The Macroeconomic and Other Benefits of Energy Efficiency

Final report

Prepared by

Eva Alexandri, Cambridge Econometrics
Piet Boonekamp, ECN
Unnada Chewpreecha, Cambridge Econometrics
Antonio De Rose, EY
Roel Drost, EY
Laurent Estourgie, EY
Cyrus Farhangi, EY
Daniël Funcke, EY
Sanna Markkanen, Cambridge Econometrics
Guido Moret, EY
Hector Pollitt, Cambridge Econometrics
Caroline Rodenburg, EY
Felix Suerkemper, Wuppertal Institut
Sacha Tensen, EY
Perrine Theillard, EY
Johannes Thema, Wuppertal Institut
Paul Vethman, ECN
Florin Vondung, Wuppertal Institut
Monique Voogt, SQ Consult

Contact:

Hector Pollitt
Cambridge Econometrics Ltd,
Covent Garden
Cambridge, UK
CB1 2HT
hp@camecon.com
Tel: +44 1223 533100

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Executive Summary

1.1 Purpose and scope of the study

This report sets out the positive and negative impacts of improvements in energy efficiency in buildings that could come about through a recast of the Energy Performance Buildings Directive (EPBD).

Successive studies have shown that energy efficiency offers many of the most cost-effective options for meeting global emission 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, societal and environmental impacts.

In this report four different scenarios are assessed, based upon the policy options set out in the Impact Assessment. These can be summarised as:

- Option 0: No-change option (reference case)
- Option I: Enhanced implementation and soft law, including clarification and simplification of the current Directive (S1)
- Option II: Enhanced implementation, including targeted amendments for strengthening of current provisions (S2)
- Option III: Enhanced implementation and increased harmonization, while introducing substantial changes (S3)

All other factors are assumed to remain constant across the scenarios, so that the model results are able to isolate the effects of these specific policy changes.

1.2 Economic impacts

Macro economy

The macroeconomic impacts are positive overall at EU level, both for GDP and employment. The main reason for the positive results is a reduction in fossil fuel imports, which also improves energy security. Reduced spending on imported fuels is replaced with higher spending on goods that are more likely to be produced domestically. There is also a shift towards more labour-intensive sectors.

The national results largely reflect shares of energy-efficiency investment (relative to GDP). Countries with large investment goods sectors are also expected to see larger increases in both output (GDP) and employment. In terms of GDP, countries that produce energy domestically and/or export energy suffer from reductions in energy demand, while countries that are energy intensive and/or import energy benefit from reductions in energy demand. Countries with economies that are focused more towards consumer goods and services are likely to see smaller increases in employment than those that produce capital equipment.

The results show a reduction in output and employment in the utilities and extraction sectors due to the energy saving measures. However, small rebound effects and reductions in imports limit the overall impacts on Europe's domestic extraction sectors. The construction and engineering sectors benefit from the investment in energy efficiency and 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 reference case. Because these positive economic impacts are driven largely by higher levels of investment, the impact is greatest in scenario S3 where the energy efficiency investment is the largest.

Public budgets

The impact on public budgets is calculated in current prices and so many reductions reflect falling prices (a lack of inflation) due to reductions in expenditure on expensive energy products in the scenarios. Income from energy excise duty, VAT and auctioned ETS allowances falls, although revenues from corporation tax increase as firms make profits from cutting energy costs. Expenditure impacts include reduced spending on energy and changes to social transfers.

The overall budget change at EU level is positive for all policy scenarios, ranging from €4,443m in S1 to €28,104m in S3 in monetary terms. However, as many changes in public balances reflect price reductions, it is better to look at budget impacts as % of GDP. This shows an estimated budget improvement of 0.02% of GDP in S1, ranging to 0.11% of GDP in S3 at EU level.

Industrial competitiveness

The quantification of energy efficiency impacts on competitiveness is difficult to assess due to confidentiality issues. However, the focus of this report is on improving energy efficiency in buildings so it is mainly households and services that are affected directly, rather than industrial users of energy.

Even so, there may be some indirect effects. The key sectors that are likely to be affected by an increase in energy efficiency are insulation, flat glass and construction sector SMEs. The size of each sector will depend on the demand for their products, which is in turn dependent on the policies implemented. In estimating the future size of the sectors, the key assumptions are those made on the renovation market growth rate for each scenario.

