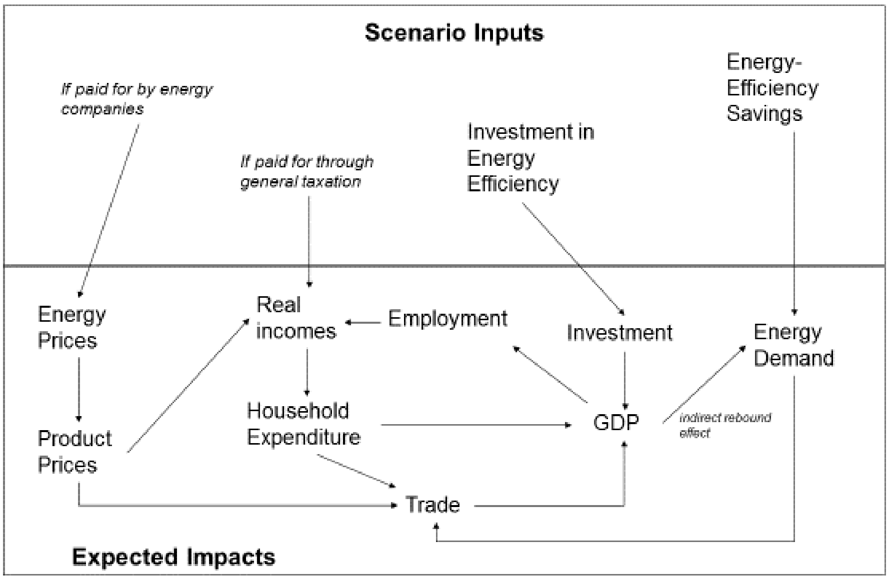
- estimates of energy savings
- estimates of the cost of these savings

- information about which energy carriers have been displaced (mainly gas or electricity for buildings, forming part of the estimates above)
- an assumption about how the energy efficient investment is financed

Apart from the financing assumption, these inputs are derived from the results of the PRIMES model. The assumption about financing is determined as part of the scenario design. In general, it is assumed that buildings investment is made by the occupants of buildings, reflecting the revised and better enforced regulation; private businesses increase prices to cover costs; and government increases VAT rates. For households, this investment may displace spending on other things in the short run, while businesses may pass on the costs through higher product prices.

Figure 0.2 describes the main economic linkages in the model. The two main inputs, energy savings and the investment requirements are entered on the right-hand side. Investment affects GDP and output levels directly, whereas changes in energy demand have an indirect effect in most European countries via changes in trade patterns (i.e. fuel imports likely to be reduced, while domestic production of other goods may increase).

Figure 0.2 Main Model Linkages



Source(s): Cambridge Econometrics

The lower left-hand side of the diagram shows some of the multiplier effects and inter-dependencies in the model. Higher production levels lead to increases in employment (and also wages, not shown on the diagram), in turn boosting incomes and expenditure.

On the top-left and far left of the diagram, we can see the impacts of financing the energy efficiency measures. The nature of the impacts depends on the financing methods chosen.

One important aspect is the diagonal line from output and GDP to energy demand, which represents the indirect rebound effect in the model. As production levels increase, there will be an increase in energy consumption as well (all other things equal). Research using a previous version of E3ME has shown that the rebound effect can be as high as 50% if measured in the long run at global level – i.e. 50% of the original energy savings are lost through indirect increases in energy consumption.

Finally, the diagram does not show the impacts on greenhouse gas and other environmental emissions, but these would be expected to fall in line with changes in energy demand – with the extent that they fall depending on the fuels that are displaced.

Comparison with other exercises carried out for DG ENER

The modelling that was carried out by Cambridge Econometrics for DG ENER in 2015 used a similar approach to assess the effects of energy efficiency, taking the results from the PRIMES model as inputs to the scenarios.

A slightly different approach was used for the EPBD report, as the focus on buildings in that report meant that more detail could be obtained by using analysis by Ecofys as inputs. However, the methodology beyond that stage was largely the same.

Crowding out in E3ME

An important issue that is raised in macroeconomic modelling exercises is 'crowding out'. The term crowding out has traditionally been used to describe higher levels of public expenditure leading to lower levels of private expenditure due to supply constraints. More recently in academic debates it has been applied to supply constraints more generally, but particularly in relation to financial resources.

In the scenarios in this report, higher investment in household energy efficiency is funded by lower rates of spending on other consumer products, so there is a direct crowding out effect (i.e. net debt levels do not change). The process is similar for businesses (which raise prices) and government (which raises taxes). However, the model does not as standard impose strict crowding out in other parts of the economy; for example, the construction sector is able to increase its output and use resources that in the reference scenario are unemployed (e.g. unemployed workers). There are restrictions in the labour market, as wages increase in response to tightening conditions but the level of output is largely determined by the level of aggregate demand.

This sits E3ME apart from the more common CGE macroeconomic modelling approach, where crowding out is strictly enforced and outcomes are determined by supply-side factors. To test the sensitivity of the model results to assumptions about crowding out two variants of each scenario were assessed, one with no crowding out and one with partial crowding out.

2.1 The six impact areas in E3ME

The results from E3ME are fed into the analysis for each of the six impact areas described throughout this report. In some cases, the E3ME results comprise the majority of the indicators that are presented in the analysis (e.g. economy and labour market, environment and public budgets). However, in each case additional quantitative analysis is carried out. The methodologies applied to do this are described in the main report.

2.2 The reference scenario

In this study, the E3ME reference scenario was calibrated to match the PRIMES 2016 reference scenario. E3ME takes the following indicators from the projections directly:

- GDP and sectoral economic output
- energy and ETS prices
- projections of energy demand by sector and by fuel
- CO_2 emissions by sector
- population

These indicators combined allow us to construct an economic reference scenario based on the energy system results from PRIMES.

E3ME is frequently calibrated to match published PRIMES projections and the software routines to do the matching are now well established[55] and have not been revised from previous studies. Further details are provided in Appendix B.

[55] 'Studies on Sustainability Issues – Green Jobs; Trade and Labour', Final Report for the European Commission, DG Employment, available at: ec.europa.eu/social/BlobServlet?docId=7436&langId=en
'Employment effects of selected scenarios from the energy roadmap 2050', Final Report for the European Commission, DG Energy, available at: http://ec.europa.eu/energy/en/content/employment-effects-selected-scenarios-energy-roadmap-2050-0
'A policy framework for climate and energy in the period from 2020 up to 2030. Impact Assessment', available at: http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52014SC0015

Appendix B The Reference and Policy Scenarios

1 The reference scenario

The starting point for the E3ME analysis was the 2016 reference scenario that was developed with the PRIMES model. Inputs to E3ME, including both assumptions used by PRIMES (e.g. energy prices, economic growth rates) and the full energy balances from the PRIMES results were made consistent.

The same information was taken for each of the scenarios and thus the design of the scenarios in E3ME matches that from the PRIMES model as closely as possible:

- EUCO27
- EUCO30
- EUCO33
- EUCO35
- EUCO40

The E3ME reference scenario was calibrated to match the latest version of the reference scenario derived from the PRIMES model. E3ME takes the following indicators from the projections directly:

- GDP, consumer expenditure sectoral economic output
- energy and ETS prices
- projections of energy demand by sector and by fuel
- total CO_2 emissions

E3ME's FTT:Power submodel (Mercure, 2012), which looks in detail at the power generation sector, has been updated so that its outputs are fully consistent with the PRIMES results (given differences in model classifications, etc.). The main outputs from the FTT submodel that have been calibrated to match PRIMES are:

- fuel inputs into thermal power plants
- electricity capacity
- investment by the electricity supply sector
- electricity prices

The FTT:Power submodel is used in E3ME to estimate power sector capacity and electricity generation. However, in the scenarios presented in this report we do not apply FTT:Power as this would create inconsistencies with the PRIMES model results. Instead, results are fixed to match the figures from PRIMES.

1.1 Economic indicators

The E3ME reference scenario was updated to be consistent with the economic indicators that were fed into the PRIMES model. These include projections of Gross Domestic Product (GDP), sectoral Gross Value Added (GVA) and consumer expenditure. The calibration was made in terms of growth rates and not actual levels, as the two models have slightly different vintages of historical data. The last year of historical data in E3ME is currently 2014.

The PRIMES reference scenario GDP figures were provided in 2010 prices, but inputs to the scenarios were made using 2013 prices. Changing the price base to be consistent to the scenario information may have resulted in slightly different levels compared to the input file but growth rates are unchanged.

The calibration was made at Member State level.

Further processing

While the PRIMES datasets provide figures for sectoral GVA and household consumption on a constant price basis, the classifications used are at a higher level of aggregation than those in the E3ME model and further processing is therefore required to calibrate the more detailed E3ME outputs.

PRIMES sectoral GVA growth rates were mapped to the E3ME sectors, while all the categories of household expenditure were set to grow using historical trends and then constrained to the published total for household expenditure. Disposable income was set to grow at the same rate as household expenditure.

Gross economic output in each sector was set to grow at the same rate as GVA (and hence at the same rate as the PRIMES assumptions), while the other components (apart from household expenditure) of final demand at sectoral level (e.g. investment and trade) were set to grow at rates based on historical rolling averages and then constrained to be consistent with the total output projections.

Prices for industries other than the energy-related ones reported in the PRIMES figures were projected using historical trends.

1.2 Energy demand

The PRIMES projections include a comprehensive set of projections of energy demands and the resulting emissions. E3ME's projections for the reference scenario were set to match the growth rates from PRIMES. The high level of detail of the PRIMES outputs makes it possible to map them straightforwardly to the E3ME classification.

1.3 Energy and CO_2 prices

Fuel prices in E3ME were set to match the baseline fossil fuel price assumptions shown in the table below. Prices of the economic outputs of the energy-related industries in E3ME were also made consistent with these assumptions, as shown in Table 0-1.

Table 0-1 PRIMES reference scenario energy prices, euro 2013/boe

	2010	2020	2030
Oil	62.6	75.0	93.8
Gas	39.5	48.3	56.8
Coal	16.7	14.3	20.5

Source(s): PRIMES results

CO_2 prices in E3ME's reference scenario were also updated to be consistent with the prices in the PRIMES projections (see Table 0-2). The revenues from the ETS allowances that are auctioned to the power generation sector are recycled into reducing VAT rates, so as to ensure fiscal neutrality.

Table 0-2 PRIMES reference scenario CO_2 price, euro 2013/tCO2

	2010	2020	2030
EU ETS sectors	11.2	15.0	33.5

Source(s): PRIMES results

A key driver in the scenarios is electricity prices. Electricity prices could be calculated within E3ME but, because it is an energy systems model, the PRIMES model conducts this calculation at a much higher level of detail. Electricity prices from 2010-30 in the

E3ME baseline case (and also in the scenarios) were therefore set to match the projections from PRIMES.

1.4 CO_2 emissions

The PRIMES projections provide only a total for energy-related CO_2 emissions, and not the underlying detail by sector. The E3ME projections for CO_2 were updated to match the PRIMES total, taking into account the energy demand projections.

1.5 Annual time series

All the PRIMES projections were converted to annual time series using linear interpolation across the five-year time periods that are solved and published for PRIMES.

1.6 Model calibration

The E3ME model software includes a built-in function for model calibration. The procedure has two main stages.

In the first stage, the outputs from the PRIMES model are stored on one of the E3ME databanks as annual time series. The model is solved with all the econometric equation sets forced to match the figures that are stored. The differences ('scaling factors') between what the model would have predicted on its own and the figures on the databank are calculated and saved. These are then written on to another databank.

In the second stage, the model is solved with the equation sets allowed to predict the outcomes. However, the scaling factors are applied to these results, so that the model once again reproduces the published PRIMES figures. It is now possible, however, to change the model inputs and use the equations to obtain different model outcomes, while maintaining consistency with the published reference scenario.

2 The policy scenarios

This section describes the policy scenarios that were modelled, focusing on the way that the PRIMES results were integrated as inputs to E3ME. Table 0-3 outlines the five policy scenarios.

Table 0-3 The policy scenarios

PRIMES scenario name	Short description
EUCO27	27% energy-efficiency target
EUCO30	30% energy-efficiency target
EUCO33	33% energy-efficiency target
EUCO35	35% energy-efficiency target
EUCO40	40% energy-efficiency target

2.1 CO_2 prices

Table 0-4 shows the EU ETS prices in each scenario. In each case the prices are consistent with the prices used in the energy sector assessment with the PRIMES model. Non-ETS sectors do not face carbon prices in any of the scenarios.

Table 0-4 Policy scenario EU-ETS prices, 2013euro/tCO$_2$

	2030
EUCO27	42.0
EUCO30	27.0
EUCO33	26.5
EUCO35	20.0
EUCO40	14.0

Source: PRIMES results

2.2 Power generation and electricity prices

An important input to the scenarios is the amount of investment required to bring about the changes in the power generation mix. Additional investment by the electricity supply sector was added exogenously into E3ME. It is assumed to be financed by higher electricity prices, which are also taken from PRIMES.

2.3 Energy efficiency and investment

In E3ME, the energy efficiency savings were entered exogenously in the model and were set to match the PRIMES results as closely as possible. The change in final energy demand from PRIMES was used as a guide for the level of energy efficiency savings. These savings were then distributed among sectors and energy carriers, using as a guide the level of investment made by each sector and the shares between energy carriers in proportion to energy consumption.

The investment costs are also taken from the PRIMES results. In the case of the scenario results presented in Part IV of this report, it is assumed that the energy efficiency investment is self-financed by firms and households. This has an impact on firms' costs and profits and households' ability to purchase other goods. Investment made by the public sector is financed by changes in taxation (adjustments to the standard rate of income tax).

In the alternative financing scenario presented in Part IV, Section 2.8, it is assumed that all of the investment is funded by public budgets, leading to increases in the standard rate of income tax.

2.4 Revenue recycling

The general approach in this report is that the scenarios are directly revenue neutral with regards to costs to the public sector of energy efficiency investment and changes to the revenues from auctioned ETS allowances. We have not made the scenarios fully budget neutral, however, for example do not make any corrections to changes in income tax receipts. Instead these impacts are reported in the public budget impact area.

In each Member State, standard VAT rates are adjusted to cover the balance from changes in government sector investment costs and ETS revenues.

Appendix C Further policy details

This appendix includes details on the assumptions made in the modelling (mainly in PRIMES) to reflect the proposed updates to the EED that are included in the policy scenarios. As the results from PRIMES are fed into E3ME, the same policies are included in the analysis in this report.

Standards

Standards (eco-design, building codes and CO_2 standards for vehicles) are intensified for all sectors in the different policy scenarios. Standards are an essential feature of a cost-effective approach. Both modelling experience and current practice show that the benefits in terms of economies of scale and overcoming market failures by using internal market rules are very important. For the most ambitious scenarios, the application of BAT (best available technology) in industry is assumed.

Energy Efficiency Values

Shadow Energy Efficiency Values (EEVs) were applied and scaled up representing yet to be identified policy measures aiming at achieving energy savings (notably reflecting implementation of Article 7, other national incentives and saving schemes). As EEVs apply to the entire residential, tertiary and industrial sectors, they trigger the most cost-effective options in these sectors.

Behavioural discount rates

The use of behavioural discount rates was adjusted with increasing energy efficiency levels in 2030. The European Commission is working on an improvement of financial instruments and other financing measures on the European level to facilitate access to capital for investment in thermal renovation of buildings. Together with further labelling policies for heating equipment and for other product groups, increased investment in thermal renovation of buildings can lead to a reduction of behavioural discount rates for households and the service sector.

The transport system

Some specific measures that are aimed at improving the efficiency of the transport system and managing transport demand are included in the more ambitious scenarios. This is done in line with measures assumed in the scenarios presented in the Staff Working Document on Low Emission Mobility[56] (e.g. full internalisation of local externalities on the interurban network, ambitious deployment of Collaborative Intelligent Transport Systems, promotion of efficiency improvements and multimodality, taxation).

Heat pumps

Scenarios that are more ambitious than EUCO27 assumed policies that facilitate the uptake of heat pumps. This assumption reflects option 3.b of the Article 7 analysis, which would allow counting savings stemming from on-site renewable energy (e.g. heat pumps) within the 25% exemptions, more ambitious eco-design/labelling policies and the change of the primary energy factor.

[56] SWD(2016) 244 final.

Appendix D Review of Previous Studies

1 Introduction

This chapter presents the findings from the review of recent literature and data sources that was carried out early in the study. Some of the findings from the review were carried forward into the later modelling tasks, but the review also holds information that is useful in its own right.

2 Economy and labour market

2.1 Introduction

Some of the relevant literature comes from previous studies that have been carried out using the E3ME model. Most recently, the EPBD report assesses the effects of energy efficiency improvements in buildings, finding that GDP could increase by 0.6% in 2030 and employment by 0.3%.

Unlike the EPBD report, however, the interest in the present study is on energy savings across the whole economy and not just the buildings sector. This means that some of the expected impacts could be different to those outlined in the EPBD report. Notably, competitiveness effects could be much more substantial.

Possibly more relevant to the present report are the results of the previous 2015 study that was carried out for DG ENER by a team led by Cambridge Econometrics. These results are summarised in the box below.

A wider literature review of economic impacts can be found in the IEA's *Multiple Benefits* report (2014). The IEA's report identified a range of impacts but found that the likely scale of the impacts is highly dependent on the size of energy efficiency programme implemented.

Box 0-1 Assessing the Employment and Social Impact of Energy Efficiency

Some of the main findings of this study in terms of economy and labour market outcomes are summarised as follows:

- This study emphasises that energy efficiency can have a range of benefits to households, businesses and wider society.
- Some of the benefits that result from investment in energy efficiency (e.g. GDP) increases can be readily quantified, while others such as health improvements are more difficult to estimate.
- Estimated GDP increases in previous studies typically lie in the range of 0.3% to 1.3% depending on time periods, geography and the scale of the programme under consideration.
- The study estimates that gross EU28 employment in the provision of energy efficiency goods and services sold in 2010 amounted to approximately 0.9m jobs. This figure increases to 2.4m jobs if other activities that could potentially generate energy savings are included in the analysis.
- The modelling in the study found that the implementation of more ambitious energy efficiency programmes to reduce energy consumption by 30% compared to the PRIMES 2007 baseline. This could produce an increase in employment at EU level of 0.7-4.2m by 2030.

Source(s): Cambridge Econometrics et al. (2015).

The scenarios that are described in Chapter 3 of Cambridge Econometrics et al. (2015) cover a wider range of sectors and show potentially a much higher level of ambition in terms of energy savings than the EPBD report. This makes two aspects of the analysis much more important:

- rebound effects
- crowding out effects

These issues are discussed further below.

2.2 Rebound effects

Rebound effects have often been put forward as a negative aspect of energy efficiency programmes. These effects refer to the increased consumption of energy and/or non-energy services induced by the implementation of energy efficiency measures (de la Rue du Can et al., 2015). On one hand, improved energy efficiency has the effect of reducing the price of energy goods, causing higher energy consumption (direct rebound effect). On the other hand, the lower spending on energy goods implies an increase in available income, leading to higher consumption of other goods and services (indirect rebound effect). Higher levels of energy efficiency can also produce economy-wide impacts when affecting the price of intermediate and final goods (AEA, 2017).

More recently, the literature, led by the IEA's 2014 *Multiple Benefits* report, has suggested that the rebound could be viewed either positively or negatively when macroeconomic benefits such as higher GDP are taken into account, but is something that policy makers must be aware of. Gillingham et al. (2015) similarly criticised the unwarranted focus on potentially detrimental rebound effects and argued in favour of a more precise assessment of the welfare implications of energy efficiency policies. Model-based estimates of the scale of rebound effects vary from close to zero to up to 50% at global level (Barker et al, 2009). Important variations exist across sectors, having for example an estimated 18% average rebound effect in the road transport sector (Llorca and Jamasb, 2016; Stapleton et al., 2016) and a 60% rebound for the construction sector (Du et al., 2017). Some studies have estimated specific rebound effects of more than 100% (Freire-González, 2017).

It is clear from the literature that rebound effects must be accounted for in analysis of ambitious energy efficiency programmes. Rebound effects are driven by economic ties and are discussed further in Section 2.5 below, which also includes a list of previous estimates of the size of the rebound effect.

2.3 Crowding out

Successive studies have shown assumptions about crowding out to be critical to determining the estimated impacts of energy efficiency scenarios. Macroeconomic models typically either assume full crowding out or no crowding out and the choice of model determines the choice of assumption that is made.

Crowding out occurs due to supply constraints on the economy. If the economy is operating at maximum capacity, then any additional activity will have to substitute for activity elsewhere rather than be additional. Under models that assume diminishing marginal returns[57] (which includes most CGE models) this means that a negative impact is guaranteed. Indeed, the CGE modelling approach assumes full capacity in capital markets, meaning that higher investment in energy efficiency must be at the expense

[57] According to the law of diminishing marginal returns, the marginal output of a production process decreases as the amount of a certain production factor is incrementally increased, *ceteris paribus*.

of investment elsewhere in the economy. Under CGE conditions therefore, investment and GDP would not be expected to increase.

Crowding out could occur in any economic market. Three important examples are:

- Labour markets – if full employment is reached, it is not possible to increase employment further. Instead, any additional demand for labour will push up wage rates, displacing workers from other sectors rather than increasing the total level of employment.
- Capital markets – if all available finance is used, it is not possible for banks to issue new loans for investment. Higher demand for capital instead leads to higher interest rates which will either encourage higher savings rates (displacing consumption) or reduce capital investment elsewhere.
- Product markets – if companies are producing at full capacity they cannot produce more. They will instead meet higher demand by pushing up the prices for their goods.

Optimisation models, including CGE models, assume by default that all available resources are used, meaning that crowding out will occur in all economic markets. However, simulation models allow for the possibility of spare capacity so that additional production may take place.

This issue has been debated by economists since at least the mid 20th century. Different schools of economic thought have developed based on different theories about market capacity and potential crowding effects. The treatment by different economists of the different markets varies across all the three examples above, but differences are particularly stark in financial markets, where mainstream economics assumes a fixed money supply, which does not appear consistent with the activities of modern central banks (Pollitt and Mercure, 2017; McLeay et al, 2014; Keen, 2011). In the context of energy policy (albeit in the US), Pollin et al (2014) notes that crowding out is unlikely to occur in a decarbonisation scenario, in part because investment by the energy sector is reduced compared to baseline.

It is very hard to find clear evidence of whether crowding out occurs in reality or not because of the absence of a counterfactual case. Most of the studies that are available are based on modelling exercises and therefore embody assumptions about crowding out without testing. There is slightly more consensus (and therefore less debate) about labour markets as it is accepted that employment cannot exceed the number of people available (and unemployment exists). For product markets, Eurostat publishes data on capacity utilisation for key sectors of the economy (see Part III, Section 2.3). However, even this is not sufficient to determine whether higher rates of capacity utilisation at sectoral level lead to higher prices and displacement of other activity.

Previous studies that are not fixed to a single modelling approach therefore apply sensitivities to test crowding out assumptions (as well as previous studies published by DG ENER, see IEA/IRENA, 2017). A similar modelling approach is adopted in the present study. It is described in detail in Part III, in terms of how crowding out might occur in all three markets outlined above. The modelling results presented in Part IV include scenario versions without crowding out and with partial crowding out due to capacity constraints in the construction sector. There is therefore a range of impacts produced by E3ME.

2.4 GDP

The standard metric that is used to assess the macro level impact of energy efficiency programmes is GDP. The majority of studies have reported a positive impact of energy efficiency policies on GDP, regardless of the methodological approach that was employed to conduct the study. Table 0-5 provides some references, along with a description of their main findings.

Table 0-5 GDP impacts of investing in energy efficiency

	Reference	Scope	Main findings
1	Cambridge Econometrics and Verco, 2012, Jobs, Growth and Warmer Homes. Evaluating the Economic Stimulus of Investing in Energy Efficiency Measures in Fuel Poor Homes	UK	This study estimates that investing in energy efficiency measures in energy poor households could increase GDP by 0.2%.
2	Lutz et al.,2012, Economic Impacts of Energy Efficiency and Renewable Energy in Germany	Germany	By 2030 German GDP could increase by €22.8 bn due to the implementation of energy efficiency measures.
3	ENE et al.,2012, Energy Efficiency: Engine of Economic Growth in Eastern Canada	Canada	Between $4 and $8 of additional GDP could be generated by every $1 spent on energy efficiency improvements.
4	Joyce et al., 2013, Monetising the multiple benefits of energy efficient renovations of the buildings of the EU	EU	Energy efficiency programmes to renovate buildings could lead to GDP increases in the range of 1.2-2.3%.
5	Prognos, 2013, Ermittlung der Wachstumswirkungen der KfW-Programme zum Energieeffizienten Bauen und Sanieren	Germany	GDP could rise by 0.25% compared to baseline values.
6	Acadia Center, 2014, Energy Efficiency: Engine of Economic Growth in Canada	Canada	Energy efficiency programmes could potentially increase GDP by $5-8 per $1 spent. A total net GDP increase of $230 bn to $580 bn over the period 2012-2040 is expected.
7	Navius Research, 2014, Macro-economic Effects of Energy Efficiency Improvements	Canada	This research finds that energy efficiency measures increased GDP by about 1% over the period 2002-2012.
8	Energy2030, 2015, Accelerate Energy Productivity 2030	US	This report assesses the economic impact of doubling energy productivity in the US by 2030. It is estimated that achieving such a target would result in a net GDP increase of $922bn by 2030. In the particular case of buildings, $331bn cumulative investment costs and $409bn cumulative cost savings would be required in order to contribute to meet the target.
9	Cantore et al., 2016, Does energy efficiency improve technological change and economic growth in developing countries?	29 developing countries	The authors conclude that lower levels of energy intensity are associated with higher total factor productivity in the manufacturing sector. They also provide evidence of a robust negative

			relationship between energy intensity and GDP.
10	Rajbhandari and Zhang, 2017, Does energy efficiency promote economic growth?	56 high and middle income countries	This World Bank working paper concludes that promoting energy efficiency has the potential to support higher economic growth in the long term.

Source(s): Cambridge Econometrics' elaboration based on the referenced reports.

2.5 Other macroeconomic indicators

A comprehensive assessment of the impact of energy efficiency measures at the macroeconomic level requires analysis of other indicators such as:

- sectoral output
- household income and consumption
- investment & interest rates
- international trade
- prices and inflation

Sectoral output

Energy efficiency programmes can improve competitiveness, by lowering production costs. Eventually, this decline in production costs will be translated into lower prices of products that affect domestic and external demand positively. ECEEE (2013) suggests that energy efficiency programmes have a higher potential than energy price cuts to improve EU competitiveness in the global market[58]. Similarly, Astrov et al. (2015) pointed out that energy efficiency improvements limited the competitive loss for European manufacturing industries in international markets that was caused by higher gas and electricity prices in Europe.

Firms can effectively improve their resilience to energy price shocks by adopting more energy efficient technologies, therefore avoiding sudden spikes in their energy costs. While energy generally accounts for a minor share of production costs, it represents a key cost component for energy-intensive industries such as aluminium, chemicals, glass and cement sectors. Flues et al. (2013) provided evidence of energy-intensive industries (in this case the steel sector) reacting to higher energy prices by improving their energy efficiency. The existence of a rebound-effect however counteracted the idea of a negative relationship between steel production and energy input prices.

Household income, consumption and rebound effects

The impact of energy efficiency on household income and consumption has been extensively discussed in the existing body of knowledge. Specifically, there is a vast literature with a focus on how savings in energy bills are subsequently spent, potentially leading to rebound effects. As described in the existing literature (Greening et al., 2000; Maxwell et al., 2011) three types of 'rebound' effects[59] can be identified:

- Direct rebound effect – refers to the increase in consumption of a product / service that results from a reduction in its costs, e.g. longer heating hours due to more efficient heating systems.
- Indirect rebound effect – refers to the additional spending on consumption that takes place when energy efficiency savings free some income to be spent on other

[58] See, also, IEEP (2013) for further discussion on how energy efficiency could improve EU presence in international markets.
[59] See, also, Maxwell et al. (2011) for further explanations on the 'rebound' effect and various case studies.

products and services, e.g. households' energy savings from more energy efficient heating may be spent on transport services. More specifically, we can distinguish:

  - Income effect – energy efficiency savings are instead spent on other goods and services that may be energy-intensive.
  - Energy price effect – if demand for energy falls, so do energy (or, in the EU, ETS) prices, which favours consumption elsewhere.

- Economy wide rebound effect[60] – In addition to the previous two effects which are observed at microeconomic level, there is also an effect at macroeconomic level. This refers to the increase in consumption that is caused by an increase in productivity and economic growth that emanates from higher efficiency. Table 0-6 provides an overview of the different methodological approaches that could be employed to assess the rebound effect.

Table 0-6 Overview of available methodologies for assessment of the rebound effect

The table below summarises the main methodologies that are available for the assessment of the rebound effect:

REBOUND TYPE	METHOD OF ANALYSIS
Direct	Micro-econometric modelling of households/producers, including estimating price elasticities, income elasticities, etc.
Indirect	Micro-econometric/Macro-econometric modelling of households/producers: estimation of cross-price or substitution elasticities (impact of a change in the price of one factor/good on the demand of the other factor/good)
Economy-wide (NB: Economy-wide rebound is often measured jointly with indirect rebound)	Macro-econometric models (often estimate behavioural relationships within an input-output (IO) structure) or Computable General Equilibrium (CGE) models

Source(s): Reproduced from Maxwell et al. (2011).

Using the E3MG model, Barker et al. (2009) propose the following equations to measure the rebound effect:

1. 'macroeconomic rebound effect' = 'indirect rebound effect' + 'economy-wide rebound effect'
2. 'total rebound effect' = 'macroeconomic rebound effect' + 'direct rebound effect'
3. 'gross energy savings from IEA energy-efficiency policies' = 'net energy savings (taken as exogenous in E3MG)' + 'direct rebound energy use'
4. 'change in macroeconomic energy use from energy-efficiency policies from E3MG' = 'energy use simulated from E3MG after the imposed exogenous net energy savings' – 'energy use simulated from E3MG before the imposed exogenous net energy savings'

[60] In the main report, this is grouped as a type of indirect rebound effect.

5. 'total rebound effect as %' = 100 times 'change in macroeconomic energy use from energy-efficiency policies from E3MG' / 'gross energy savings from IEA energy-efficiency policies'
6. 'direct rebound effect as %' = 100 times 'direct rebound energy use' / 'gross energy savings from IEA energy-efficiency policies'
7. 'macroeconomic rebound effect as %' = 'total rebound effect as %' – 'direct rebound effect as %'

This set of equations is applicable to E3ME. Other scenarios different than the 'IEA energy-efficiency policies' could be analysed using the same methodology.

Table 0-7 provides an overview of some previous assessments of the rebound effect across various economies.

Table 0-7 Previous assessments of the rebound effect

	Reference	Scope	Main findings
1	Greening et al., 2000, Energy Efficiency and Consumption — the Rebound Effect — a Survey	US	This paper reviews the previous contributions on the rebound effect from energy efficiency improvements in the US economy. It suggests that the range of estimates for the size of this effect is very low to moderate.
2	Vikström, P. (2004). Energy efficiency and energy demand: A historical CGE Investigation on the rebound effect in the Swedish economy 1957	Sweden	This piece of research estimates a 50-60% rebound effect associated to a 12 and 15% increase in energy efficiency (in energy and non-energy sectors respectively).
3	Barker et al., 2009, The Macroeconomic Rebound Effect and the World Economy	Global	This paper models the total rebound effect arising from the IEA WEO 2006 energy-efficiency policies for final energy users. It finds that the total rebound effect over the period 2013-2030 is around 50% by 2030, averaged across the whole economy.
4	Maxwell et al., 2011, Addressing the Rebound Effect	Global	This report presents a comprehensive literature review of previous assessments of the rebound effect. The following case studies are discussed: a) household cars and heating/cooling; b) household cars, heating, lighting, production; c) energy efficiency policies and programmes; d) household appliances; e) lighting; f) road freight private transport; g) French eco pastille scheme and vehicles; h) mobile data traffic; and i) paperless office and ICT. The report presents many different estimates of the scale of the rebound effect. For example, a range of 20% to 30% is estimated in the case of Austrian space heating.
5	Chitnis et al., 2012, Estimating Direct and Indirect Rebound	UK	This study estimates the rebound effect related to several measures that have been implemented to improve energy efficiency in dwellings. It suggests that the rebound effects from measures under consideration are in the range of 5% to

	Effects for UK Households		15% and that they are dominated by the indirect effects. The methodology that this study employs is based on estimates of income elasticity and greenhouse gas intensity.
6	Nadel, 2012, The Rebound Effect	US	This research suggests that direct rebound effects are around 10% or less; while indirect rebound effects seem to be around 11%.
7	Guerra Santin, 2012, Occupant Behaviour in Energy Efficient Dwellings: Evidence of a Rebound Effect	Netherlands	This paper confirms the existence of a rebound effect that relates to energy consumption for heating. The finding is supported by an analysis of different behavioural patterns among the occupants of dwellings that present various degrees of efficiency.
8	Aydin et al., 2014, Energy Efficiency and Household Behaviour: The Rebound Effect in the Residential Sector	Netherlands	Based on a sample of 560,000 households, this paper reports the existence of a rebound effect in the case of the 26.7% of homeowners and the 41.3% of tenants that were considered for the survey.
9	Gillingham et al., 2014, The Rebound Effect and Energy Efficiency Policy	US	The literature review conducted for this paper suggests that the total microeconomic rebound effect is in the range of 20% to 40%.
10	Wang et al., 2016, Measurement of energy rebound effect in households: evidence from residential electricity consumption in Beijing, China	China	The authors estimate long and short-run direct and indirect energy rebound effects for the household sector in Beijing. Their findings support the hypothesis of a higher direct rebound effect in the long-run (40%) compared to an indirect one (15%). As there is no backfire effect, energy efficiency policies prove to be effective in reducing energy demand in Beijing.
11	Stapleton et al., 2016, Estimating direct rebound effects for personal automotive travel in Great Britain	UK	The study considers the period from 1970 to 2011 and corroborates previous US based studies estimating an average 19% direct rebound effect for use of private cars. As such, approximately a fifth of potential fuel savings from improved car efficiency is lost through increased travelling.
12	Llorca and Jamasb, 2016, Energy efficiency and rebound effect in European road freight transport	EU	The authors rely on data over 20 years for 15 European Member States to study the rebound effect in the road freight transport sector. Results show the existence of a tiny 18% rebound effect on average. This effect however is higher in countries where energy efficiency improvements and quality of logistics are more pronounced.
13	Freire-González, 2017, Evidence of direct and indirect rebound effect in households in EU-27 countries	EU	The study uses price elasticities and input-output tables to estimate household rebound effects in each EU Member State. It finds high rebound effects for some countries, greater than 100%.
14	Du et al., 2017, The energy rebound effect for the construction industry: empirical evidence from China	China	This paper estimates a 59.5% rebound effect for the Chinese construction industry between 1990 and 2014. The effect is declining over time, and the authors conclude that approximately half of the potential energy saving by technical change is achieved.

15	Zhang and Peng, 2017, Exploring the direct rebound effect of residential electricity consumption: an empirical study in China	China	This study estimates a 72% direct rebound effect for the Chinese residential electricity consumption sector. Additionally, differences arise when considering different income groups (68% for low income and 55% for high income groups) and climate regimes (68% for light rainfall and 86% for heavy rainfall regimes).

Source(s): Cambridge Econometrics' elaboration based on the referenced reports.

Investment

In the short run, energy efficiency programmes could boost investment since new equipment is needed for most energy saving measures. In the long run, energy efficiency improvements could create further investment stimulus since lower energy bills could free additional financial resources for investment purposes. These effects will be reinforced by additional investments that business will need in order to meet the higher demand that results from lower energy bills, and also from the additional income that is spent by those who are employed in energy-efficiency related activities for buildings and other sectors.

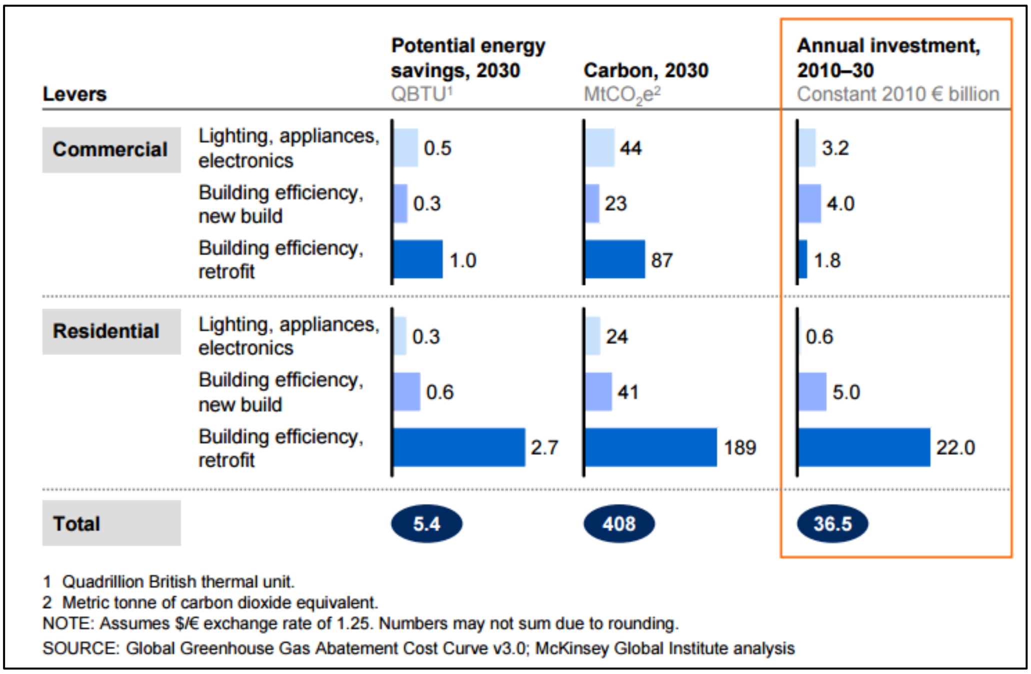
There may also be negative investment effects in the energy sector itself. For example, if the demand for electricity falls by enough, eventually plans to invest in new power generation or replacement capacity will be delayed or cancelled. Energy efficiency has the potential to reduce peak demand and the required level of investment in electricity generation, transmission and distribution systems to satisfy it. However, over the longer term we can expect the overall impact of energy efficiency on the level of investments in the energy sector to be neutral (Couder, 2015).

The recent study for DG ENER (Cambridge Econometrics et al., 2015) modelled the impact of energy efficiency measures in the EU. The results from the E3ME model reached the following conclusions regarding investment:

- In the period 2020-2025 the measures would lead to a small increase in investment, following a small increase in GDP.
- From 2026 onwards investment and output would both grow substantially due to more ambitious energy efficiency measures.
- The increases in GDP from energy efficiency are mainly driven by the additional investment in energy efficiency.

Figure 0.3 provides an example of some estimates of the direct investment costs required to achieve a given level of energy savings (taken from a CO_2 cost curve). The focus is on buildings and the figures shows the key importance of residential dwellings in energy efficiency and reducing greenhouse gas emissions more generally.

Figure 0.3: Potential increases in investments related to energy efficiency



International trade

There are two dimensions in which energy efficiency programmes hold the potential to affect current account imbalances: (a) equipment trade; and (b) fuels / energy trade. Specifically, countries that produce and export the equipment which is needed for the transformation of current infrastructure and buildings into more efficient ones will see an improvement in their trade balances. Moreover, energy efficiency improvements will produce a decline in the amount of fuel / energy which is required and imported.

The issue of energy security is clearly linked to international trade. Energy efficiency has the effect of lowering energy demand, energy prices and investments in new or replacement capacity (Couder, 2015). A reduced level of energy demand has the consequence of reducing foreign energy dependency thanks to the declined amount of fuel / energy which is required and imported, therefore hampering the exacerbation of trade deficits. Fossil fuel imports particularly affect trade balances to the point that, in 2013, trade deficits in European Member States like Austria, Finland and Spain were entirely due to energy (JRC, 2015).