Under the most optimistic assumption in S3, where the renovation market doubles by 2030 (to €167-250bn), the insulation industry market also doubles (to €15bn) and the flat glass industry market increases by 40% (to €15.1bn) The main opportunities for SMEs lie in the construction industry, for example in installing insulation and undertaking other building renovations.

The value of buildings

It is also difficult to assess the impact of energy efficiency on the value of buildings, because both sale and rental prices are influenced by a multitude of endogenous and exogenous factors (in particular the influence of the location in the value of real estate), as well as market conditions and general supply-demand balance.

There is, however, evidence that suggests that better energy performing buildings show shorter vacancy periods, have a lower loss of rental income due to changing tenants and, as such, show a more positive operating impact for the owner. In the commercial sector, buildings that fail to keep up with technological advances, including widespread advances in energy efficiency, risk becoming obsolete, especially in unfavourable market conditions (such as periods of low or negative economic growth). The analysis, based on the findings of a literature review, shows that better performing buildings can attract an increased sale value of between +5.2% and +35% in the commercial sector and between no change and +14% in the residential sector. The corresponding increases in rental values are +2.5% to +11.8% and +1.4% to +5.2% for commercial and residential properties respectively.

1.3 Social impacts

Health

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 level of investment: greater savings are derived from greater levels of investment. The benefits also accumulate over time. The cost savings related to healthcare costs, mortality and morbidity range from €24m pa in S1 to €925.9m pa in S3 over 2020-2030.

The absolute values of productivity gains are not as significant as the other health-related cost savings, but are nevertheless considerable at the EU28 level. The estimated productivity gains for the EU28 range from €53.4m to €88.9m pa (S3) in 2020-2030.

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.

The number of households that may be lifted from energy poverty (based on each indicator above) across the EU lies between 194,000 and 310,000 (LOW impact scenario/scenario S1) and between 5.17m and 8.26m (HIGH impact scenario/scenario S3), depending on the energy poverty indicator considered and, crucially, the degree to which policy is targeted towards fuel-poor households.

1.4 Environmental impacts

Most of the changes in final energy demand are in the buildings sector, which is to be expected considering the focus of all three scenarios on energy efficiency improvements in buildings. The changes in energy consumption in other sectors are the result of indirect impacts (e.g. rebound effects).

Both the reductions in final energy consumption for buildings and for the whole economy are driven by the level of investment in energy efficiency in the different scenarios. The impact on final energy consumption by buildings in the EU28 ranges from -0.7% in S1 to -14.8% in S3, while for the whole economy the range is from -0.4% in S1 to -6.9% in S3. Even when rebound effects and the energy consumption required to produce energy efficient equipment and materials are taken into consideration, all scenarios show a reduction in final energy consumption, although the magnitude of this reduction varies.

Both CO_2 and GHG emissions decrease in all scenarios. Again, the magnitude of the impact is driven by the level of investment and energy savings, with the change in CO_2 emissions in the EU28 ranging from -0.5% in S1 to -7.8% in S3. The change in GHG emissions ranges from -0.4% in S1 to -6.0% in S3.

The demand for materials in the EU28 increases due to higher buildings investment, as well as rebound effects from higher rates of economic activity. As a result, material consumption is higher in S3 than in S1 and S2. It is worth noting, however, that most of the increase in material consumption relates only to the initial investment that is being made. Once the investment is completed, material consumption will return close to baseline values.

Both water consumption and land use for the power sector in the EU28 are expected to decline in S2 and S3, with the impacts of S1 on both land use and water consumption being negligible. The impact on both water and land use is greatest in the high investment scenario (S3), which shows an estimated reduction of 2.8% for water consumption and 4.5% for land use by the power sector in the EU28.

However, there is quite a wide range of uncertainty around these results, because a substantial share of the land use depends on local geography and the technologies used. As such, these results should be treated with caution.

1.5 Conclusions

This report attempts to quantify many of the ‘multiple’ benefits of energy efficiency that have been identified by the IEA. 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 when assessing a programme of energy efficiency in buildings. These benefits cover all three of the economic, social and environmental spheres.

The results in this report thus support the development of a large-scale programme of investment in energy efficiency across Europe’s stock of buildings. However, the report also finds that to realise all the potential benefits of energy efficiency, carefully designed policy will be required. Most notably, to reduce energy poverty to the maximum extent possible, policies should be tailored to target fuel-poor households. In summary, the challenges for policy makers relate to an efficient implementation of an enhanced EPBD and ensuring proper enforcement.

Part I. Introduction

2 Introduction to the project

2.1 Overview

This document presents the final report for:

Study for a comprehensive assessment of the macroeconomic and other benefits of Energy Efficiency, with a particular focus on buildings

The study team was led by Cambridge Econometrics and also included ECN, EY, SQ Consult and the Wuppertal Institut.

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.

2.2 Background to the study: The EPBD and energy efficiency in buildings

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[1], hereafter EED) and the recent 2030 framework for climate and energy policies have provided targets for reducing energy consumption for the years 2020 and 2030.

There are several directives that aim to assist the EU with meeting these targets. The most prominent of these are the EED and the Energy Performance of Buildings Directive (2010/31/EU, hereafter EPBD). The EED has defined a set of binding and non-binding measures to help achieving the 2020 energy efficiency target and the EPBD sets targets and energy performance requirements for the building sector. Buildings account for 40% of energy consumption in the EU and have been identified as one of the areas where substantial energy savings can be made in a cost-effective manner, especially as the age and quality of the buildings stock varies substantially across Europe.

The EPBD was introduced in its current form in the EU in 2010, as an update to a 2002 Directive which introduced rules on energy performance of buildings in the EU, to try to deliver improved energy efficiency in buildings. Its key implementing measures include the introduction of energy performance certificates, the requirement that all new buildings must be near zero energy by 2020 (public buildings by the end of 2018), energy performance requirements for new buildings and major renovation of buildings, and inspection schemes for heating and air conditioning systems. This important piece of legislation at EU level was supplemented by parts of the EED, which also recognised buildings as a key area of potential energy savings. The EED requires that Member States define national building renovation strategies as part of their National Energy Efficiency Action Plans (NEEAPs), and to renovate at least 3% of the total floor area of buildings owned and occupied by central government each year.

There have been several assessments of the EPBD led by the European Commission, including the work most recent report from Concerted Action EPBD III and a recent Ecofys[2] report. Many of these assessments have highlighted that there remain a number of gaps in the coverage of the EPBD, suggesting that a further recast of the Directive

[1] 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

[2] Ecofys (2015), Public Consultation on the Evaluation of the EPBD.

may be required, in order that energy efficiency policy meets the strict targets that have been set. The European Commission has taken measures to monitor how Member States implement the current EPBD, up to and including sending reasoned opinions to a number of Member States, and indeed taking one Member State to court, suggesting that the current legislation is not without issues.

Other relevant legislation at European level includes the Ecodesign and Energy Labelling framework directives (2009/125/EC and 2010/30/EU). These cover a range of appliances used by households and commercial organisations, setting standards in each case. These directives have therefore also had an impact on energy consumption (particularly of electricity) in buildings across the EU.

2.3 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 targets. In many cases, energy efficiency measures have been shown to be 'negative cost', meaning that it would be economically advantageous to implement them.

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 seven impact areas:

- economy and labour market
- health and well-being
- environmental impact
- social aspects
- public budgets
- industrial competitiveness
- the value of buildings

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

3 Introduction to this report

The analysis in this report estimates the positive and negative impacts of improvements in energy efficiency in buildings that could come about through a recast of the EPBD. The specific policy scenarios are described in Part II and the approach that we used to assess each of the seven 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 our methodology.

Part II. Scenarios

1 Introduction

In this report four different scenarios are assessed. These include a reference case and three policy scenarios. The reference case is described as the 'no-change' option and is discussed further in the next section. The following two sections then introduce and describe the wide range of policy 'measures' that were considered and the three policy 'options' that included a selection of the different measures. These three policy options form the scenarios that are assessed later in this report.

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

2 No-change option

The no-change option means no additional measures beyond the existing ones, including continued implementation of the current EPBD and related regulatory and non-regulatory instruments. This approach could be supported by measures that could maximise the impact of the EPBD by encouraging its full transposition.