Another element that will reinforce this 'circuit' is the subsequent effect of changes in energy demand on prices (see below).

Prices and inflation

Energy efficiency improvements will affect energy demand and may induce a transition to other fuels. This could eventually alter fuel and energy prices, and feed the energy demand-price loop[61]. If these effects are strong enough to have a reflection in the global picture, lower energy demand will lead to a decline in energy prices. As a ballpark estimate of the magnitude of these effects, the increase in oil prices that lasted for about three years and peaked in 2012 could have cost €300 bn to the EU (IEA, 2014).

[61] See, also, IMF (2014) for further discussion and examples of the effects of a decline in oil prices. However, when considering energy efficiency outside the transport sector it is gas prices that are more likely to be affected.

Energy efficiency policies also have the potential to affect highly energy prices at the regional and country level. Wiser et al. (2005) reviewed the bulk of literature focusing on energy efficiency improvements in the US and their impact on natural gas prices. While variations in the magnitude of gas price reductions are significant, all previous studies concluded that energy efficiency measures, together with renewables deployment, put downward pressure on natural gas demand and prices. On average, a 1% reduction in national gas demand corresponded to a 0.8% to 2% decrease in wellhead gas prices (Wiser et al., 2005). More recently, Carnall et al (2011) estimated a total amount of almost $50 billion benefits over 20 years in terms of lower energy bills to electricity and gas consumers after the introduction of a water heater standard. These savings primarily affect consumers who purchase the more efficient appliance, but all natural gas consumers benefit from reduced gas prices.

Additionally, low domestic energy prices could contribute to improved competitiveness by reducing production costs[62] if they are not matched in other countries. Such a result is perhaps most likely for electricity.

2.6 Employment

A key indicator with which to evaluate the impact of energy efficiency measures on wider society is employment. As acknowledged in the existing literature, energy efficiency improvements hold the potential to create more jobs than new energy generation investments (see, also, Friends of the Earth Cymru, 1996). Previous research suggests that the vast majority of job creation that results from energy efficiency takes place in labour-intensive industries such as construction (see, also, Deutsche Bank Group, 2011; The Energy Efficiency Industrial Forum, 2012).

Some empirical evidence

Table 0-8 summarises some of the findings of previous research on the impact of energy efficiency improvements on employment.

Table 0-8 Previous research on the impact of energy efficiency on employment

	Reference	Scope	Main findings
1	Association for the Conservation of Energy, 2000, Energy Efficiency and Jobs: UK Issues and Case Studies	UK	This study assesses the effects related to seven energy efficiency investment programmes that were implemented in the UK. In terms of job creation, the study suggests that the direct employment created per £1m invested is in the range of 10-58 (person-years during programme). Indirect employment created over 15 years per £1m invested is found to be above 60 person-years.
2	Scott et al., 2008, The impact of DOE building technology energy efficiency programs on U.S.	US	The fiscal Year 2005 Building Technologies programme could create 446,000 jobs by 2030

[62] See, also, European Commission (2014b) for a comparison of energy costs across Europe and a discussion of its implications in terms of competitiveness and international trade.

	employment, income, and investment		and increase wage income by $7.8 bn.
3	Ürge-Vorsatz et al., 2010, Employment Impacts of a Large-Scale Deep Building Energy Retrofit Programme in Hungary	Hungary	17 jobs (person-years) are expected to be created per million euro invested in energy efficiency.
4	Wei et al., 2010, Putting Renewables and Energy Efficiency To Work: How Many Jobs Can The Clean Energy Industry Generate in the U.S.?	US	Ambitious energy efficiency programmes combined with a 30% renewable portfolio standards target in 2030 could generate over 4m full-time-equivalent job-years by 2030.
5	Power and Zalauf, 2011, Cutting Carbon Costs: Learning from Germany's Energy Saving Program	Germany	900,000 jobs have been created in retrofitting dwellings and public buildings since 2006.
6	Lutz et al., 2012, Economic Impacts of Energy Efficiency and Renewable Energy in Germany	Germany	127,000 additional jobs could be created in 2030 by implementing further energy efficiency measures, i.e. €301bn of additional investment by 2030.
7	Cambridge Econometrics and Verco, 2012, Jobs, Growth and Warmer Homes. Evaluating the Economic Stimulus of Investing in Energy Efficiency Measures in Fuel Poor Homes	UK	This study reports that investing £2.6 bn in energy efficiency could create 71,000 jobs by 2015 in the UK.
8	Acadia Center, 2014, Energy Efficiency: Engine of Economic Growth in Canada	Canada	This study estimates a total net increase in employment of 1.5 to 4.0 million job-years. In other words, $1m invested in energy efficiency measures generates 30 to 52 job-years.
9	Navius Research, 2014, Macro-economic Effects of Energy Efficiency Improvements	Canada	The study reports that energy efficiency improvements increased employment by 2.5% from 2002 to 2012.
10	Oliveira et al., 2014, A prospective analysis of the employment impacts of energy efficiency retrofit in the Portuguese building stock by 2020	Portugal	The authors focus on direct, indirect and induced jobs created until 2020 due to the introduction of four retrofit measures in the Portuguese building sector. Results show that the number of jobs created is greater than the number of jobs lost due to the reduction in energy demand.
11	UK Energy Research Centre, 2014, Low carbon jobs: the evidence for net job creation from policy support for energy efficiency and renewable energy	Numerous countries	The study reviews existing literature on green jobs creation. Energy efficiency is found to be more labour-intensive (in terms of electricity produced) than fossil fuel power plants, but the number of jobs created highly depends

			on the macroeconomic conditions of the considered country. 0.3-1 jobs/annual GWh saved are created in the energy efficiency sector.
12	Cantore et al., 2017, Promoting renewable energy and energy efficiency in Africa: a framework to evaluate employment generation and cost effectiveness	Africa	The analysis shows that fostering low carbon generation and energy efficiency will lead to additional jobs. In addition, increasing the uptake of energy efficiency measures tend to reduce the costs associated to every additional job created.
13	Garrett-Peltier, 2017, Green versus brown: comparing the employment impacts of energy efficiency, renewable energy, and fossil fuels using an input-output model	US	$1 million spending in industrial energy efficiency creates 7.41 full-time equivalent jobs (3.98 direct and 3.43 indirect), which is higher than the 2.65 jobs created with the same investment in the fossil fuel sector.

Source(s): Cambridge Econometrics' elaboration based on the referenced reports.

Unemployment and employment

As acknowledged in the existing literature, it is important to evaluate the existence of idle capacity in the labour market, i.e. the population who potentially could be activated and participate in the economy if needed. An assessment of the employment created at sectoral level could also improve our understanding of a possible crowding-out effect which happens in the labour market. In this context, an important issue to bear in mind is the existence of skills shortages which might prevent energy efficiency programmes from achieving their full potential. A way forward to account for this issue would be to undertake an additional analysis of skills forecasts in sectors such as construction, electricity or engineering (see, Cambridge Econometrics, GHK and Warwick Institute for Employment Research (2011) and IEA (2014) for further discussion).

Wage rates

The evolution of wage rates could give us a first indication of the quality of the jobs which are created. A preliminary expectation is that investing in energy efficiency will create both low- and high-paid jobs depending on the qualifications and availability of skilled workers required. Changes in wages will also allow us to see whether an income redistribution process is taking place in the economy as result of the energy efficiency programmes implemented.

2.7 Comparison with previous results from E3ME

Table 0-9 presents results for GDP and Employment for 2030 from the 2015 *Assessing the Employment and Social Effects of Energy Efficiency* report[63] alongside the results from earlier sections of this report. The table shows results for the 30% efficiency target (EUCO30 scenario here, EE30 in the 2015 report) compared to the reference case (rather than to the EUCO27 scenario as elsewhere in this report). In both cases the variant with no crowding out is shown.

[63] See http://ec.europa.eu/energy/sites/ener/files/documents/CE_EE_Jobs_main%2018Nov2015.pdf

The E3ME model was used in both projects, but produces slightly different results. This section explains the reasons for the differences.

At EU level, there is very little difference between the findings of the two studies but there are some larger differences at Member State level. Since the 2015 report there have been some updates to both E3ME and the reference scenario. E3ME has incorporated more recent data, which have provided longer time series with which to re-estimate the model's equations. This means that some of the model's parameters have changed, although in most cases the differences are not very big. The largest difference in the model's data and parameters relate to Croatia, reflecting revisions and improvements to the data published by Eurostat.

One important change to model specification is how trade is modelled in E3ME. The current version of E3ME includes a more advanced representation of bilateral trade (i.e. point-to-point between two countries) that is more sensitive to changes in prices and technology than the previous specification. This revision explains some of the differences in results, particularly in Member States with high trade ratios.

The other important difference to the 2015 study is the assumption about how the investment was financed. The 2015 study was based on public financing, similar to the sensitivity discussed in the previous section, but with changes to income tax rates rather than VAT rates. As noted in Section 2.4, the self-financing approach can lead to slightly worse results when households must fund the efficiency measures (as purchases of other products are immediately displaced). This explains the lower GDP results for Romania and other countries with a strong focus on buildings in the scenario.

The pattern of variation in the employment results is quite similar to that for GDP, with little change at EU level, but some differences at Member State level. There is a strong correlation between the changes in GDP results and the changes in employment results between the two studies.

The most noticeable difference is that in the 2015 study there were some countries that had negative impacts on employment but this is not the case in the 2016 results. The largest difference is in Lithuania, where a better result for GDP (driven by trade), is matched by an improvement in the demand for labour. The employment results for Finland become positive, despite no change to GDP, because of changes in the patterns of sectoral employment which relate to the differences in the financing mechanism for the energy efficiency.

Some of the other more minor changes to employment results relate to updated projections of employment and unemployment that have been integrated to E3ME, reflecting more recent data in Europe. As discussed in Section 2.3, the rate of unemployment in the reference case can have an impact on employment results as it determines the number of people that are available to fill new jobs and the responses in wage rates through the econometric equations.

Table 0-9: Comparison of results with 2015 study (30% efficiency scenario compared to reference case, no crowding out)

	GDP 2015	GDP 2016	Employment 2015	Employment 2016
Austria	0.9	1.0	0.0	0.3
Belgium	2.2	1.2	0.5	0.4
Bulgaria	3.0	1.2	0.4	0.0
The Czech Republic	2.8	2.3	0.6	0.8
Cyprus	0.3	0.8	0.4	0.3
Germany	1.1	1.3	0.1	0.3
Denmark	2.0	0.4	0.7	0.3
Estonia	2.4	1.3	0.5	0.5
Spain	0.4	0.8	0.3	0.5
Finland	1.1	1.1	-0.2	0.6
France	1.0	1.4	0.2	0.5
Greece	1.5	1.2	0.9	0.8
Croatia	4.6	0.4	0.9	0.3
Hungary	1.5	1.7	0.3	0.6
Ireland	0.9	0.8	0.4	0.3
Italy	2.2	1.0	1.1	0.2
Lithuania	0.5	1.2	-0.5	0.6
Latvia	2.5	1.9	0.4	0.5
Luxembourg	0.7	1.0	0.4	0.1
Malta	0.2	1.9	0.1	0.6
The Netherlands	2.0	0.8	0.4	0.2
Poland	2.0	0.5	0.3	0.3
Portugal	1.0	1.3	0.3	0.8
Romania	2.2	0.9	0.6	0.1
Sweden	1.1	0.8	0.1	0.3
Slovenia	1.6	0.9	0.4	0.4
Slovakia	1.0	1.3	0.2	0.3
The UK	0.7	0.8	0.0	0.4
EU28	1.1	1.1	0.3	0.4

3 Health

3.1 Literature review and data sources

The literature review focuses on existing literature on the health impact of air pollution, monitored through physical and monetary indicators. The main sources that were reviewed in detail are synthesised in Table 0-10. The table also gives a brief summary of the type of information provided by each source and its key findings.

Table 0-10 Data sources for health impacts of air quality

	Source	Geography	Main findings
1	Grey et al., 2017, The short-term health and psychosocial impacts of domestic energy efficiency investments in low-income areas: a controlled before and after study	UK	The study focuses on the associations between housing warmth improvements, health and psychosocial factors. Energy efficiency improvements are found to increasing subjective wellbeing, financial conditions, thermal satisfaction and reducing social isolation. However, energy efficiency measures do not lead to better physical or mental conditions in the short term. According to the authors, improved health outcomes may materialise in the longer term.
2	Ahrentzen et al., 2016, Thermal and health outcomes of energy efficiency retrofits of homes of older adults	US	This study provides evidence on energy retrofits improving reported health conditions (in terms of emotional distress and sleep) of old low-income populations living in affordable housing, especially due to a more stabilised thermal environment.
3	Hamilton et al., 2015, Health effects of home energy efficiency interventions in England: a modelling study	UK	Through a scenario analysis, the authors show how properly implemented energy efficiency measures have the potential to improve health by reducing exposure to cold and outdoor air pollutants as well as stabilising indoor thermal conditions. It is, however, crucial to have some ventilation to guarantee a minimum level of indoor air quality.
4	Shrubsole et al., 2015, A tale of two cities: comparison of impacts on CO_2 emissions, the indoor environment and health of home energy efficiency strategies in London and Milton Keynes	UK	Depending on the uptake level of energy efficiency measures, households living in the cities of London and Milton Keynes could benefit from important health improvements over the period 2011-2050. Specifically, the authors estimate a 3 and 4 months increase in life expectancy at birth in Milton Keynes and London, respectively. However, health improvements highly depend on the inclusion of purpose-provided ventilation (PPV) among implemented efficiency measures.

5	WHO (2016), Health risk assessment of air pollution - general principles	Global	An air pollution health risk assessment (AP-HRA) estimates the health impact to be expected from measures that affect air quality, in different socioeconomic, environmental, and policy circumstances. This document introduces the concept of AP-HRA, describes in broad terms how the health risks of outdoor air pollution and its sources are estimated, and gives an overview of the general principles for the proper conduct of an AP-HRA for various scenarios.
6	French Senate (2015), French Senate Committee Report on the economic and financial cost of air pollution, Paris	Europe, France	This report evaluates the effects of air pollution in France. It estimates that it costs France some €100 bn each year, citing impact to health as the major expense (between €68 bn and €97 bn euros).
7	WHO Regional Office for Europe (2015), Economic cost of the health impact of air pollution in Europe, WHO Regional Office for Europe Publications, 2015	Europe	Current estimates of the joint effects of ambient and household air pollution include an estimated 7 million premature deaths globally each year, representing one in eight of the total deaths worldwide. In the WHO European Region as a whole, the estimated mortality in 2010 was approximately **600,000 premature deaths**, which represents a marked decrease from 2005 for the region overall. The annual economic cost of premature deaths from air pollution across the countries of the WHO European Region stood at US$1.431 trillion. The overall annual economic cost of health impacts and mortality from air pollution, including estimates for morbidity costs, stood at US$1.575 trillion. Information for model: **Number of premature deaths /**
8	Walton H., et al. (2015), Understanding the Health Impacts of Air Pollution in London. A report for Transport for London and the Greater London Authority	Europe, UK	The report estimates that in London in 2010 the number of deaths attributable to long-term exposure to NO_2 is 5,879. This is in comparison to the estimate that, in 2010, the number of deaths attributable to long-term exposure to man-made particulate matter ($PM_{2.5}$) was 3,500. The total cost in London of these health impacts ranged from £1.4 billion to £3.7 billion. Short-term exposure to NO_2 was associated with about 420 hospital admissions for respiratory disorders in 2010 in London. The equivalent figure for $PM_{2.5}$ is estimated to be 1990 admissions.

9	WHO (2014), Ambient (outdoor) air pollution and health factsheet, WHO Media Centre, Factsheet N°313, March 2014	Global	This factsheet on outdoor air quality and health summarises the main findings of the WHO relative to outdoor air quality and health effects. It presents some key facts and background elements and then focuses on key air pollutants (PM, O_3, NO_2, SO_2) and the existing detailed health assessments of these pollutants. "WHO Air Quality Guidelines" estimate that reducing annual average particulate matter (PM_{10}) concentrations from levels of 70 µg/m^3, common in many developing cities, to the WHO guideline level of 20 µg/m^3, could reduce air pollution-related deaths by around 15%. Several European studies have reported that the daily mortality rises by 0.3% and for heart diseases by 0.4%, per 10 µg/m^3 increase in ozone exposure.
10	European Environment Agency (2014), Air quality in Europe	Europe 28	This report provides a mortality estimation per exposure and per region in the EU.
11	OECD. (2014), The Cost of Air Pollution: Health Impacts of Road Transport, OECD Publishing, Paris	OECD countries	This study reports on the economic cost of the health impacts of air pollution from road transport – on a global scale but with special reference to China, India and the OECD countries. The cost of outdoor air pollution in OECD countries, both deaths and illness, was about USD 1.7 trillion in 2010. Available evidence suggests that road transport accounts for about 50% of this cost, or close to USD 1 trillion. Methodology used: standard method for calculating the cost of mortality - the Value of Statistical Life (VSL) as derived from individuals' valuation of their willingness to pay to reduce the risk of dying (VSL EU = 3.6 million dollars (USD in 2005)) Indicative estimates suggest that morbidity would add 10% to the mortality cost figures
12	WHO (2012), Burden of disease from Ambient Air Pollution for 2012, World Health Organization	Global	In new estimates released, WHO reports that in 2012 around 7 million people died - one in eight of total global deaths – because of air pollution exposure. Globally, 3.7 million deaths were attributable to ambient air pollution (AAP) in 2012. Europe accounts for 280,000 of these deaths.

13	AEA Technology Environment (2005), Damages per tonne emission of $PM_{2.5}$, NH_3, SO_2, NOx and VOCs from each EU25 Member State (excluding Cyprus) and surrounding seas, report for the European Commission DG Environment	Europe 25	This report provides the **damage per tonne of pollutant ($PM_{2.5}$, SO_2, NOx, NH_3 and VOCs)**, accounting for variation in the site of emission by providing estimates for each country in the EU25 (2005 data).
14	EU CAFE (2005), Service Contract for Carrying out Cost-Benefit Analysis of Air Quality Related Issues, in particular in the Clean Air for Europe (CAFE) Programme	Europe	This document defines in detail the methodology used for quantification and valuation of the health impacts of ozone and particulate matter for the cost-benefit analysis (CBA) being undertaken as part of the Clean Air For Europe (CAFE) programme. Results are based on modelling a uniform relative reduction in emissions of each pollutant within each country. As such, they represent something of an average of damages between rural and urban emissions.
15	WHO (2004), Environmental burden of disease: Country profiles for the year 2004	Europe	WHO presents country data on the burden of disease that is preventable through healthier environments. These estimates provide the stepping stone for informed policy making in disease prevention. The country profiles provide an overview of summary information on selected parameters that describe the environmental health situation of a country, as well as a preliminary estimate of health impacts caused by environmental risks for the year 2004. Such preliminary estimates can be used as an input to more refined estimates of a country's health impacts.
16	WHO (2004), Systematic review of health aspects of air pollution in Europe	Europe	This report summarises the most recent information on the health effects of air pollution. It is based on the results of a comprehensive review of scientific evidence organised by the World Health Organization in support of air pollution policy development in Europe, and in particular the European Commission's Clean Air for Europe (CAFE) programme.

The literature in the table above provides a range of figures, ratios and statistics on the relationships between air pollutant concentrations, physical health impacts (increase/decrease in mortality, morbidity and sometimes other health damages) and the monetary valuation of these outcomes. There are a range of values used, reflecting different methodologies and assumptions.

One important difference between the studies is that, while some studies have a global approach on air pollution (both indoor and outdoor air pollution), others solely focus on outdoor air pollution.

3.2 Output indicators

The main output indicators for health relative to indoor and outdoor pollution are the mortality and morbidity costs due to indoor and outdoor pollution in the European Union. Some studies have monetised the annual economic cost of health impacts and mortality from air pollution in France (source 6 for indoor and outdoor air pollution), the European Union (source 7 for indoor and outdoor air pollution) or the OECD countries (source 11, outdoor air pollution only). Methods employed to measure this output indicator are generally based on the mean value of life, obtained through contingent valuation studies or willingness to pay surveys. Data from these studies could allow defining a baseline for current costs of mortality and morbidity due to indoor and outdoor air pollution.