The European Commission monitors how Member States implement the current EPBD. This monitoring has had a positive impact on the adoption of national legislation and now most Member States declare complete transposition. The Commission is also undertaking a number of additional activities to support the correct transposition of the EPBD, for example by funding projects on information exchange and research on best practices, and the development of standards.

A study on EPBD compliance[3] has helped to raise attention within Member States of the missed opportunities linked to the lack of compliance. It is noted that sharing of good practice, stimulated by exchange platforms such as the concerted action, could help in reducing the compliance gap. It is assumed that, under the no-change option, this work would continue.

The Commission will also keep implementing the Directive, in particular with respect to the implementation of the common EU voluntary certification scheme (Article 11(9) of the EPBD) in order to provide relevant information for market participants in the non-residential sector with a reliable comparison tool of buildings' energy use across borders.

Other EU initiatives in relation to buildings (following e.g. the communication on sustainable buildings or the construction sector) are unchanged in both the no-change reference case and the policy scenarios. Related legislation, including the EED and Ecodesign Directive, are expected to continue in their current form.

3 The policy measures

A wide range of policy alternatives was considered in the scenarios. The most relevant ones are described briefly below and are discussed in more detail in the final Impact Assessment (from which these descriptions are taken). Both regulatory and non-regulatory measures are considered, and action at different spatial levels is also considered: EU, national, regional and local.

The following measures build upon or amend the current EPBD and are linked explicitly to a series of drivers for policy development in the Impact Assessment.

[3] European Commission (2015), Energy Performance of Buildings Directive (EPBD) Compliance Study, available at https://ec.europa.eu/energy/sites/ener/files/documents/MJ-04-15-968-EN-N.pdf

Simplification measures

To remove outdated or inefficient provisions identified during the implementation of the current Directive, two simplification measures are identified on the basis of the evaluation report and the EPBD Concerted Action:

Remove the mandatory study of the feasibility of high-efficiency alternative systems

The Directive would be amended to remove the need to document and verify the assessment of alternative heating and cooling systems preceding the construction of new buildings.

This measure will address the concern of Member States who identified this provision as creating an unnecessary burden.

Simplify the provision on regular inspections and ensure that the objective of the inspections is achieved more effectively

The Directive would be amended to simplify and modernise the provisions on inspections of heating and air-conditioning systems. For complex buildings (e.g. non-residential buildings), the commissioning of these systems (current practice) and the proposed support to building automation systems would ensure good performance levels and signal the need for maintenance intervention. For less complex buildings (e.g. single family houses) safety inspections (e.g. gas, electricity, boilers, etc.) could be used to provide information on the efficiency of existing technical systems and perform effective maintenance works (as suggested in the Heating and Cooling Strategy). This measure would address the fact that inspections of the energy efficiency of heating and cooling systems tend to be burdensome, difficult to implement, and partially duplicating EPC's recommendations. More effective approaches to regular inspections could be used instead and would ensure that building performance in operation is maintained and/or improved.

Measure 1: Accelerate the decarbonisation of buildings by significantly increasing renovation rates

This measure addresses underlying drivers to the problem of low renovation rates (split incentives, long lifetime of buildings); and identified gaps in the existing Directive (a stronger market signal for the renovation of existing buildings is missing). It includes two sub-measures:

- 1A. Set milestones for the decarbonisation of the building stock by 2050
- 1B. Oblige the renovation of buildings to reach a given standard before transactions

Measure 2: Fine tune the implementation of minimum energy performance requirements

This measure addresses findings from the evaluation on remaining barriers not sufficiently addressed through the implementation of the existing Directive, as well as the underlying drivers (slow uptake of new minimum requirements in a sector as conservative as the buildings sector, national implementation problems).

It considers two alternative sub-measures:

- 2A. Improve transparency of calculation methodologies and provide further clarification on the cost-optimal setting of minimum performance requirements
- 2B. Change the framework for cost-optimal calculations by including additional co-benefits and going beyond cost-optimality when setting minimum requirements

Measure 3: Modernisation using smart technologies and simplification of outdated provisions for the benefit of citizens

This measure tackles the streamlining and modernisation of outdated provisions, simplifying them and adapting them to technical developments. It therefore tackles the inefficiency of certain components of the EPBD as well as the need to modernise the Directive to facilitate the integration of the EU building stock into the smart energy system of the future (and underlying drivers preventing the integration of smarter technologies in buildings and support to electro-mobility). It includes three complementary sub-measures:

- 3A. Document the initial performance of technical building systems and maintain their operational performance over time
- 3B. Framework for the introduction of a smart-readiness indicator
- 3C. Support to electro-mobility

Measure 4: Enhance financial support and information to users through reinforced energy performance certificates

This measure tackles some of the drivers behind slow renovation rates by reinforcing EPCs and improving the efficiency of financing schemes; it also tackles drivers behind weak enforcement at national level, facilitating compliance checking. It considers two sub-measures:

- 4A. Reinforced quality of energy performance certificates to enhance financial support
- 4B. Harmonised template for certificates

4 The three policy options

4.1 Overview

The policy measures described above are packaged into three broader sets of policy options, which form the basis for the analysis in this report. Table 2.1 summarises the options and they are described in more detail below. Further information is available in the Impact Assessment. The next section discusses how these options were assessed in the modelling.

Table II.1 The three policy options

Measures	Option 0: No-change option	Option I: Enhanced implementation and soft law, including clarification and simplification of the current Directive	Option II: Enhanced implementation, including targeted amendments for strengthening of current provisions	Option III: Enhanced implementation and increased harmonization, while introducing substantial changes
Simplification measures			S1 S2	
Measure 1: Accelerate the decarbonisation of buildings by significantly increasing renovation rates			1A	1A 1B
Measure 2: Fine tune the implementation of minimum energy performance requirements		2A	2A	2A 2B
Measure 3: Modernisation using smart technologies and simplification of outdated provisions for the benefit of citizens			3A* 3B** 3C**	3A 3B 3C
Measure 4: Enhance financial support and information to users through reinforced energy performance certificates			4A	4A 4B

Source(s): European Commission

* This measure includes a simplification component addressing outdated provisions in Articles 6, 7, 14, 15 and 16 of the current Directive

** These two measures modernise current provisions in light of technical development and the need to support smart technologies and electro-mobility

Option I: Enhanced implementation and soft law, including clarification and simplification of the current Directive

This option considers the set of proposals that enhance the implementation of the existing regulatory framework without amending the EPBD. It builds on the work being done at EU, national and regional levels to actively implement the Directive. Compared with the no-change option, it goes one step further in proposing soft law and guidance that could improve the implementation and enforcement of the legislation and the use of voluntary measures which have not yet been explored by Member States.

This option proposes a way to intensify implementation of the current legislation through:

- Guidance for clarifying the calculation of the energy performance of buildings and the calculations and implementation of the cost-optimal levels of minimum requirements (Measure 2A).

These form scenario S1.

Option II: Enhanced implementation, including targeted amendments for strengthening current provisions

This option includes the set of proposals presented above that go beyond the proposal of Option I and require targeted amendments of the current EPBD to address the problem drivers more extensively:

- Set milestones for the decarbonisation of the building stock by 2050 (Measure 1A).
- Clarify provisions on calculation methodologies and on implementation of cost-optimal levels of minimum performance requirements (Measure 2A).
- Document the initial performance of technical building systems and maintain their operational performance over time (Measure 3A).
- Framework for the introduction of a smartness indicator (Measure 3B).
- Support to electro-mobility (Measure 3C).
- Reinforced quality of energy performance certificates quality to enhance the financial support (Measure 4A).

Option II also addresses drivers associated with regulatory failures by:

- Improving the effectiveness of EPCs with measures that strengthen, modernise and further integrate the EPC schemes within a framework that aids compliance checking and effectiveness of financial support (Measure 4A).
- Simplifying the EPBD with measures that modernise the provisions related to regular inspections with ICT and repeal of the provisions related to mandatory documented feasibility studies for efficient systems (Measure 3A).

These form scenario S2.

Option III: Enhanced implementation and increased harmonisation, while introducing substantial changes in the legal text

This policy option includes the most ambitious measures explored, some of which go beyond the current intervention logic of EPBD.