The main output indicators for health relative to outdoor pollution are:

- Opportunity cost of mortality and morbidity. This measures the opportunity cost of mortality and morbidity due to outdoor air pollution. There are different ways how to estimate it. One study (source 13) measures the marginal cost of damage caused per tonne of pollutant ($PM_{2.5}$, SO_2, NOx, NH_3 and VOCs) for human health and for crops for each EU country in 2005. By plugging in the estimated decrease in tons of pollutants for each EU country in the different energy efficiency scenarios, one can estimate the savings in health costs for each scenario (by isolating the crop aspect, which is out of the scope of this study). Another study (source 10) calculates the number of mortality and morbidity cases due to ozone and particulate matter in each EU28 country in 2010. This could serve as an illustration to show the specific impact of these air pollutants on mortality and morbidity.
- Healthcare cost. This describes the variation in public finance due to outdoor air pollution. One study calculated the impact on social security spending in France (source 6). From this figure, we can consider extrapolating the results to calculate the cost at the level of the European Union.

4 Environmental impacts

4.1 Key issues and scope of the work

The environmental impacts of energy efficiency can be grouped into several categories:

- reductions in greenhouse gas emissions
- reductions in emissions of local air pollutants (e.g. SO_2, NOx)
- other benefits of reduced energy consumption (mainly impacts on land and water)
- impacts on material consumption

4.2 Links to the EPBD report

It should be noted that the environmental impacts from improvements in energy efficiency depend quite strongly on which energy carrier sees reduced consumption. For example, if the energy savings are taken from coal consumption then there could be a substantial reduction in greenhouse gas emissions; however, if the savings come from electricity generated from renewables then there would be no overall impact on emissions.

It should also be noted that, aside from the choice of energy carrier, it does not matter which sector makes the energy savings. For example, the effects of reducing electricity consumption by 1% are the same, whether the savings are made by industry or in buildings. This means that many of the findings from the literature review from the EPBD report are also relevant here.

Each of the four categories listed above is discussed in the sections below.

4.3 Energy consumption and greenhouse gas emissions

The available literature very much focuses on the relationship between energy efficiency and greenhouse gas emissions (see previous section for impacts on local air pollutants). The US EPA (2009) report categorises the set of studies on energy efficiency which are reviewed according to the following typology:

- Potential studies – these provide estimates of the overall cost-effective energy saving potential.
- Energy resource plans – these assess the resource contribution from energy efficiency for a specific geographic area or energy system.
- Programme portfolio evaluations and programme filings – these consist of detailed plans of energy that can be saved through improvements to energy efficiency and the associated costs and benefits.
- CO_2 reduction potential studies – these focus on the potential impacts that energy efficiency could have on reducing CO_2 emissions.

Besides calculating the avoided tons of CO_2 emitted into the atmosphere, some studies have tried to produce a monetary value representing the avoided future costs of climate change. However, there is still no agreement on how to properly estimate the social cost of carbon (SCC), which highly varies according to modelling assumptions[64]. Table 0-11 provides an overview over some of the most relevant studies on the topic published from the early 2000s.

Table 0-11 Overview of studies on the impact of energy efficiency on the environment

	Reference	Scope	Main findings
1	Aunan et al., 2000, Reduced Damage to Health and Environment from Energy Saving in Hungary	Hungary	CO_2 emissions savings are estimated to be in the range of $86-$222 million per year.
2	Interlaboratory Working Group, 2000, Scenarios for a Clean Energy Future	US	This report estimates carbon emissions levels up to 2020. When a maximum reduction of 565m tCO_2 in 2020 is considered, energy efficiency accounts for 65% of total emissions reductions.
3	EPRI, 2007, The Power to Reduce CO_2 Emissions: The Full Portfolio	US	This report suggests that energy efficiency measures, combined with low-carbon supply technologies, could contribute substantially to a 45% reduction in power-sector CO_2 emissions from 2007 levels in the US.

[64] For further information on the current debate, see: https://www.carbonbrief.org/qa-social-cost-carbon.

4	IPCC, 2007, Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change	OECD / Global	This study estimates that more than 2,500 $mtCO_2$ emissions reductions could be achieved through end-use energy efficiency improvements.
5	Kutscher, 2007, Tackling Climate Change in the U.S.: Potential Carbon Emissions Reductions From Energy Efficiency and Renewable Energy by 2030	US	The report suggests that energy efficiency accounts for a large share of the CO_2 emission reductions that are needed by 2030 to achieve an overall reduction of 60%-80% by 2050. This study also reports that energy efficiency accounts for 57% of the 1.2 bn tons of carbon-equivalent savings that could be achieved by 2030.
6	National Action Plan for Energy Efficiency, 2008, National Action Plan for Energy Efficiency Vision for 2025: A Framework for Change	US	By assuming a target of achieving all cost-effective energy efficiency by 2025, this study reports that a reduction in greenhouse gas emissions of 500 million metric tons of CO_2 could be achieved annually.
7	EEA, 2009, Annual European Community greenhouse gas inventory 1990-2007 and European Union emissions inventory report 2009	EU	The EU industrial sector improved its energy efficiency by 30% over the period 1990-2007. This reduction translates into a 22% CO_2 emissions reduction with respect to 1990 levels.
8	Gonce and Somer, 2010, Lean for Green Manufacturing	Global	This document suggests that the implementation of some operational changes that are oriented to improving energy efficiency could reduce CO_2 emissions.
9	SEAI, 2011, Economic Analysis of Residential and Small-Business Energy Efficiency Improvements	Ireland	The Home Energy Saving (HES) scheme is expected to lead to CO_2 emission reductions of approximately 1.5 tonnes per dwelling. The SME Programme is expected to result in CO_2 emission reductions of 1,800 kt by 2030.
10	ADEME, 2012, Energy Efficiency Trends in industry in the EU	EU	This document reports recent trends followed by EU industry over the period 1990-2010. It is found that the most significant reduction in emissions happened in 2009 (48% of the total decline over the period). However, that figure also reflects a decline in emissions related to the slowdown in economic activity as result of the 2009 financial crisis.
11	DECC, 2012, The Energy Efficiency Strategy: The Energy Efficiency Opportunity in the UK	UK	This study reports that current policies are expected to lead to a 24% and 28% reduction of GHG emissions by 2020 and 2030, respectively.
12	ECONOLER, 2013, Impact Assessment Report of Clean	Turkey	This report presents the main results of an assessment of investments in energy efficiency which were financed by the CTF

	Technology Fund in Renewable Energy and Energy Efficiency Market in Turkey		funds. In particular, it is estimated that more than 43 million tCO_2eq will be saved by the end of the lifespan of the projects which have been funded by the scheme.
13	Green Building Council of Australia, 2013, The Value of Green Star - A Decade of Environmental Benefits	Australia	This report suggests that the construction of 'Green Star' certified buildings could lead to a 45% emission reduction in comparison to the BAU case.
14	Asian Development Bank, 2015, Improving Energy Efficiency and Reducing Emissions through Intelligent Railway Station Buildings.	China	Although this report does not provide any quantification of the emission savings, it presents a detailed description of the potential of improving energy efficiency and reducing emissions by developing 'intelligent railway station buildings'.

Source(s): Cambridge Econometrics' elaboration based on EPA (2009) and other reports.

Besides the listed studies, in the last few years there has been a noticeable growing interest in examining the impact of energy efficiency policies in China and other major carbon emitters, both at the sectoral and country level. Zhang et al. (2014) compared the benefits of implementing an energy efficiency strategy in the Chinese iron and steel sector to the application of command and control regulations. Besides achieving a relevant reduction in pollution control costs, the authors concluded that energy efficiency can potentially avoid the emission of 463 $MtCO_{2eq}$ in 2030. Similarly, the cement sector can achieve savings of approximately 252 $MtCO_{2eq}$ in 2030 if energy efficiency measures are introduced (Zhang et al., 2015). Although complementary to other low-carbon policies, energy efficiency measures represent the most cost-effective solution to achieve carbon emission targets in countries with a high potential for efficiency improvements. Vera and Sauma (2015) compared the effects of introducing a $5/$TonCO_2$ carbon tax with the introduction of some insulation measures in the Chilean power sector to achieve a 2% reduction in residential electricity demand. Their analysis provided evidence in favour of a greater reduction in emissions due to energy efficiency compared to the carbon tax. Improving insulation in the power sector had also the benefit of reducing energy prices.

The uptake of energy efficiency measures can help to achieve relevant emission cuts also in the residential sector. Park et al. (2017) studied the impact of introducing more efficient technologies (heating and cooling devices) in the Republic of Korea and 31 Chinese provinces. Through a scenario analysis, the authors estimated the avoided carbon emissions by region assuming different penetration rates of more efficient technologies. Savings estimates highly varied from region to region, but the highest reductions were achieved in the provinces of Northern China where coal is the main fuel used for heating and electricity generation. Contrary to Park et al. (2017), Levy et al. (2015) considered the implementation of insulation measures in the residential and power sector in the US. Results show that full compliance with the International Energy Conservation Code 2012 would bring annual reductions of 80 million tons of carbon from electricity generation units and an average $49 per ton of avoided CO_2 of monetised climate and health benefits.

4.4 Impact on local air pollutants

The impact on SO_2, NOx and particulates can also be determined by macroeconomic models such as E3ME. These pollutants are released into the atmosphere as a result of combustion processes (coal and petrol in particular) and non-combustion processes such as agriculture fertiliser application.

While these pollutants can have impacts on crops and buildings (as discussed in the series of ExternE studies[65]), by far the largest impacts are on human health and the environment. The effects on human health are discussed in more detail in the previous section.

Given their persistence in the atmosphere and possibility to travel long distances, polluters like sulphur dioxide and nitrogen oxide have the potential to cause serious damages to natural ecosystems such as freshwaters, forests and grasslands as well as buildings of cultural heritage (EEA, 2014). Their deposition is the root cause of acid rain, which led to loss of fisheries and degradation of forests from the 1970s in countries like Sweden, Poland and Germany. Besides acidification, nitrogen compounds can alter the soil nutrient balance and cause increased plant growth and species competition (the so-called "eutrophication"). Over time, this phenomenon poses a serious threat to biodiversity conservation (Emmett et al., 2007).

Once the urgency to address these air pollutants was recognised, a set of international control measures and national emission limits were imposed within the UNECE Convention on Long-Range Transboundary Air Pollution (CLRTAP) in 1979. As a result, countries like the UK experienced large decreases in SO_2 (-94% from 1970 to 2010) and NOx (-58% from 1970 to 2010) emissions (CEH, 2012), but the risk of acidification and eutrophication in certain European areas still persists (EEA, 2017)[66].

4.5 The energy sector's land and water requirements

Even energy savings from electricity that is produced from renewables may produce environmental benefits. For example, if fewer wind turbines are installed, there could be benefits for natural landscapes that are left unspoiled.

It is difficult to measure, let alone estimate, impacts on natural landscapes, but it is possible to use land requirements, in terms of number of square kilometres required per GW of capacity, or GWh of generation, as a proxy measure. It is important to be careful in interpreting the results, however, as the land requirements for biomass consumption are far higher than requirements for any other generation technology – but there is less impact on local landscapes from biomass.

The method for estimating land requirements is relatively basic. By applying a unit value of area per GW of capacity (or GWh of generation) it is possible to derive total land required by the power sector. Several studies have produced estimates of the coefficients required, including Fthenakis and Kim (2009).

A similar approach can be applied to estimate water requirements. It is noted that there is quite a lot of uncertainty in the estimates, as there is a large degree of heterogeneity within each plant type (e.g. some CCGT plants use a lot more water than others). However, given this uncertainty, it is possible to derive estimates for water consumption, defined as cubic metres per GWh and summed across all generation. Macknick et al (2011) provides a set of coefficients that can be used for this purpose, which are presented in Table 0-12. It should be noted that the figures in the tables are withdrawals that preclude other use of the water, and hydro generation is assigned a

[65] See http://www.externe.info/externe_d7/

[66] For more information, see: https://www.eea.europa.eu/data-and-maps/indicators/exposure-of-ecosystems-to-acidification-3/assessment-2.

value of zero; however, as energy efficiency is unlikely to displace hydro power in Europe this is not important.

Table 0-12: Water withdrawals by generation technology

	Water withdrawals m^3/MWh
Natural gas	1.16
Hydro	0.00
Nuclear	5.01
Wind	0.00
Biomass	3.99
Geothermal	0.00
Coal	4.57
Solar PV	0.00
Solar CSP	0.00

Source: Macknick et al (2011)

4.6 Impacts on material consumption

The links between energy consumption and material consumption are highly complex and relatively unexplored. It is not always clear from the literature whether the relationship should be positive or negative; on the one hand there are clear linkages between some material extraction/production and energy consumption (e.g. steel and cement are energy intensive) but capital-intensive energy efficient goods are often quite material-intensive in nature.

Material Flow Analysis (MFA[67]) has typically used input-output analysis to understand existing material demands, but the fixed nature of input-output analysis has prevented sophisticated scenario analysis. Fischer-Kowalski et al (2011) provides a detailed overview and history of the approach, plus suggestions for future development. Overall, the authors concluded that material flow analysis can now be used to deliver meaningful results thanks to the improved quality level in key input data. MFA data reporting has now become mandatory in many industrialised countries and, while certain issues remain unsolved (e.g. limited disaggregation by economic sector), MFA is gaining the potential to answer a wide variety of research questions.

A relatively small number of macroeconomic models (E3ME, EXIOMOD, GINFORS) incorporate MFA into their core structure, but including as endogenous many of the relationships that are fixed in input-output analysis. The level of detail in terms of material types is typically low in the models as they are limited by the economic sectors published by Eurostat and other statistical offices, but they are able to provide estimates of Domestic Material Consumption (DMC), as well as sometimes other indicators such as TMR and RMC. This aspect of the E3ME and GINFORS models is described in Barker et al (2007) and an example of the results from E3ME is provided in Ekins et al (2011). The models have not, however, been used previously to assess the impacts of energy efficiency on material consumption.

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[67] Material flow analysis refers to the systematic appraisal of the physical flows and stocks of materials and natural resources within a given system (the economy, different industrial sectors or ecosystems). For more detailed information, see for example: https://www.oecd.org/environment/indicators-modelling-outlooks/MFA-Guide.pdf.

Our approach in this study is to use the existing structure in E3ME to estimate the impacts of European energy efficiency programmes on DMC.

5 Social aspects

5.1 Introduction to the literature review

The most important social impacts result from energy efficiency that is implemented in buildings. The literature review in the EPBD report covers social impacts in quite some detail. Although the scenarios presented in this report are less focused on buildings than those in the EPBD report, it is noted that there are still substantial energy savings from buildings, and therefore the social impacts in terms of fuel poverty are relevant. For this reason, a brief summary of the relevant literature is reproduced below[68]. The focus is on residential buildings, as energy efficiency in non-residential buildings is likely to have limited direct impact on social welfare[69].

5.2 Energy poverty

Energy efficiency improvements in homes can have certain micro-level benefits, most notably a reduction in the number of households who live in energy poverty. Energy poverty describes a condition wherein a household is unable to ensure an adequate thermal regime in its living space (Boardman 1991, 2010). Energy poverty can thus be understood as a state of deprivation of basic energy services, which is an energy-related manifestation of general poverty and which has been shown to hold the risk of increased morbidity (Rudge/Gilchrist 2005; Marmot Review Team 2011) or even mortality (Healy 2003). Accordingly, when examining the benefits of energy efficiency programmes in regard to energy poverty alleviation, impact assessments should focus on achieved or projected energy cost savings for vulnerable households or increased indoor comfort levels within their dwellings.

Rebound effects associated with energy cost reductions at the household level can be considerable. Any reduction in energy costs, whether as a result of fuel subsidies or improved energy efficiency, enables households to decide whether to reap energy cost savings or to “reinvest” them into higher living comfort through increases in temperature levels (see e.g. Milne/Boardman 2000). Many low-income households that are lifted out of energy poverty by energy efficiency improvements may choose to increase their indoor temperature, foregoing any potential reduction in their energy bills. Ability to increase indoor temperature to more comfortable levels has multiple health benefits, as living in cold and poorly ventilated homes is linked to a range of health problems. Retrofits and other energy efficiency improvements that enable energy poor households to improve indoor temperatures may have positive impacts on mental health and incidences of cardiorespiratory diseases, and can thus help reduce health inequalities (UCL Institute of Health Equity 2010 and 2014; International Energy Agency 2014).[70]

If poverty alleviation and health improvements are the overarching policy targets, positive measurements/estimates on either of these indicators (reduction in energy

[68] For more detailed review of existing literature, see the EPBD report https://ec.europa.eu/energy/sites/ener/files/documents/final_report_v4_final.pdf

[69] Indirect impact arising from possible employment effects and productivity gains are discussed in the EPBD report (see link above), Appendix B Section 2 (pp. 73-88) and Section 3 (pp. 88-91)

[70] The health benefits of improved indoor temperature and ability to keep adequately warm at home are discussed in detail in the EPBD report (see link above), Appendix B, Section 3 (pp. 88-91).

costs or increase in living comfort) provide evidence for successful energy poverty alleviation.

5.3 Direct impacts of improved energy efficiency

The published literature uses a range of different methodologies and indicators to assess the social impacts of energy efficiency improvements in residential buildings. There is no strong consensus on the best approach to use, and it may be that the most suitable assessment approach depends on factors specific to the programmes being evaluated.

Nevertheless, the evidence suggests that there is the potential to substantially alleviate energy poverty in the EU through improving the energy efficiency in residential buildings. To be effective, the programmes must target households who live in energy poverty or low-income households in low-quality housing.

The UK Department of Energy & Climate Change (DECC) estimates of the savings associated with the different energy efficiency measures vary by year and by household characteristics, and are adjusted for comfort taking[71] (i.e. direct rebound effects). Results from the latest assessment (DECC, 2014) indicate that low-income households, which typically spend a greater share of their expenditure on energy, tend to see the largest reductions in bills as a proportion of total expenditure: the poorest 30% are expected to benefit from a reduction of between 0.6% and 1.6% of total expenditure, compared to a reduction of between 0.2% and 0.5% for other deciles.

In an analysis of a clustered, randomised community trial on the effects of building insulation in New Zealand, Howden-Chapman et al. (2007) found that insulating existing houses led to a significantly warmer, drier indoor environment and resulted in improved self-rated health. Insulation was associated with a small increase in bedroom temperatures during the winter (0.5°C) and decreased relative humidity (-2.3%), despite energy consumption in insulated houses being 81% of that in uninsulated houses' (i.e. a 19% reduction).

Likewise, using data on self-reported thermal comfort as well as indoor temperature from an extensive survey of some 2,500 dwellings participating in England's Warm Front energy efficient refurbishment scheme, Hong et al. (2009) found that Warm Front was effective in increasing the mean indoor temperature from 17.1°C to 19.0°C, leading to an increase in the proportion of households feeling thermally 'comfortable' or warmer from 36.4% to 78.7%.

An evaluation of the ARBED programme in Wales, which aimed to reduce energy consumption among low-income households by improved energy efficiency, provided similar results (Patterson, 2012). Using engineering estimates for the performance of implemented measures, Patterson (2012) estimated that the average cost saving for households was £216/year, reducing energy expenditures by about a quarter. Furthermore, responding to a household questionnaire, 35% of respondents asserted a significant increase in the comfort level.

In a different context, results of the SOLANOVA Project, a pilot house-like passive retrofit of a low-quality prefabricated block in Hungary, provided evidence that the promotion of very high-efficiency new construction and retrofitting standards has the potential to eliminate energy poverty. By comparing occupants' pre- and post-retrofit energy billing data, Hermelink (2007) finds that the implemented measures reduced the monthly heating expenses from €96 to €16 per dwelling, demonstrating that heating can be affordable even for the lowest-income Hungarian households.

[71] For any heat consumption reduction measure or renewable heat pump or insulation measure the savings are adjusted by 15% to allow for comfort taking.

In Ireland, SEAI/Combat Poverty (2009) compared households who participated in the Irish Warmer Homes Scheme with those who did not participate in the scheme. Although no statistically significant differences between the groups were found in terms of achieved fuel cost savings (approximately £85/household), the proportion of participating households with children who were able to keep a comfortable temperature at home rose from 27% to 71%. Households in the participating group also showed a significant decrease of respondents finding it difficult to pay their energy bills on time, with the share declining from 48% to 28%.