Option III further addresses drivers associated to market failures by:

- Having a more direct market action to boost the activity and investments. In requiring buildings to reach a given standard before they are sold or rented, the intervention goes beyond the logic of setting minimum energy performance standards in building codes (Measure 1B).

Option III also further addresses drivers associated with regulatory failures by harmonising aspects so far left to subsidiarity:

- Additional sustainability co-benefits in the cost-optimal calculation framework (Measure 2B).
- New targeted ambition for new buildings in 2030, beyond cost-optimality and including the mandatory setting for minimum requirements for the indoor environment (Measure 2B).
- Further harmonisation of the EPCs (Measure 4B).

These form scenario S3.

Part III. Methodological Approach

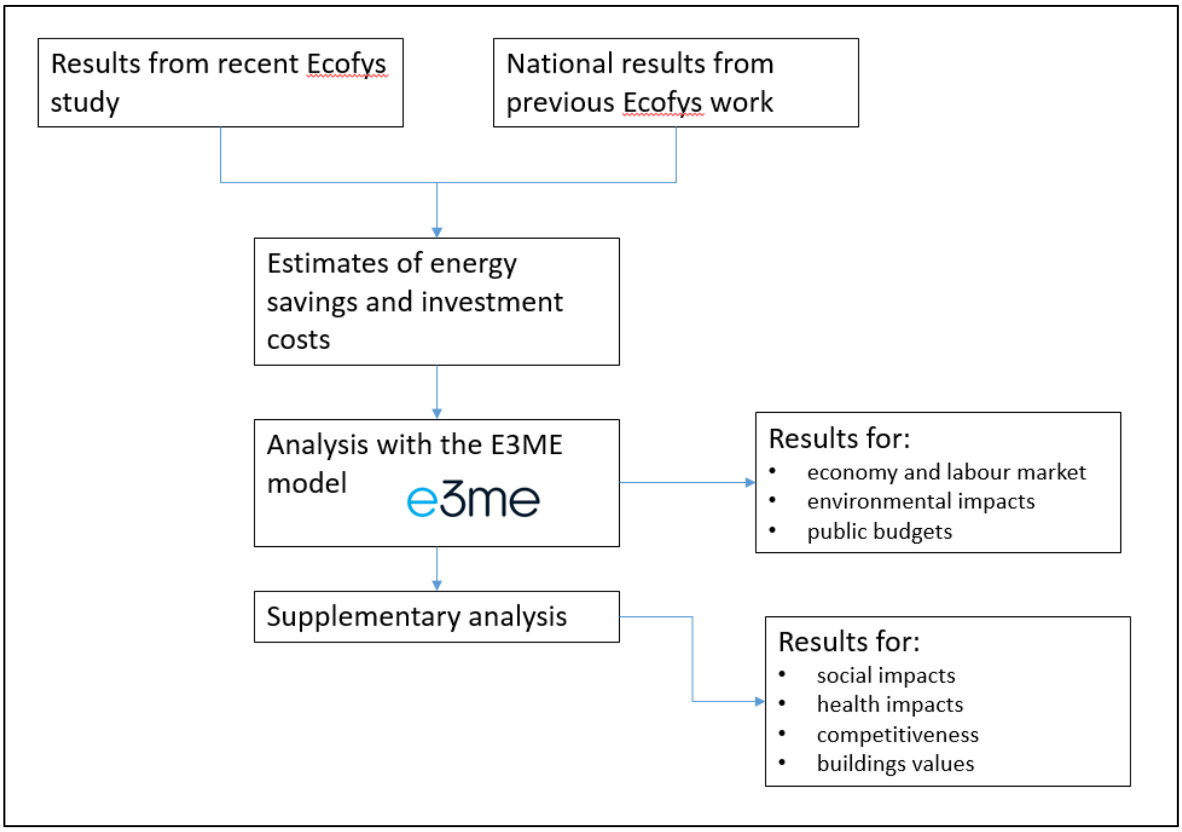
1 Introduction

This chapter describes the approach that was used to estimate quantitatively the impacts of each policy option, covering each of the seven impact areas. Before getting to the impact areas, however, the next section describes how the levels of energy savings were estimated at Member State level.