5.4 Indirect impacts of improved energy efficiency

Energy expenditure savings and ability to maintain more comfortable indoor temperature can have other benefits, which may reinforce the positive effect on household budgets. For example, the greatest health benefits of energy efficiency retrofits have been found to accrue among households that, prior to the implementation of energy efficiency measures, underutilised heating energy services due to budgetary constraints (cf. Grimes et al., 2011). Improved physical and mental well-being due to better indoor climate levels may also positively affect educational achievement or work performance (Thomson et al. 2009), increasing labour market participation and productivity and enabling the uptake of financially more attractive career paths. In countries where healthcare costs are high, health improvements due to improved housing conditions can also increase disposable incomes of vulnerable households due to decreased medical spending.

In addition to the financial impact contributing to poverty alleviation, energy efficiency retrofits or moving into new, energy-efficient buildings may hold another potential social benefit related to improved social integration of underprivileged households by reducing social isolation caused by feelings of embarrassment regarding one’s living conditions (Barton et al. 2004; Bashir et al. 2014).

However, when inadequately designed or implemented, improvements in the energy efficiency of the existing building stock can also have negative effects, in particular if the costs of energy efficiency improvements are passed on to the tenants who cannot afford higher housing costs. For example, a recent study issued by the UK Department of Energy & Climate Change (Fuerst et al. 2013) found that higher ratings on EPCs were associated with higher property values, indicating the potential for tension between ecological and social targets in the housing sector.

6 Public budgets

6.1 Background

The approach used to assess impacts on public budgets has not been further developed from the EPBD study. For reference, the figure that summarises the approach is reproduced below. The IEA *Multiple Benefits* report (2014) provides a comprehensive overview of the potential public budget impacts of energy efficiency. The evidence review presented in the IEA report informs the discussion of public budget impacts presented in the EBPD report and in this report.

The discussion on the impacts of energy efficiency on public budgets in the EPBD study focused on the public budget impacts of energy efficiency in buildings. The approach used in the EPBD study categorised the sources of the impacts of energy efficiency in buildings into three groups:

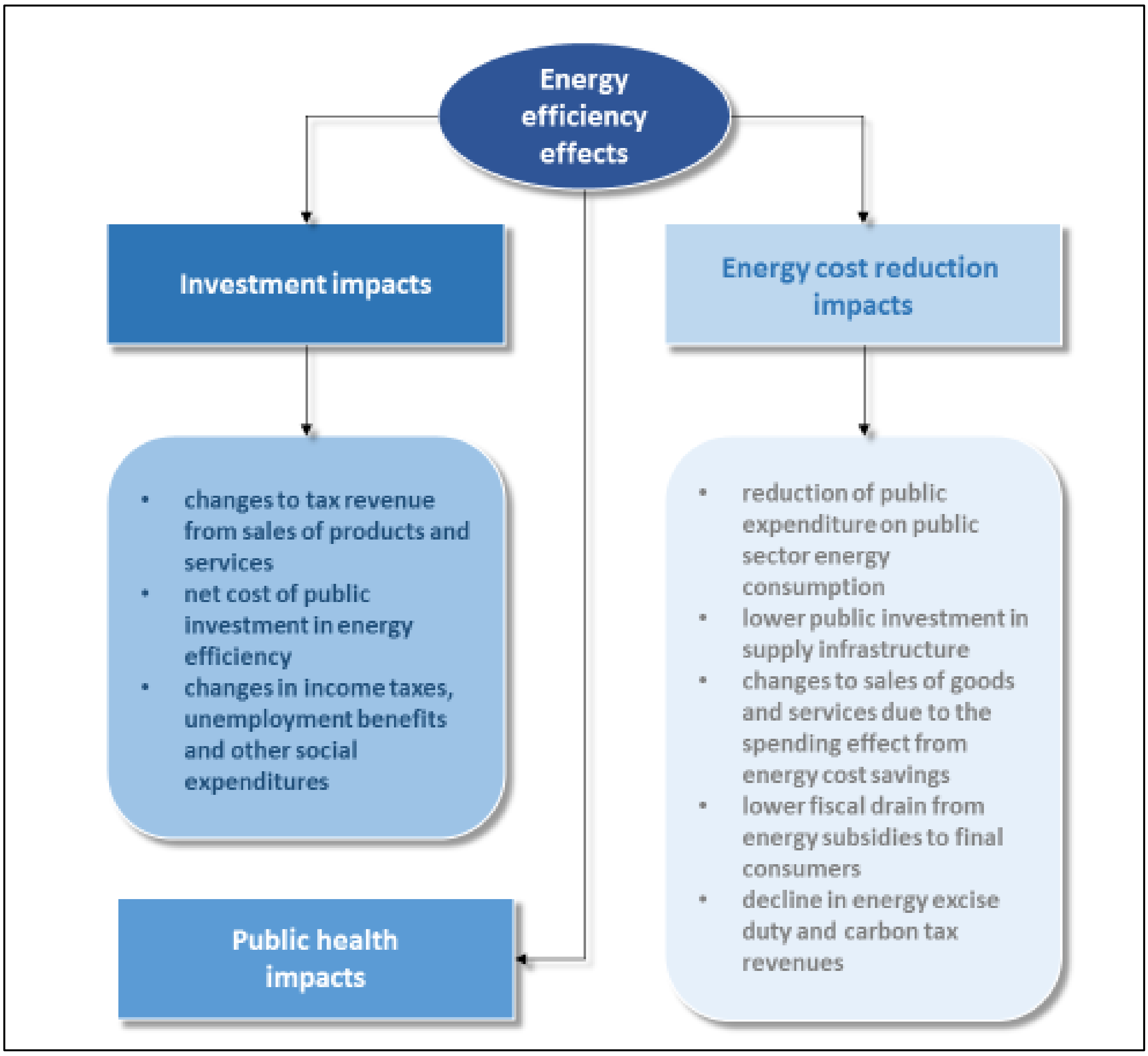
1) Investment impacts

2) Energy cost reduction impacts

3) Public health impacts

The same categories are also relevant for a wider assessment of energy efficiency.

Figure 0.4 The effects of energy efficiency on public budgets



Source(s): EPBD report

Public funding through subsidies, grants, loans and fiscal schemes is playing a crucial role in fostering the uptake of energy efficiency measures in several economic sectors. After the introduction of the Energy Efficiency Directive in 2012, numerous support schemes were introduced in the European Member States to limit energy consumption and achieve the 20% energy efficiency target by 2020. As a result, public financial support in the EU increased from approximately €6 billion in 2012 to €7.1 billion in 2014, with the majority of funds allocated to the buildings sector (ECOFYS, 2016). However, different trends can be identified when considering individual Member States. While countries like Spain, Belgium, the Netherlands and the UK increased substantially the amount of subsidies granted, public funding in countries like Austria, Portugal and Greece shrank considerably.

Beyond assessing the economic, social and environmental benefits of enhanced energy efficiency in the economy, a strand of literature draws attention to the effects of energy efficiency policies on public budgets. Given the existence of numerous benefits and costs of programmes supporting the uptake of energy efficiency improvements, it is hard to deduct a priori the direction and magnitude of their impact on public budgets. Curtin (2012) considered the case of public spending to promote external wall insulation in Ireland. Regardless of the supporting scheme, the tax revenue to government from the retrofitting more than offset the subsidy granted to the private investor. According to the author, the calculated revenue to the government could be even higher when also considering the reduced social welfare and health spending of external wall insulation (Curtin, 2012).

Much of the literature on the impacts of energy efficiency on public budgets lean towards impacts on the health system. Even though in this study health is a separate topic area, some key relevant findings are presented here. In summary, it is found that the public health impacts of energy efficiency can have a significant impact on public budgets. The public health impacts of energy efficiency arise primarily from two main sources: (1) improved indoor air quality and thermal comfort because of energy efficiency improvements to residential buildings; (2) reduced ambient pollution levels and improved ambient air quality because of reduced energy consumption across the economy.

Large-scale implementation of energy efficiency measures and policies to limit air pollution emissions could improve air quality and reduce the risk of severe future impacts, in addition to having considerable climate co-benefits (OECD, 2016). As shown in Section 3, it is widely accepted that energy efficiency measures – in residential and commercial buildings, transport and industry – have positive impacts on public health. Yet these are, at present, rarely calculated as part of energy efficiency policy impact assessment or appraisal, largely due to the methodological challenges associated with the process (IEA, 2014). Most notably, the level of public health spending, and hence estimates of the potential savings, are highly dependent on the health system in each country as well as on climatic factors. At the European level, the annual health benefit of reducing air pollution in Europe is estimated to range from USD 7bn to USD 11bn (€5-8bn) (Copenhagen Economics, 2012) (IEA, 2014).

Reduced risk of chronic and long-term illness and disability due to improved air quality can also have a longer-term knock-on effect, reducing productivity losses (the cost of lost days of work) and welfare spending. When considering both the economic gains made up from less hospitalisation need, reduced outlay of public subsidies and reduced energy bills for public buildings and institutions, Copenhagen Economics (2012) estimated an annual revenue increase between €30 and €40 billion in 2020 in the EU.

Leaving aside the health issues, it is important to recognise the existence of different results depending on the specific retrofit measure and support scheme considered. Rosenaw et al. (2014) analysed the budgetary effects of funding solid wall insulation in the UK. Despite solid wall insulation being one of the most expensive retrofit measures, budget neutrality was achieved in the case of a non-repayable grant provided by the government. When considering a public loan scheme, the costs of the public funding were more than offset by additional tax receipts and revenues.

More recently, Mikulic et al. (2016) relied on an input-output model to calculate the public revenues related to energy efficiency renovation for each € million invested by the government to promote energy efficiency in the Croatian building sector. The authors calculated that the indirect and induced effects of efficiency improvements were higher than 40% of the investment value, meaning that energy efficiency supporting policies can be implemented without deterioration of the public deficit.

Additional studies that look at the potential impacts of energy efficiency on public budgets are listed in Table 0-13. This table also provides a summary of the key findings of each study.

Table 0-13 An overview of relevant studies on the impact of energy efficiency on public budgets

	Reference	Scope	Main findings
1	Ministry of Industry, Tourism and Trade and IDEA, 2007, Saving and Energy Efficiency Strategy in Spain 2004-2012	Spain	This report presents the main results of several scenarios that were modelled to assess the impact of the 2008-2010 Action Plan. It provides estimates on public services consumption, direct and indirect savings, associated investments and public support among others.
2	Meyer and Johnson, 2008, Energy Efficiency in the Public Sector – A Summary of International Experience with Public Buildings and Its Relevance for Brazil	Brazil, US, UK, Germany and others	This paper provides empirical evidence for several countries and makes policy recommendations for the Brazilian economy. For example, the paper reports that the Berlin Energy Saving Partnership (ESP) has increased public sector energy savings by 26% and relates this to the Brazilian context.
3	Energy Efficient Cities Initiative, 2011, Good Practices in City Energy Efficiency: Vienna, Austria (European Union) – Municipal Eco-Purchasing	Austria	This document provides an assessment of the ÖkoKauf Program which has been running since 1999. Specifically, investments to improve energy efficiency in the case of administrative buildings, day care centres and public schools have led to €1.5m in cost savings and 1,723 tonnes of CO_2 emission reduction per year.
4	DECC, 2012, The Energy Efficiency Strategy: The Energy Efficiency Opportunity in the UK	UK	This document finds that 14% of total energy use in business and the public sector is consumed in organisations that are not implementing any type of energy efficiency measures.
5	Zámečník and Lhoták, 2012, Should the Government Invest in Energy Efficiency of Buildings? Macroeconomic Impact Assessment	Czech Republic	This study that finds that every CZK 1m that is invested in enhanced energy efficiency in buildings (dwellings and the public sector) provokes a direct fiscal effect of CZK 0.967m. This results mainly from increased employment and overall tax income.
	Rosenow et al., 2014, Fiscal impacts of energy efficiency programmes - the example of solid wall insulation investment in the UK	UK	The paper finds that a considerable proportion of the investment needed to finance a scheme funding solid wall insulation would be offset by increased revenues and savings. It also emphasises the positive effects of implementing a loan scheme, which holds the potential of generating further revenue for the Exchequer.
7	SEAI, 2014, Annual Report 2014 on Public Sector Energy Efficiency Performance	Ireland	In 2013, energy savings for the Irish public sector were equivalent to 14% of the consumption that was expected for a BAU scenario where no energy efficiency investments were implemented.

8	Frontier Economics, 2015, Energy Efficiency: An Infrastructure Priority	UK	This assessment finds that a programme to make British buildings more energy efficient would result in £8.7bn of net benefits. This report also suggests that investment in energy efficiency should be considered as another form of infrastructure.

Source(s): Cambridge Econometrics' elaboration based on several reports.

7 Industrial competitiveness

7.1 Key issues and scope of work

The EU objectives set out to achieve higher levels of energy efficiency, both in industry and in the construction sector, may have several effects on European competitiveness. In particular, increased levels of energy efficiency could have the following effects:

- Reduction in energy costs for energy intensive industries: Energy costs can comprise a significant part energy intensive industries' cost structure. At a detailed sectoral level, energy costs may represent more than 3% of total production costs, and more than 10% of added value. Energy efficiency is thus a key opportunity for cost reduction and competitiveness improvement in industry.
- Impacts on SMEs: Energy Efficiency may be more difficult to implement in small enterprises. For the construction sector, given that the majority of companies are SMEs, it is necessary to pay attention to weaknesses and strengths regarding energy efficiency improvements.
- Global market shares of European Industries related to improved energy efficiency in construction and industry: The macroeconomic effects of energy efficiency improvements go beyond GDP and employment growth. In particular, European energy intensive industrial sectors (such as steel, pulp & paper, aluminium, cement, glass or chemistry), which are particularly exposed to international competition, may benefit from new opportunities arising from the shift in demand towards more efficient and higher quality materials and processes.
- Emergence and positioning of European firms on breakthrough technologies and innovation in energy efficiency products and solutions: new technologies and innovation will certainly be a key pillar to achieving energy efficiency targets. For instance, innovation on energy-saving building materials, new efficient cooling and heating technologies, or even smart-meters for energy-consumption regulation, will contribute to improved energy efficiency across all sectors. European industries may position themselves on disruptive innovation and gain competitiveness on these fledgling markets.
- Investment attractiveness of the European construction sector: Market trends for construction, renovation and rehabilitation in the housing and services sectors may trigger new opportunities for value creation. These trends throw into question the European industry's capacity to adapt its means and rhythm of production to meet the increased domestic demand, and stay competitive compared to external players.
- Increase in productivity: Workers' productivity is closely tied to their indoor working environment; health effects of improved energy efficiency in buildings may result in better productivity and ultimately affect competitiveness.

Therefore, the key factors to take into account are:

- Energy-intensive industries
- Industries that deliver/produce energy efficiency investment goods
- SMEs
- Construction sector

7.2 Building on previous work

The EPBD report included only a limited consideration of industrial competitiveness, based on the results of E3ME model simulations. In part, this was because many of the factors that affect competitiveness are less relevant to energy efficiency in buildings.

There were also two important limitations to this approach – first, that E3ME cannot go into a very high level of sectoral detail and second that many non-economic factors (e.g. labour productivity) were not covered by the analysis. The approach in this report is therefore to supplement the E3ME results with a more detailed analysis of the key energy intensive sectors.

7.3 Literature review and data sources

The table below shows the EU provisions that are relevant for competitiveness and the related literature sources that were analysed. It also presents the relevant sources on the effects of smart financing on competitiveness.

Table 0-14 Energy Efficiency and its effects on competitiveness

EE legislation	Scope	Measures	Relevance for competitiveness	Literature Review
EED				
Art. 5 and 6	Purchasing by public bodies	* 3% of the buildings owned by governments renovated/yr (central governments of MS renovate each year 3% of the total floor area of the buildings they own and occupy that do not meet the minimum efficiency requirements set under the EPBD). * public sector should purchase energy efficient buildings, products and services defined through EU legislative acts (EPBD, Eco-Design, etc.).	* **Construction industry:** innovation opportunities and market growth. * **Building renovation industry and providers' competitiveness** (namely flat glass, insulation): innovation opportunities and market growth.	1 - Eurochambers 2016, Eurochambres response to the public consultation on the review of directive 2012/27/EU on energy efficiency 2 - Eurima 2016, Consultation on the review of directive 2012/27/EU on energy efficiency Interviews with construction industries, flat glass and insulation industries.
Art. 7	EE obligation schemes	* Article 7 is responsible for half the energy savings the EED should achieve[72]. * Objective: 1.5% energy savings / yr thanks to Energy Obligation Schemes put in place by energy distributors & retail energy sales companies through EE measures.	* **Energy Intensive Industries and SMEs' competitiveness**: energy consumption reductions can be achieved through energy obligation schemes. * **Commercial opportunities for utilities**: energy utilities and other energy providers can use energy	3 - IEA, 2015, "Accelerating Energy Efficiency in small and Medium-sized Enterprises" 4 - ICF International, 2015, "study on energy efficiency and energy

[72] European Commission, Communication from the Commission to the European Parliament and the Council – Implementing the Energy Efficiency Directive – Commission Guidance, 6.11.2013. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013DC0762&from=en.

			efficient programmes to build customer relationships, establish value-added services, address energy supply constraints such as peak demand. * **Low costs, industries' competitiveness**: cost reductions are more relevant for industries in which product differentiating is difficult. * **Producers of energy efficient solutions:** high demand for energy efficient solutions to achieve the targets set out in the Energy Obligation Schemes.	saving potential in industry and on possible policy mechanisms" 5 - ECF, 2014, "Macro-economic impacts of the low carbon transition"
Art. 8	Energy audits and management systems	* Article 8 states that MS shall promote the availability to all final customers of high quality energy audits which are cost-effective and : - carried out in an independent manner by qualified and/or accredited experts. - implemented and supervised by independent authorities under national legislation. * For large enterprises, mandatory energy audits are required.	* **Energy intensive industries competitiveness**: obligated energy audits and enhanced energy management systems can lead to a better understanding of energy consumption. With this enhanced understanding, energy efficient measures can be implemented more easily. * **SMEs' competitiveness**: because SME enterprises account for over 60% of the EU's energy demand, the directive explicitly focuses on SMEs and imposes regular energy audits.	8 - ECEEE 2016, Enhancing the impact of energy audits and energy management in the EU
Art. 9-11	Smart metering and billing	* Empowering energy consumers to better manage consumption: easy and free access to data on consumption through individual metering. * National incentives for SMEs to undergo energy audits. * Large companies will make audits of	* **SMEs' competitiveness**: access to data and information is key for SMEs to implement EE projects. This can be largely improved through smart metering and energy audits. * **Energy Intensive Industries' competitiveness:** energy audits are an	3 - IEA, 2015, "Accelerating Energy Efficiency in small and Medium-sized Enterprises" 4 - ICF International, 2015, "study on energy

		their energy consumption to help them identify ways to reduce it. * Monitoring efficiency levels in new energy generation capacities.	efficient tool for identifying energy saving potentials that are adapted to each industrial site.	efficiency and energy saving potential in industry and on possible policy mechanisms"
Art. 15	Operation infrastructure	* Energy efficiency for energy transformation, transmission and distribution sector. * MS must ensure that national energy regulatory authorities, TSOs and DSOs maximise the energy efficiency potential of smart grids, assess and improve energy efficiency in the design and operation of the gas and electricity infrastructure and ensure that tariffs and regulations fulfil specific energy efficiency criteria.	* **Energy intensive industries' competitiveness:** will be able to compete on a lower cost base. * **Producers of energy efficient solutions competitiveness**: increased market opportunities.	4- ICF International, 2015, "study on energy efficiency and energy saving potential in industry and on possible policy mechanisms"
Art. 20	EE fund, financing and support	* MS shall facilitate the establishment of financing facilities, or use of existing ones for energy efficiency improvement measures to maximise the benefits of multiple streams of financing.	* **All industries**: increased financing for the investments in energy efficient improvement measures. * **Energy intensive industries' competitiveness:** will be able to compete with lower cost bases. * **SMEs' competitiveness:** in general have more difficulties in raising financing.	3 - IEA, 2015, "Accelerating Energy Efficiency in small and Medium-sized Enterprises" 4 - ICF International, 2016, "study on energy efficiency and energy saving potential in industry and on possible policy mechanisms" 1 - Eurochambers 2015, Eurochambers response to the public consultation on the review of directive 2012/27/EU on energy efficiency
ECO-DESIGN AND ENERGY LABELLING				

Eco-design	A framework for the setting of eco-design requirements for energy-related products	* Ensure that products covered by implementing measures may be placed on the market and/or put into service only if they comply with those measures and bear the CE marking. * Designate the authorities responsible for market surveillance. They shall arrange for such authorities to have and use the necessary powers to take the appropriate measures incumbent upon them under this directive. * Ensure that consumers and other interested parties are given the opportunity to submit observations on product compliance to the competent authorities.	* **Energy producers' competitiveness**: consumers respond positively to better information to advise with their purchases and behaviour. Additionally, increased regulation can reduce the import of foreign products in the European Union.	4 - ICF International, 2015, "study on energy efficiency and energy saving potential in industry and on possible policy mechanisms"
Energy labelling	Induction of labelling and standard product information on the consumption of energy and other resources by energy-related products	* Ensure that all suppliers and dealers established in their territory fulfil the obligations and that misleading displays of other labels, marks, symbols or inscriptions are prohibited. * Oblige the supplier to make the product compliant with the relevant requirements.	* **Energy producers' competitiveness**: consumers respond positively to better information to advise with their purchases and behaviour. Additionally, increased regulation can reduce the imports of foreign energy in the European Union.	4 - ICF International, 2015, "study on energy efficiency and energy saving potential in industry and on possible policy mechanisms"
SMART FINANCING				
Smart Financing for Smart Buildings	Mobilising investments into energy efficiency in buildings	* Improvement of public procurement rules, standardisation of investment procedures or better monitoring of energy performance.	* **SME's competitiveness**: access to finance is key for SMEs to implement EE projects. This can be improved through smart financing. * **General industry competitiveness:** EE Investments have well-known positive cash-flow and competitive impacts resulting from delivered energy cost savings.	3 - IEA, 2015, "Accelerating Energy Efficiency in small and Medium-sized Enterprises" 2 - Energy efficiency - the first fuel for the EU Economy 6 - Review of the Energy

		* **Construction industry competitiveness:** boosting innovation in building materials, including in the area of renewables in buildings, potentially increasing trade on building-related materials as well as in the area of building information technologies. * **Energy services industry competitiveness:** boosting innovation in technologies, potentially increasing trade on energy performance software and data collection and monitoring.	Performance of Buildings Directive, including the 'Smart Financing for Smart Buildings' initiative 7- Eurochambres 2016, Eurochambers response to the public consultation on the review of directive 1012/27/EU on energy efficiency

Table 0-15 Main findings of the literature review

	Source	Scope	Main findings
1	Eurochambres 2016, Eurochambres response to the public consultation on the review of directive 2012/27/EU on energy efficiency	This publication is the position paper of the business community at EU level in which it responds to the public consultation on the review of directive 2012/27/EU on energy efficiency.	Mandatory procurement rules for integrated general sustainability policy targets lead to more complex and costly bidding processes, particularly for SMEs.

2	Eurima 2016, Consultation on the review of directive 2012/27/EU on energy efficiency	This response to the public consultation presents the opinion of the European insulation Manufacturers Association on the EED.	The public sector, if all parts are included, has a huge buying power and could be a very important player in transforming the market towards highly efficient buildings and products.
3	International Energy Agency, 2015, Accelerating Energy Efficiency in small and Medium-sized Enterprises	This publication describes the importance of SMEs to the economy, SME energy demand and energy efficiency potential, benefits beyond energy savings, barriers to the uptake of energy efficiency measures, and some of the challenges facing programme designers and managers. It provides guidance on how the barriers and challenges can be addressed.	**Importance of SMEs to the economy and energy consumption** SMEs are important drivers of economies around the world. In the European Union, SMEs employ almost 90 million people, generate about 1.1 million new jobs per year and contribute almost 30% of GDP, worth USD 5.5 trillion. Their share of energy demand differs country by country, but the IEA estimates that SMEs account for at least 13% of global final energy consumption annually. In the UK, SMEs account for around 45% of total business energy use. **Benefits of EE for SMEs** Improving SMEs' energy efficiency is a key way to increase their profitability and competitiveness. As well as reducing SMEs' energy costs, greater energy efficiency can improve SMEs' product quality and output, reduce risks and liabilities, enhance resilience and enable new business opportunities. Studies indicate that the value of the productivity and operational benefits derived can be up to 2.5 times the value of the energy savings (IEA). Numerous studies have indicated that the cost-effective savings potential of SMEs is in the range of 10% to 30% of their energy demand. Eurochambres (the Association of European Chambers of Commerce and Industry) estimates that the short-term energy reduction potential among its 20 million EU members is 10% to 20% (Eurochambres, 2014). Another estimate puts the energy efficiency potential of industrial SMEs in the European Union at more than 25% of consumption (Thollander and Palm, 2013). Energy efficiency programmes also stimulate the growth of national and global markets for energy-efficient goods and services, providing significant business opportunities for SMEs themselves as suppliers **Barriers and key issues** SMEs usually do not have internal capacity to develop and implement energy efficiency projects, and lack information about where and how energy is used in their companies.

			They also scope financial barriers: more severe credit conditions, higher price per unit of energy then larger companies. Key issues for enabling SMEs to implement energy efficiency projects are access to information, capacity building and access to finance.
4	ICF International, 2015, study on energy efficiency and energy saving potential in industry and on possible policy mechanisms	This study assesses the energy saving potential of industrial and selected tertiary sectors that make a key GDP contribution to the EU. The main emphasis of the study is energy intensive industries; for which the study presents a bottom-up analysis of eight industrial sectors, which contribute to more than 80% of industrial final energy consumption in the EU28 Member States	**Pulp and paper**: Incremental process efficiency improvements reflecting recently developed technologies is anticipated to occur as the sector meets existing legislative requirements (e.g. EED, EU-ETS, IED), and further innovates to develop new products to improve margins and market lead. The past trends in reduction of energy intensity are anticipated to continue in a BAU scenario (energy intensity in TOE/dried tonne: 0.389 in 2015; 0.373 in 2020; 0.344 in 2030). Technically feasible savings identified would represent energy consumption savings of 19% in 2030. **Iron and steel**: The EU iron and steel industry has been continuously improving its energy intensity over time, primarily driven by commercial factors of increasing energy prices. Based on the limitations of emerging energy efficient technologies in steelmaking, energy intensity is expected to reduce gradually from 2011-2030 in a BAU scenario (energy intensity in TOE/dried tonne: 0.341 in 2015; 0.338 in 2020; 0.331 in 2030). Technically feasible savings identified would represent energy consumption savings of 24% in 2030. **Non-metallic minerals**: Overall, production in the non-metallic minerals sector is assumed to remain relatively flat through 2050 (BAU scenario), since many of the sectors are dependent of technological breakthroughs that are not available today. Technically feasible savings identified would represent energy consumption savings of 19% in 2030 (only 3.3% saving under economic scenario 1 – considering only <2 years payback energy saving opportunities). **Chemicals and pharmaceuticals**: It is assumed that sector intensity will decrease by 0.5% per year through 2020, as plant-level efficiency is maximised, making it more difficult to make further improvements, and then by 0.25% through 2050. Technically feasible savings identified would represent energy consumption savings of 25% in 2030 (only 4% saving under economic scenario 1 – considering only <2 years payback energy saving opportunities).

			<u>Non-ferrous metald</u>: Over this 22 year period, the energy consumption trend has been gradually reducing by an approximate rate of 0.5% p/a while production of aluminium and copper has been relatively constant over the same period. This gradual reduction trend is expected to continue as the EU continues its strong growth in production of secondary metal through improved waste management schemes in recycling and recovering useful scrap metal. Technically feasible savings identified would represent energy consumption savings of 22% in 2030 (only 5.5% saving under economic scenario 1 – considering only <2 years payback energy saving opportunities). **Potential measures for improving energy efficiency in industries are proposed:** Mandatory implementation of EnMS for large enterprises Mandatory sub-metering requirements Mandatory requirement of energy managers for large energy intensive enterprises Development of insurance for energy performance Increased promotion and facilitation of energy use within industrial clusters **For each measure, the potential energy savings are identified by sector.**
5	European Climate Foundation, 2014, Macro-economic impacts of the low carbon transition	The purpose of the analysis is to explore the macroeconomic impacts of decarbonisation on the basis of an extensive literature review, by comparing a BAU scenario to decarbonisation scenarios on a number of key parameters.	Future competitiveness of European industry will mostly rely on drivers which are unaffected by whether Europe engages in decarbonisation. Energy costs would remain a key competitiveness driver for a number of energy intensive industries which represent the bulk of industrial carbon emissions (steel, cement, aluminium, chemicals, pulp & paper). There are encouraging signs that important energy efficiency opportunities and breakthrough technologies could be commercially viable and usable by these industries by 2030. The study confirms the high trade intensity of EIIs, except for the cement industry which remains protected by high transport costs.
6	Energy Efficiency Financial Institutions Group, 2015, Energy Efficiency - the first fuel for the EU Economy	This reports, which covers buildings, industry and SMEs, examines the strategic importance of investments in energy efficiency for the European Union. It concludes by stating several key	While European industry is world leading in energy efficiency, continued and increasing energy efficiency investment flows will enhance its global competitiveness, protect against energy price volatility and deliver further cost savings in all segments.

		market and policy recommendations.	
7	Review of the Energy Performance of Buildings Directive, including the 'Smart Financing for Smart Buildings' initiative	This impact assessment evaluates the Energy Performance of Buildings Directive in light of the experience gained over the period of its application according to five criteria: Relevance, Effectiveness, Efficiency, EU-added value and Coherence. It also analyses the impact of the 'Smart Financing for Smart Buildings' initiative. It must be stated that this source does not prejudge the final decision of the Commission.	
8	European Council for an Energy Efficient Economy, 2016, Enhancing the impact of energy audits and energy management in the EU	This report reviews Article 8 of the EED with regards to its contents, effects on competitiveness, current implementation and improvement potential.	1 - Within industry, energy demand is dominated by the energy intensive industries, which are responsible for nearly 80% of industry's final energy demand: * primary metals * chemical industry * non metallic minerals * paper, pulp and printing industry * food industry 2 - The update of energy saving measures, although reasonable from a strictly micro-economic perspective, is often delayed or prevented by fear for fallback in competitiveness due to initial investments and production breaks due to the implementation of the efficiency measures. 3 - The positive effects of energy efficiency go far beyond energy savings: increased productivity, reduced maintenance and operational costs, improved product quality, less resource consumption, etc. The IEA states that the due to these multiple benefits the monetary value can exceed the direct cost savings by 250%.

Appendix E Additional Results at Member State level

This appendix includes additional detailed results that were excluded from the main report for reasons of space.

Table 0-16: Degree of crowding out in each scenario at Member State level (%)

	EUCO27	EUCO30	EUCO33	EUCO35	EUCO40
EU28	0.0	0.0	3.1	8.1	19.0
AT	0.0	0.0	0.0	3.4	13.3
BE	0.0	0.0	3.4	9.3	21.3
BG	0.0	0.0	0.0	0.0	0.0
CY	0.0	0.0	0.0	0.0	0.0
CZ	0.0	0.0	4.2	10.6	23.6
DE	0.0	0.0	8.5	15.3	28.4
DK	0.0	0.0	0.0	0.0	8.4
EE	0.0	0.0	0.0	0.0	0.0
EL	0.0	0.0	5.8	12.7	25.2
ES	0.0	0.0	0.0	0.0	0.0
FI	0.0	0.0	0.0	0.0	5.2
FR	0.0	0.0	0.0	4.1	15.0
HR	0.0	0.0	0.0	0.0	0.0
HU	0.0	1.2	16.1	25.6	42.1
IE	0.0	0.0	0.0	0.0	0.0
IT	0.0	0.0	2.9	8.7	20.3
LT	0.0	0.0	0.0	4.2	15.3
LU	0.0	0.0	0.0	0.0	2.8
LV	0.0	3.2	18.4	27.6	44.2
MT	0.0	0.0	0.0	0.0	0.0
NL	0.0	0.0	1.2	6.6	17.8
PL	0.0	0.0	3.1	10.0	23.6
PT	0.0	0.0	0.0	1.8	10.7
RO	0.0	0.0	3.0	9.0	21.4
SI	0.0	0.0	2.2	7.8	19.1
SK	0.0	0.0	4.3	10.7	24.4
SW	0.0	0.0	0.0	3.6	13.7
UK	0.0	0.0	0.1	5.1	15.8

Source(s): Cambridge Econometrics

Table 0-17 Real incomes by socio-economic group, 2030, EUCO27 (no crowding out)

	All households	First quintile	Second quintile	Third quintile	Fourth quintile	Fifth quintile
AT	25,210	14,506	20,919	22,403	26,938	29,719
BE	21,406	12,302	18,301	19,369	22,385	24,275
BG	4,814	3,851	3,874	4,275	4,899	6,081
CY	13,605	10,829	13,420	13,544	12,768	14,617
CZ	9,311	8,463	9,011	8,975	9,538	10,199
DE	26,900	17,024	22,562	24,343	28,439	30,479
DK	25,610	13,258	21,644	23,622	26,331	29,739
EE	9,906	8,499	9,691	9,588	9,399	10,666
EL	10,092	7,187	9,075	9,443	10,271	10,740
ES	18,370	11,683	15,891	16,800	19,231	20,790
FI	22,083	13,003	18,470	19,691	23,438	25,652
FR	22,952	14,171	19,450	20,582	24,405	26,446
HR	-	-	-	-	-	-
HU	5,312	4,446	4,927	5,159	5,289	6,219
IE	31,205	8,642	20,509	30,386	35,154	36,152
IT	18,661	12,626	16,786	17,330	18,813	20,812
LT	10,693	8,687	10,147	10,215	10,103	12,043
LU	28,748	15,239	23,928	26,131	31,225	33,439
LV	8,563	6,905	8,466	8,557	7,995	9,353
MT	23,714	22,119	24,326	23,386	21,824	25,112
NL	21,251	10,691	17,467	18,708	22,555	25,003
PL	8,733	7,750	8,941	8,747	8,180	9,284
PT	14,415	9,540	12,526	13,200	14,991	15,901
RO	5,514	5,232	5,582	5,389	5,133	5,803
SI	12,293	10,537	12,885	12,438	11,547	12,970
SK	11,851	10,928	12,125	11,924	10,936	12,532
SW	27,553	13,400	19,344	29,897	34,214	28,275
UK	21,619	11,574	15,901	20,565	23,039	24,592

Source(s): E3ME, Cambridge Econometrics

Table 0-18 Real incomes by socio-economic group, 2030, EUCO30 (% difference from EUCO27 scenario) (no crowding out)

	All households	First quintile	Second quintile	Third quintile	Fourth quintile	Fifth quintile
AT	0.2	0.2	0.2	0.2	0.2	0.2
BE	0.3	0.3	0.2	0.3	0.3	0.3
BG	-0.3	-0.1	-0.2	-0.1	-0.2	-0.4
CY	-0.1	0.0	0.0	-0.1	-0.1	-0.1
CZ	0.3	0.4	0.4	0.4	0.2	0.0
DE	0.0	-0.1	0.0	0.0	0.0	0.0
DK	0.0	0.2	0.1	0.0	-0.1	-0.1
EE	-0.4	-0.2	-0.1	-0.3	-0.6	-0.6
EL	0.2	0.2	0.2	0.2	0.2	0.2
ES	0.0	0.1	0.0	0.0	-0.1	-0.1
FI	0.3	0.3	0.3	0.3	0.3	0.3
FR	1.0	1.0	1.1	1.0	1.0	0.9
HR	0.0	0.0	0.0	0.0	0.0	0.0
HU	0.7	1.2	1.0	0.9	0.6	0.2
IE	-0.1	0.1	0.1	-0.1	-0.2	-0.3
IT	0.1	0.2	0.2	0.2	0.1	-0.1
LT	0.5	0.9	0.8	0.7	0.5	0.2
LU	0.2	0.3	0.2	0.2	0.2	0.2
LV	0.9	1.5	1.6	1.4	1.0	0.6
MT	0.9	0.9	0.9	0.9	0.9	0.8
NL	0.0	0.0	0.0	0.0	0.0	0.1
PL	-0.7	-0.2	-0.3	-0.5	-0.7	-1.2
PT	0.4	0.4	0.5	0.4	0.4	0.4
RO	-0.8	-0.8	-0.8	-0.8	-0.8	-0.9
SI	-0.1	0.0	-0.1	-0.1	-0.2	-0.3
SK	-0.4	-0.5	-0.5	-0.5	-0.4	-0.4
SW	0.1	0.1	0.1	0.1	0.1	0.1
UK	0.0	-1.8	-1.3	-0.6	0.3	0.3

Source(s): E3ME, Cambridge Econometrics

Table 0-19 Real incomes by socio-economic group, 2030, EUCO33 (% difference from EUCO27 scenario) (no crowding out)

	All households	First quintile	Second quintile	Third quintile	Fourth quintile	Fifth quintile
AT	1.4	1.4	1.4	1.4	1.4	1.5
BE	1.3	1.4	1.3	1.3	1.4	1.4
BG	0.2	0.7	0.4	0.4	0.2	-0.1
CY	0.0	0.2	0.1	0.0	0.0	-0.1
CZ	2.0	2.3	2.3	2.4	1.9	1.5
DE	1.3	1.2	1.4	1.4	1.3	1.1
DK	0.2	0.6	0.5	0.2	0.0	0.0
EE	0.3	1.8	1.8	0.9	-0.2	-0.1
EL	0.8	0.9	0.9	0.9	0.9	0.9
ES	0.2	0.5	0.4	0.3	0.2	0.1
FI	1.8	1.9	1.9	1.8	1.7	1.6
FR	2.2	2.2	2.3	2.2	2.2	1.8
HR	1.3	1.4	1.3	1.3	1.4	1.4
HU	1.8	3.3	2.6	2.2	1.5	0.6
IE	0.0	0.7	0.7	0.3	-0.1	-0.4
IT	1.0	1.2	1.3	1.2	1.1	0.6
LT	1.4	2.8	2.5	2.0	1.3	0.5
LU	0.4	1.3	0.8	0.5	0.4	0.3
LV	2.8	4.5	4.1	3.3	2.7	2.0
MT	0.0	0.0	0.0	0.0	0.0	-0.1
NL	0.6	0.6	0.6	0.6	0.6	0.6
PL	-0.5	0.7	0.5	0.1	-0.5	-1.6
PT	0.9	1.0	1.1	1.0	0.9	0.8
RO	-0.9	-0.8	-0.7	-0.8	-0.9	-1.1
SI	0.1	0.4	0.3	0.3	0.1	-0.2
SK	-0.9	-1.1	-1.0	-1.1	-0.7	-1.0
SW	0.3	0.4	0.3	0.3	0.4	0.3
UK	0.7	-0.9	-0.4	0.1	1.0	0.9

Source(s): E3ME, Cambridge Econometrics

Table 0-20 Real incomes by socio-economic group, 2030, EUCO35 (% difference from EUCO27 scenario) (no crowding out)

	All households	First quintile	Second quintile	Third quintile	Fourth quintile	Fifth quintile
AT	2.3	2.3	2.3	2.3	2.3	2.4
BE	1.6	1.8	1.5	1.6	1.7	1.8
BG	0.4	1.1	0.7	0.6	0.5	0.0
CY	-0.2	0.3	0.1	-0.1	-0.2	-0.4
CZ	3.0	3.5	3.4	3.5	2.8	2.3
DE	1.8	1.7	2.0	1.9	1.8	1.5
DK	0.1	0.6	0.4	0.0	-0.2	-0.2
EE	0.4	2.0	2.1	1.1	-0.4	-0.2
EL	1.3	1.3	1.3	1.3	1.4	1.3
ES	0.3	0.7	0.5	0.4	0.3	0.1
FI	2.9	3.0	3.0	3.0	2.8	2.7
FR	3.0	3.1	3.2	3.1	3.0	2.7
HR	0.0	0.0	0.0	0.0	0.0	0.0
HU	2.6	4.7	3.8	3.1	2.2	0.8
IE	0.2	1.1	1.1	0.5	0.0	-0.5
IT	1.4	1.7	1.8	1.7	1.5	0.9
LT	2.1	4.1	3.6	2.9	1.9	0.9
LU	0.4	1.5	0.8	0.5	0.3	0.3
LV	3.9	6.3	5.5	4.4	3.7	2.8
MT	0.1	0.2	0.1	0.1	0.1	-0.1
NL	1.1	1.0	1.0	1.0	1.1	1.1
PL	-0.4	1.8	1.5	0.7	-0.4	-2.1
PT	0.8	0.9	1.0	0.9	0.8	0.6
RO	-1.2	-1.2	-1.0	-1.1	-1.2	-1.5
SI	0.7	1.1	0.8	0.9	0.6	0.1
SK	-1.5	-1.9	-1.6	-1.8	-1.3	-1.6
SW	-0.2	-0.1	-0.3	-0.2	-0.2	-0.3
UK	1.1	-0.4	0.1	0.6	1.4	1.2

Source(s): E3ME, Cambridge Econometrics

Table 0-21 Real incomes by socio-economic group, 2030, EUCO40 (% difference from EUCO27 scenario) (no crowding out)

	All households	First quintile	Second quintile	Third quintile	Fourth quintile	Fifth quintile
AT	4.6	4.7	4.7	4.6	4.6	4.8
BE	3.0	3.3	2.8	2.9	3.2	3.2
BG	1.0	2.1	1.4	1.4	1.1	0.3
CY	-0.7	0.1	-0.3	-0.6	-0.7	-1.0
CZ	6.4	7.1	7.0	7.2	6.0	5.2
DE	4.0	4.1	4.3	4.2	4.0	3.6
DK	-0.3	0.5	0.2	-0.4	-0.6	-0.6
EE	1.1	2.8	3.3	2.1	0.1	0.4
EL	1.8	1.9	1.9	1.9	2.0	2.0
ES	0.8	1.4	1.1	0.9	0.8	0.5
FI	6.1	6.6	6.4	6.3	6.0	5.7
FR	5.1	5.2	5.4	5.2	5.1	4.8
HR	0.0	0.0	0.0	0.0	0.0	0.0
HU	4.1	7.7	6.2	5.0	3.5	1.4
IE	0.5	2.1	2.1	1.1	0.1	-0.7
IT	2.8	3.3	3.5	3.3	3.0	2.0
LT	4.1	7.3	6.4	5.3	3.8	2.0
LU	0.5	1.7	0.8	0.3	0.1	0.2
LV	7.4	11.1	9.8	7.9	7.0	5.6
MT	0.4	0.6	0.5	0.5	0.5	0.2
NL	2.2	2.2	2.1	2.1	2.2	2.3
PL	1.0	3.9	3.6	2.5	1.0	-1.4
PT	1.2	1.4	1.6	1.4	1.3	0.9
RO	-2.9	-2.9	-2.5	-2.7	-2.9	-3.3
SI	1.6	2.4	1.9	2.0	1.5	0.8
SK	-1.4	-2.1	-1.6	-1.8	-1.0	-1.7
SW	-0.4	-0.2	-0.5	-0.4	-0.3	-0.5
UK	2.3	1.1	1.5	1.9	2.6	2.3

Source(s): E3ME, Cambridge Econometrics

Table 0-22 Real incomes by socio-economic group, 2030, EUCO27 (partial crowding out)

	All households	First quintile	Second quintile	Third quintile	Fourth quintile	Fifth quintile
AT	25,210	14,506	20,919	22,403	26,938	29,719
BE	21,406	12,302	18,301	19,369	22,385	24,275
BG	4,814	3,851	3,874	4,275	4,899	6,081
CY	13,605	10,829	13,420	13,544	12,768	14,617
CZ	9,311	8,463	9,011	8,975	9,538	10,199
DE	26,900	17,024	22,562	24,343	28,439	30,479
DK	25,610	13,258	21,644	23,622	26,331	29,739
EE	9,906	8,499	9,691	9,588	9,399	10,666
EL	10,092	7,187	9,075	9,443	10,271	10,740
ES	18,370	11,683	15,891	16,800	19,231	20,790
FI	22,083	13,003	18,470	19,691	23,438	25,652
FR	22,952	14,171	19,450	20,582	24,405	26,447
HR	-	-	-	-	-	-
HU	5,312	4,446	4,927	5,159	5,289	6,219
IE	31,205	8,642	20,509	30,386	35,154	36,152
IT	18,661	12,626	16,786	17,330	18,813	20,812
LT	10,693	8,687	10,147	10,215	10,103	12,043
LU	28,748	15,239	23,928	26,131	31,225	33,439
LV	8,563	6,905	8,466	8,557	7,995	9,353
MT	23,714	22,119	24,326	23,386	21,824	25,112
NL	21,251	10,691	17,467	18,708	22,555	25,003
PL	8,733	7,750	8,941	8,747	8,180	9,284
PT	14,415	9,540	12,526	13,199	14,991	15,901
RO	5,514	5,232	5,582	5,389	5,133	5,803
SI	12,293	10,537	12,885	12,438	11,547	12,970
SK	11,851	10,928	12,125	11,924	10,936	12,532
SW	27,553	13,400	19,344	29,897	34,214	28,275
UK	21,619	11,574	15,901	20,565	23,039	24,592

Source(s): E3ME, Cambridge Econometrics

Table 0-23 Real incomes by socio-economic group, 2030, EUCO30 (% difference from EUCO27 scenario) (partial crowding out)

	All households	First quintile	Second quintile	Third quintile	Fourth quintile	Fifth quintile
AT	0.2	0.2	0.2	0.2	0.2	0.2
BE	0.3	0.3	0.2	0.3	0.3	0.3
BG	-0.3	-0.1	-0.2	-0.1	-0.2	-0.4
CY	-0.1	0.0	0.0	-0.1	-0.1	-0.1
CZ	0.3	0.4	0.4	0.4	0.2	0.0
DE	0.0	-0.1	0.0	0.0	0.0	0.0
DK	0.0	0.2	0.1	0.0	-0.1	-0.1
EE	-0.4	-0.2	-0.1	-0.3	-0.6	-0.6
EL	0.2	0.2	0.2	0.2	0.2	0.2
ES	0.0	0.1	0.0	0.0	-0.1	-0.1
FI	0.3	0.3	0.3	0.3	0.3	0.3
FR	1.0	1.0	1.1	1.0	1.0	0.9
HR	0.0	0.0	0.0	0.0	0.0	0.0
HU	0.7	1.2	1.0	0.8	0.6	0.3
IE	-0.1	0.1	0.1	-0.1	-0.2	-0.3
IT	0.1	0.2	0.2	0.2	0.1	-0.1
LT	0.5	0.9	0.8	0.7	0.5	0.2
LU	0.2	0.3	0.2	0.2	0.2	0.2
LV	0.8	1.3	1.4	1.3	0.9	0.5
MT	0.9	0.9	0.9	0.9	0.9	0.8
NL	0.0	0.0	0.0	0.0	0.0	0.1
PL	-0.7	-0.2	-0.3	-0.5	-0.7	-1.2
PT	0.4	0.4	0.5	0.4	0.4	0.4
RO	-0.8	-0.8	-0.8	-0.8	-0.8	-0.9
SI	-0.1	0.0	-0.1	-0.1	-0.2	-0.3
SK	-0.4	-0.5	-0.5	-0.5	-0.4	-0.4
SW	0.1	0.1	0.1	0.1	0.1	0.1
UK	0.0	-1.8	-1.3	-0.6	0.3	0.3

Source(s): E3ME, Cambridge Econometrics

Table 0-24 Real incomes by socio-economic group, 2030, EUCO33 (% difference from EUCO27 scenario) (partial crowding out)

	All households	First quintile	Second quintile	Third quintile	Fourth quintile	Fifth quintile
AT	1.3	1.3	1.3	1.3	1.3	1.4
BE	1.2	1.3	1.2	1.2	1.3	1.3
BG	0.2	0.7	0.4	0.3	0.2	-0.1
CY	-0.1	0.2	0.1	0.0	-0.1	-0.2
CZ	1.8	2.1	2.1	2.1	1.7	1.3
DE	1.0	0.9	1.1	1.1	1.0	0.8
DK	0.2	0.6	0.5	0.2	0.0	0.0
EE	0.3	1.8	1.8	0.9	-0.2	-0.1
EL	0.8	0.8	0.8	0.8	0.8	0.8
ES	0.2	0.5	0.4	0.3	0.2	0.1
FI	1.8	1.9	1.9	1.9	1.7	1.6
FR	2.1	2.1	2.2	2.1	2.1	1.8
HR	0.0	0.0	0.0	0.0	0.0	0.0
HU	1.5	2.6	2.1	1.8	1.3	0.6
IE	0.0	0.7	0.6	0.2	-0.1	-0.5
IT	0.9	1.1	1.2	1.1	1.0	0.5
LT	1.4	2.8	2.4	1.9	1.3	0.5
LU	0.4	1.3	0.8	0.5	0.4	0.3
LV	1.7	3.0	2.8	2.3	1.7	1.1
MT	0.0	0.1	0.0	0.0	0.0	-0.1
NL	0.5	0.5	0.5	0.5	0.5	0.6
PL	-0.6	0.5	0.4	-0.1	-0.6	-1.6
PT	0.9	1.0	1.1	1.0	1.0	0.8
RO	1.2	1.3	1.2	1.2	1.3	1.3
SI	0.2	0.3	0.3	0.3	0.1	-0.1
SK	-0.9	-1.1	-1.0	-1.1	-0.8	-1.0
SW	0.3	0.4	0.3	0.4	0.4	0.3
UK	0.7	-1.0	-0.4	0.1	1.0	0.9

Source(s): E3ME, Cambridge Econometrics

Table 0-25 Real incomes by socio-economic group, 2030, EUCO35 (% difference from EUCO27 scenario) (partial crowding out)

	All households	First quintile	Second quintile	Third quintile	Fourth quintile	Fifth quintile
AT	1.9	1.9	1.9	1.8	1.9	2.0
BE	1.3	1.5	1.2	1.3	1.4	1.5
BG	0.4	1.1	0.7	0.6	0.5	0.0
CY	-0.2	0.2	0.0	-0.2	-0.2	-0.4
CZ	2.4	2.7	2.7	2.8	2.2	1.7
DE	1.0	0.9	1.1	1.1	1.0	0.8
DK	0.1	0.6	0.5	0.1	-0.1	-0.1
EE	0.4	2.0	2.1	1.1	-0.4	-0.1
EL	0.9	1.0	1.0	1.0	1.0	0.9
ES	0.3	0.7	0.5	0.4	0.3	0.1
FI	2.9	3.1	3.0	3.0	2.9	2.7
FR	2.7	2.8	2.9	2.8	2.7	2.4
HR	1.3	1.5	1.2	1.3	1.4	1.5
HU	1.9	3.4	2.8	2.3	1.7	0.7
IE	0.2	1.1	1.0	0.5	-0.1	-0.5
IT	1.0	1.3	1.4	1.3	1.2	0.6
LT	1.9	3.8	3.3	2.6	1.7	0.8
LU	0.4	1.5	0.8	0.5	0.4	0.3
LV	1.8	3.4	3.0	2.3	1.8	1.1
MT	0.1	0.2	0.1	0.1	0.1	0.0
NL	0.8	0.8	0.8	0.8	0.8	0.9
PL	-0.7	1.3	1.0	0.2	-0.7	-2.3
PT	0.8	0.9	1.0	0.9	0.8	0.7
RO	-1.1	-1.1	-1.0	-1.0	-1.1	-1.3
SI	0.4	0.8	0.5	0.6	0.3	-0.1
SK	-1.7	-2.0	-1.8	-1.9	-1.5	-1.7
SW	-0.2	-0.1	-0.2	-0.2	-0.1	-0.3
UK	0.9	-0.6	-0.1	0.4	1.2	1.1

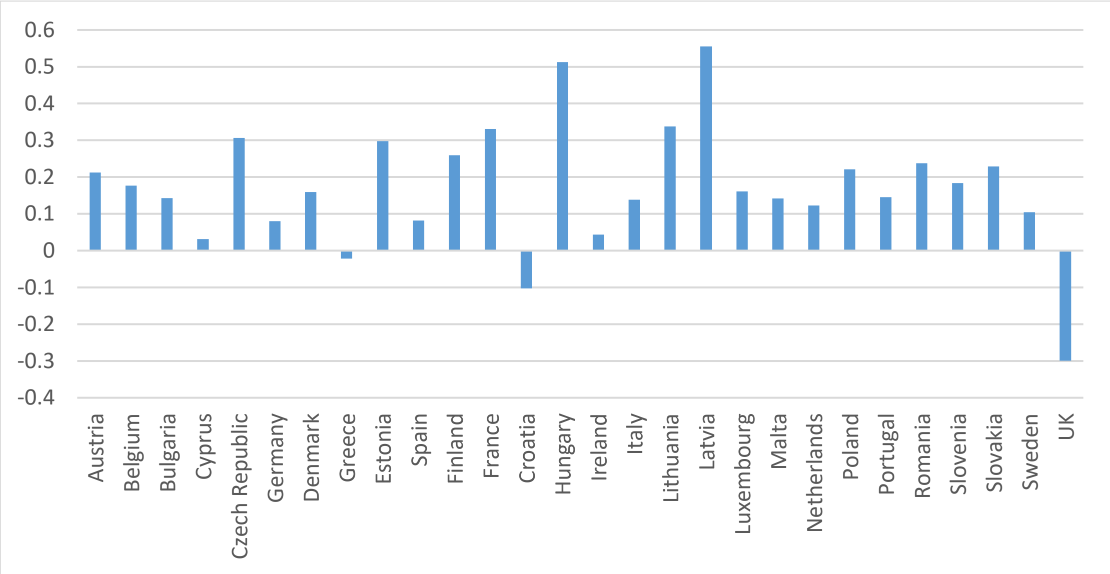
Source(s): E3ME, Cambridge Econometrics

Table 0-26 Real incomes by socio-economic group, 2030, EUCO40 (% difference from EUCO27 scenario) (partial crowding out)

	All households	First quintile	Second quintile	Third quintile	Fourth quintile	Fifth quintile
AT	2.7	2.8	2.8	2.7	2.7	2.8
BE	1.9	2.1	1.8	1.9	2.0	2.1
BG	0.9	1.9	1.3	1.2	1.0	0.2
CY	-0.8	0.0	-0.4	-0.8	-0.8	-1.1
CZ	3.9	4.4	4.4	4.5	3.6	2.9
DE	1.5	1.4	1.7	1.7	1.6	1.3
DK	-0.1	0.6	0.4	-0.2	-0.4	-0.4
EE	1.2	2.9	3.3	2.1	0.1	0.5
EL	0.9	0.9	0.9	1.0	1.0	1.0
ES	0.8	1.4	1.1	0.9	0.7	0.4
FI	5.5	6.0	5.9	5.7	5.5	5.2
FR	3.8	3.9	4.1	3.9	3.8	3.5
HR	0.0	0.0	0.0	0.0	0.0	0.0
HU	2.7	4.8	3.8	3.2	2.3	0.9
IE	0.4	2.0	2.0	1.0	0.1	-0.7
IT	1.6	1.9	2.1	1.9	1.7	1.0
LT	2.8	5.6	4.8	3.9	2.6	1.1
LU	0.4	1.5	0.7	0.2	0.0	0.1
LV	1.6	3.7	3.0	2.0	1.4	0.6
MT	0.4	0.6	0.5	0.5	0.5	0.2
NL	1.3	1.2	1.2	1.2	1.3	1.3
PL	-1.0	1.6	1.2	0.2	-1.0	-3.0
PT	1.0	1.2	1.4	1.2	1.1	0.8
RO	-2.2	-2.2	-2.0	-2.1	-2.2	-2.5
SI	0.5	1.2	0.8	0.8	0.4	-0.1
SK	-2.1	-2.6	-2.3	-2.4	-1.8	-2.2
SW	-0.3	-0.2	-0.4	-0.3	-0.2	-0.4
UK	1.6	0.2	0.7	1.1	1.8	1.6

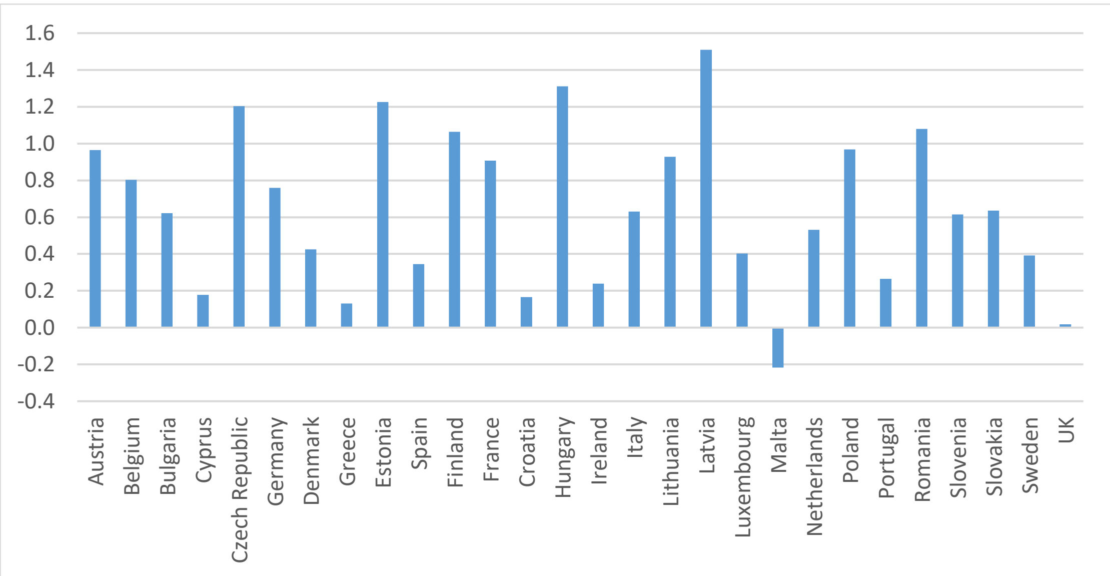
Source(s): E3ME, Cambridge Econometrics

Figure 0.5 Public budget impacts by Member State in 2030, EUCO30, as a % of GDP compared to EUCO27) (no crowding out)



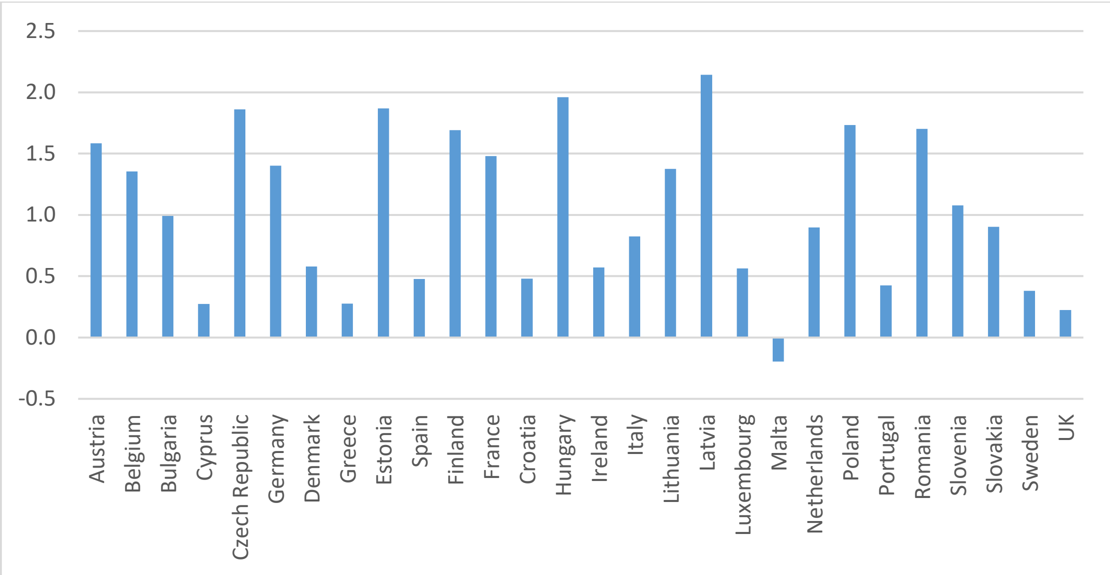
Source(s): Cambridge Econometrics

Figure 0.6 Public budget impacts by Member State in 2030, EUCO33, as a % of GDP compared to EUCO27) (no crowding out)



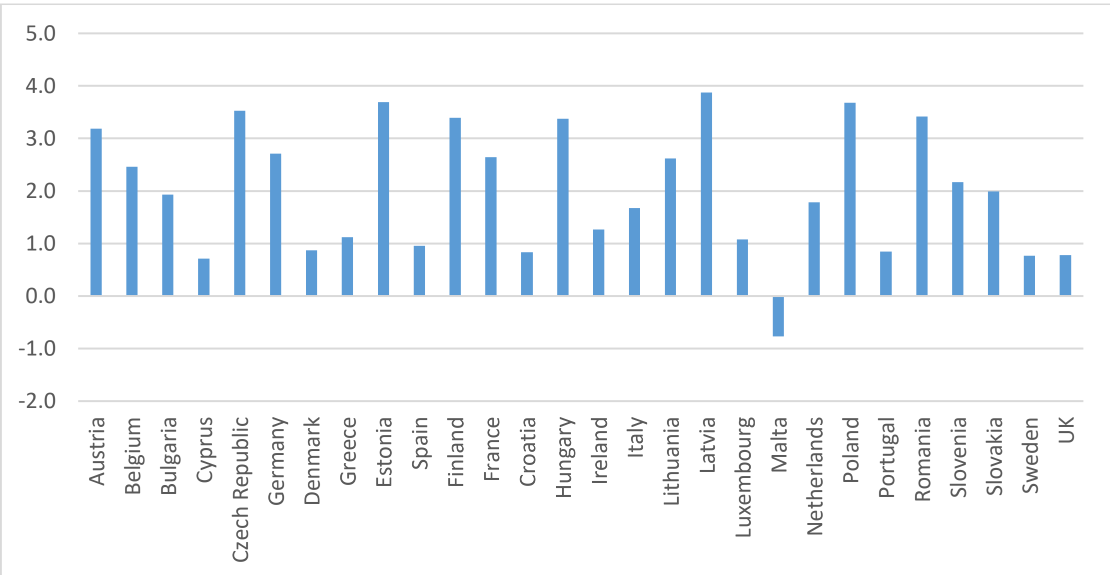
Source(s): Cambridge Econometrics

Figure 0.7 Public budget impacts by Member State in 2030, EUCO35, as a % of GDP compared to EUCO27) (no crowding out)



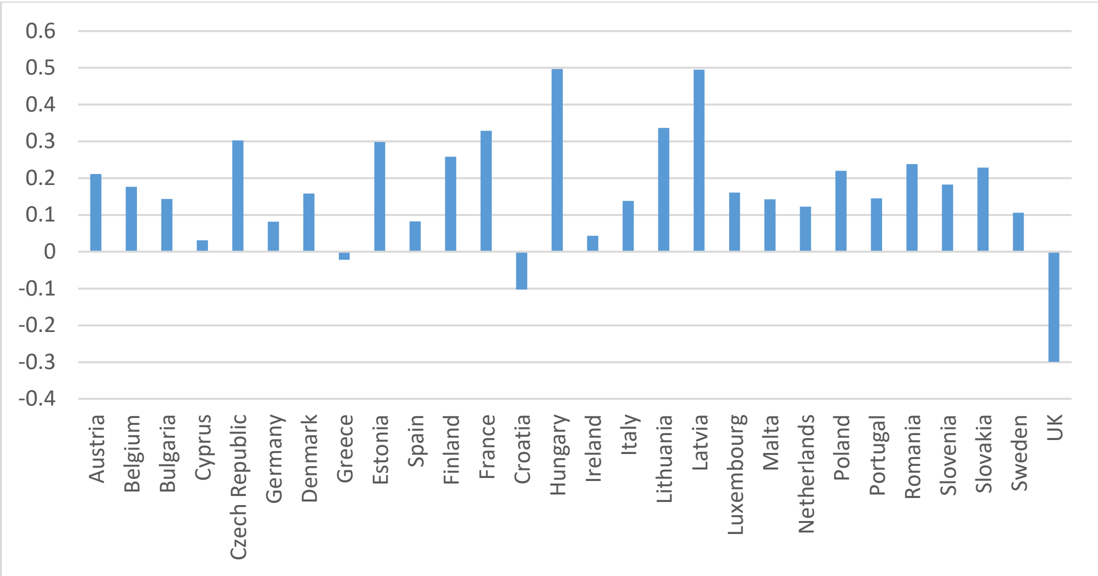
Source(s): Cambridge Econometrics

Figure 0.8 Public budget impacts by Member State in 2030, EUCO40, as a % of GDP compared to EUCO27) (no crowding out)



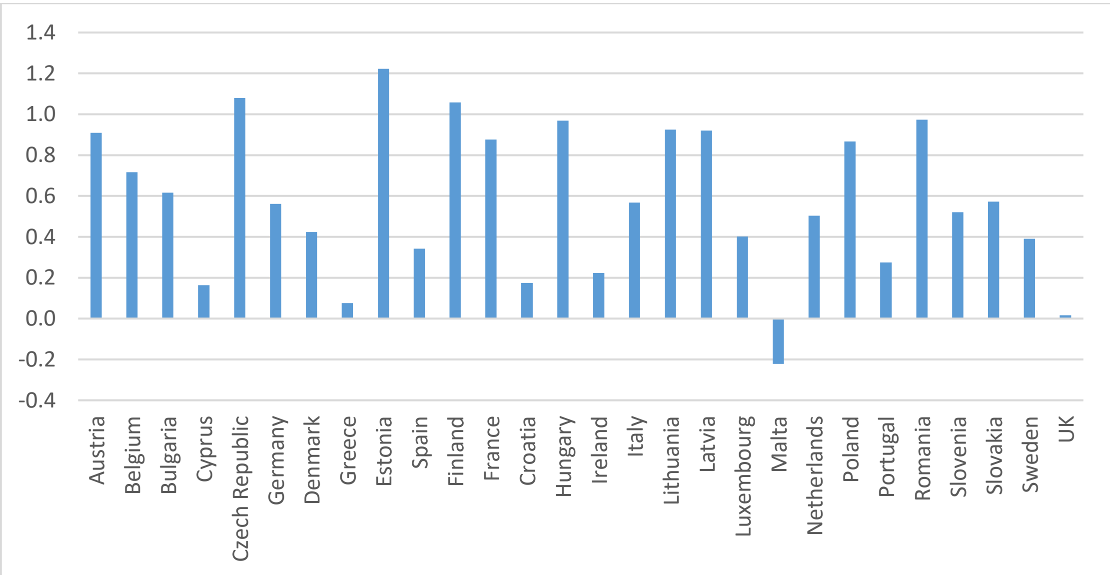
Source(s): Cambridge Econometrics

Figure 0.9 Public budget impacts by Member State in 2030, EUCO30, as a % of GDP compared to EUCO27) (partial crowding out)



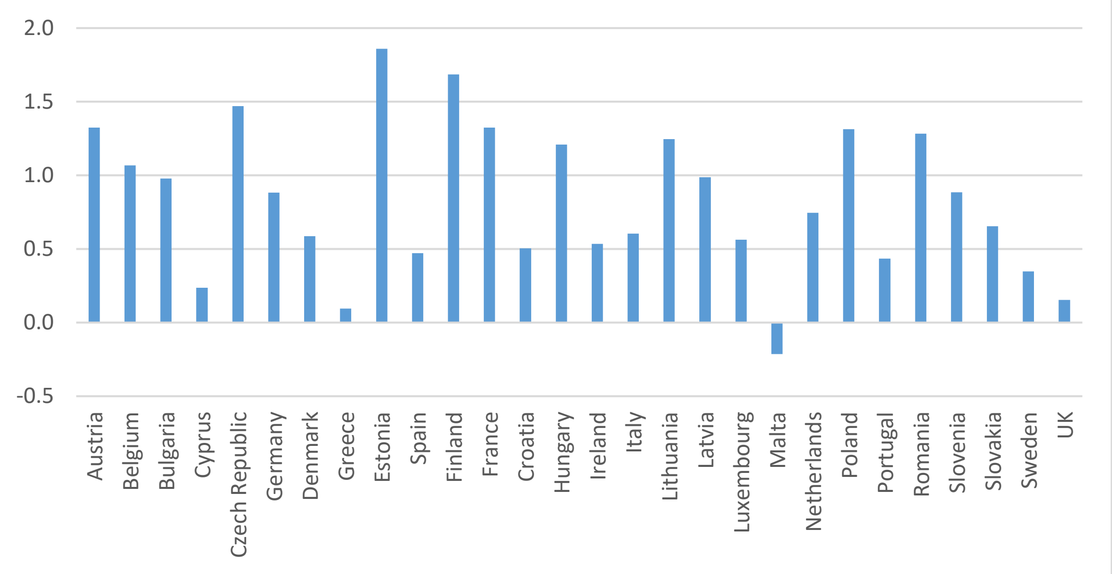
Source(s): Cambridge Econometrics

Figure 0.10 Public budget impacts by Member State in 2030, EUCO33, as a % of GDP compared to EUCO27) (partial crowding out)



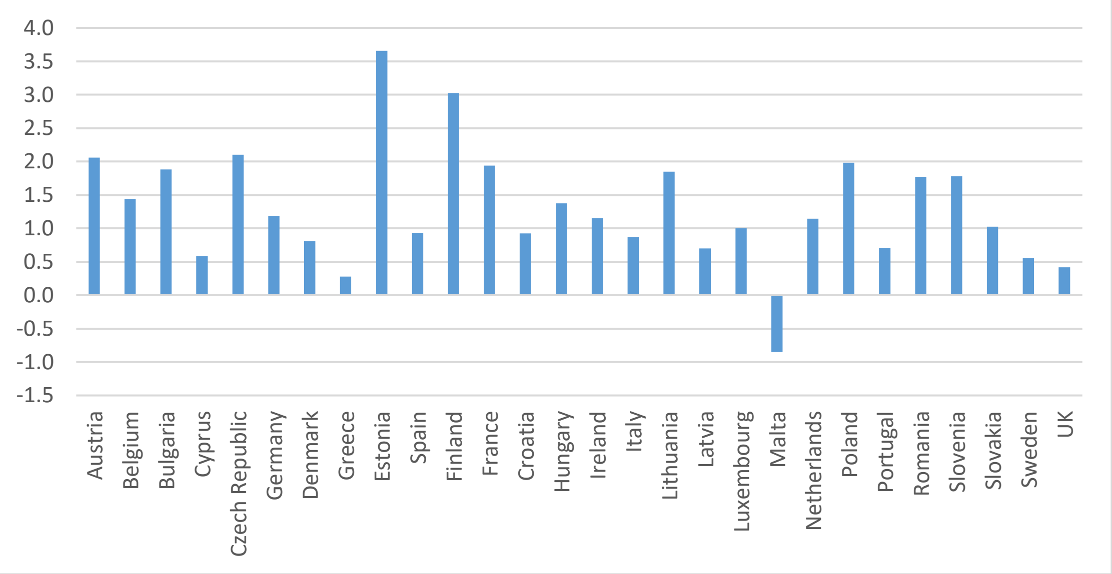
Source(s): Cambridge Econometrics

Figure 0.11 Public budget impacts by Member State in 2030, EUCO35, as a % of GDP compared to EUCO27) (partial crowding out)



Source(s): Cambridge Econometrics

Figure 0.12 Public budget impacts by Member State in 2030, EUCO40, as a % of GDP compared to EUCO27) (partial crowding out)



Source(s): Cambridge Econometrics

Table 0-27 Environmental Indicators, SO_2 & NOx, EUCO27, 2030

	No CO		Part CO	
	SO_2	**NOx**	**SO_2**	**NOx**
AT	51	142	51	142
BE	69	196	69	196
BG	281	164	281	164
CY	7	8	7	8
CZ	175	227	175	227
DE	752	1338	752	1338
DK	32	119	32	119
EE	39	37	39	37
EL	261	189	261	189
ES	457	887	457	887
FI	163	169	163	169
FR	310	842	310	842
HR	54	74	54	74
HU	37	114	37	114
IE	81	111	81	111
IT	622	988	622	988
LT	34	61	34	61
LU	1	39	1	39
LV	7	50	7	50
MT	0	2	0	2
NL	62	306	62	306
PL	719	789	719	789
PT	149	124	149	124
RO	169	242	169	242
SI	27	48	27	48
SK	58	77	58	77
SW	63	133	63	133
UK	249	821	249	821

Source(s): E3ME, Cambridge Econometrics

Table 0-28 Environmental Indicators, SO_2 & NOx, EUCO30, 2030, (% difference from EUCO27 scenario)

	No CO		Part CO	
	SO_2	NOx	SO_2	NOx
AT	13.5	6.8	13.5	6.8
BE	-1.0	-2.1	-1.0	-2.1
BG	-3.1	-1.1	-3.1	-1.1
CY	0.3	0.6	0.3	0.6
CZ	-0.4	-0.1	-0.4	-0.1
DE	0.4	2.0	0.4	2.0
DK	-5.9	-2.6	-5.9	-2.6
EE	1.8	1.7	1.8	1.7
EL	12.0	4.9	12.0	4.9
ES	12.0	7.7	12.0	7.7
FI	-3.1	-1.5	-3.1	-1.5
FR	-4.1	-3.4	-4.1	-3.4
HR	1.3	0.1	1.3	0.1
HU	36.0	13.8	36.0	13.8
IE	-4.7	-1.3	-4.7	-1.3
IT	-18.7	-7.2	-18.7	-7.2
LT	-1.4	0.1	-1.4	0.1
LU	-4.1	-0.8	-4.1	-0.8
LV	0.5	0.6	0.4	0.5
MT	-7.0	-0.2	-7.0	-0.2
NL	1.5	-1.0	1.5	-1.0
PL	1.4	2.5	1.4	2.5
PT	5.0	0.8	5.0	0.8
RO	0.4	0.0	0.4	0.0
SI	-6.9	-2.2	-6.9	-2.2
SK	-1.1	-1.1	-1.1	-1.1
SW	0.7	0.1	0.7	0.1
UK	-2.6	-4.5	-2.6	-4.5

Source(s): E3ME, Cambridge Econometrics

Table 0-29 Environmental Indicators, SO_2 & NOx, EUCO33, 2030, (% difference from reference scenario)

	No CO		Part CO	
	SO_2	NOx	SO_2	NOx
AT	14.1	5.8	14.0	5.8
BE	-3.4	-4.5	-3.4	-4.5
BG	-3.7	-0.6	-3.7	-0.6
CY	-3.0	0.0	-2.9	0.0
CZ	-5.1	-2.1	-5.0	-2.1
DE	-4.1	0.2	-4.2	0.1
DK	-15.9	-5.4	-15.9	-5.4
EE	-0.6	1.3	-0.6	1.3
EL	10.5	4.6	10.6	4.6
ES	4.2	5.4	4.2	5.4
FI	-6.7	-3.4	-6.7	-3.4
FR	-9.5	-6.0	-9.5	-6.0
HR	15.7	3.0	15.7	3.0
HU	33.0	13.3	32.7	12.8
IE	-10.6	-3.1	-10.6	-3.1
IT	-19.4	-8.1	-19.4	-8.2
LT	-5.8	0.8	-5.8	0.7
LU	-10.9	-1.7	-10.9	-1.7
LV	-0.3	1.2	-1.2	0.5
MT	19.2	4.0	19.2	4.0
NL	0.8	-2.4	0.8	-2.4
PL	-0.6	2.3	-0.9	2.3
PT	-8.7	2.3	-8.7	2.3
RO	-0.3	0.3	-0.3	0.1
SI	-19.2	-6.0	-20.1	-6.3
SK	-12.7	-7.4	-12.7	-7.4
SW	-5.2	-1.3	-5.2	-1.3
UK	-8.7	-7.3	-8.7	-7.3

Source(s): E3ME, Cambridge Econometrics

Table 0-30 Environmental Indicators, SO_2 & NOx, EUCO35, 2030, (% difference from reference scenario)

	No CO		Part CO	
	SO_2	NOx	SO_2	NOx
AT	24.7	10.6	24.8	10.7
BE	-3.6	-4.5	-3.7	-4.5
BG	14.9	9.4	14.9	9.4
CY	-9.7	-1.8	-9.5	-1.8
CZ	-8.8	-3.6	-8.6	-3.7
DE	0.1	3.1	0.0	2.8
DK	-11.4	-1.9	-11.4	-2.0
EE	-2.2	1.1	-2.2	1.0
EL	16.3	7.1	16.5	7.0
ES	0.6	4.7	0.6	4.6
FI	-3.1	-2.9	-3.2	-3.0
FR	-11.6	-6.2	-11.5	-6.2
HR	1.0	0.6	1.0	0.6
HU	44.2	18.5	43.4	17.4
IE	-11.4	-3.0	-11.4	-3.1
IT	-17.2	-7.6	-17.4	-7.8
LT	-7.9	1.0	-7.8	0.7
LU	-14.1	-1.9	-14.1	-1.9
LV	0.4	2.0	-1.5	0.6
MT	-1.7	2.5	-1.7	2.4
NL	2.8	-2.2	2.8	-2.2
PL	0.3	3.3	-0.6	3.0
PT	-11.3	3.7	-11.2	3.3
RO	-0.5	0.7	-0.6	0.3
SI	-6.0	-0.1	-5.7	-0.4
SK	-21.9	-11.7	-21.9	-11.7
SW	-8.2	-0.7	-8.3	-0.8
UK	-8.8	-7.1	-8.7	-7.0

Source(s): E3ME, Cambridge Econometrics

Table 0-31 Environmental Indicators, SO_2 & NOx, EUCO40, 2030, (% difference from reference scenario)

	No CO		Part CO	
	SO_2	NOx	SO_2	NOx
AT	42.7	10.0	59.7	16.4
BE	1.4	-2.1	0.9	-2.3
BG	9.0	11.5	8.9	11.3
CY	-7.0	0.1	-6.5	0.1
CZ	12.1	9.2	12.1	8.4
DE	-4.6	0.5	-5.2	-0.6
DK	-15.5	-3.5	-14.9	-2.4
EE	-6.5	-1.9	-6.7	-2.1
EL	17.8	8.1	16.7	7.1
ES	-11.2	-1.2	-11.2	-1.1
FI	-1.6	0.0	-2.0	-0.5
FR	-14.5	-5.1	-15.2	-6.2
HR	20.5	4.9	20.5	4.7
HU	49.3	22.0	57.6	20.8
IE	-13.3	-2.9	-13.3	-3.1
IT	-22.7	-10.3	-23.7	-11.0
LT	-9.8	2.9	-8.2	1.8
LU	-13.8	-1.2	-13.8	-1.3
LV	-4.1	1.9	-9.5	-2.3
MT	-6.6	4.1	-6.8	3.7
NL	6.0	0.5	5.7	0.5
PL	-4.6	0.9	-7.7	-0.1
PT	-18.7	10.0	-18.9	7.8
RO	15.4	7.2	14.8	5.5
SI	-22.7	-4.0	-20.4	-4.2
SK	-35.8	-16.9	-36.6	-17.5
SW	-18.6	-5.0	-20.0	-5.5
UK	-12.0	-9.6	-11.6	-9.4

Source(s): E3ME, Cambridge Econometrics

Appendix F Country classification

Table 0-32 Mapping of country abbreviations

Abbreviation	Full Member State name
AT	Austria
BE	Belgium
BG	Bulgaria
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
EE	Estonia
EL	Greece
ES	Spain
FI	Finland
FR	France
HR	Croatia
HU	Hungary
IE	Ireland
IT	Italy
LT	Lithuania
LU	Luxembourg
LV	Latvia
MT	Malta
NL	Netherlands
PL	Poland
PT	Portugal
RO	Romania
SI	Slovenia
SK	Slovakia
SE	Sweden
UK	United Kingdom
EU	EU28

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