The E3ME macroeconomic model plays a central role in the analysis and is described in Appendix A. However, the model itself is not capable of producing all the key indicators across the seven impact areas, and so supplementary analysis is required using a range of alternative approaches. Section 4 onwards in this chapter describes the approaches that were applied during the study.

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

Figure III.1 Summary of main steps in the analysis



2 Estimating the energy savings in the scenarios

2.1 Results from previous DG ENER work

The results from a separate study carried out by Ecofys[4] on behalf of DG ENER have provided key inputs to the analysis presented in this report. The key inputs required are estimates of the potential energy savings under different scenarios and the investment costs that would be needed to bring about these savings.

[4] Boermans, T, Grözinger, J, von Manteuffel, B, Surmeli-Anac, N, John, A (Ecofys) Leutgöb, K and Bachner, D (e7) (2015) 'Assessment of cost optimal calculations in the context of the EPBD' (ENER/C3/2013-414) Final report. 19 November 2015, Project number: BUIDE13705.

The following inputs were received on 15th April 2016:

- EU28 final energy demand for heating (+breakdown by fuels), hot water, cooling, auxiliary and lighting, 2013-2030 in TWh pa
- Investment costs (three types: Building envelope, HVAC-Systems, financing costs), 2013-2030 in €bn

It should be noted that the E3ME model calculates its own energy costs and CO_2 emissions from the energy inputs so for the present study only figures for energy demand were used. The figures for energy demand are converted to energy savings by taking the difference from the reference case.

Further processing

For each of the three policy scenarios, further processing was required. The first step was to allocate the energy savings to sectors, on the following basis, using floor area information from the Ecofys results (the acronyms refer to the categories in the Ecofys modelling):

- residential (SFH, SMFH, LMFH)
- commercial (OFB, TRB, EDB, TOB, HEB)
- industrial (ONB)

The second step was to allocate the energy savings to the main energy carriers in the E3ME model (coal, oil, gas, electricity, heat), again building on the information provided from the Ecofys study. Then in Step 3 the energy savings at European level must be allocated to each Member State; this uses analysis carried out by ECN (see below).

Finally, some minor conversions were carried out to ensure overall consistency:

- convert terawatt-hours (TWh) to thousand tonnes of oil equivalent (toe)
- convert investment costs to a constant price base and allocate to Member States in line with share of energy savings
- correct for small negative numbers in the investment figures at the start of the projection period, replacing with zeros

The final result of this process is a set of input data that are appropriate for use in the E3ME model.

The additional analysis carried out by ECN: allocating energy savings to Member States

Although the total energy savings in the EU are determined by the approach outlined above, a supplementary analysis was required to allocate the energy savings to Member States. This is described here.

Estimates of energy efficiency improvements at national level are based on another previous report produced by Ecofys (Boermans et al, 2015). This report studied the gap between the currently implemented energy performance standards and performance standards based on the most cost-effective approach. It is assumed that a policy shift of strengthened enforcement of the EPBD via monitoring and quality control would lead to the adoption of the more cost-effective standards. A more stringent application of the cost-effective standards can lead to greater energy savings where adopted. The size of the savings depends on the size of the initial gap between actual and potential energy consumption, the degree that the gap in standards is closed, and the time taken to close the gap.

Energy savings are calculated using the gaps in standards produced in Boermans et al (2015). The gap values have been converted to figures for the relative reduction in energy consumption. Energy consumption levels are set at those used in the study carried out by the Fraunhofer Group (Braungardt et al, 2014), henceforth shortened to

FhG, which formed the basis of determining EU energy-saving targets. The calculations are expressed as savings in millions of tons of oil equivalent (mtoe).

Calculations begin using the values for the FhG consumption levels and disaggregate new and existing buildings. Total energy consumption will be lower in new dwellings and buildings under the cost-effective energy performance standards. The energy savings are therefore equal to the FhG energy consumption levels multiplied by the relative reduction in energy consumption.

For existing buildings and dwellings, the savings are further dependent on the number of buildings that can be renovated in the following years. For the purpose of the calculation, it is assumed that 3% of the total building stock is renovated each year, implying 15% of the stock being renovated in 2020 and 45% of the stock being renovated by 2030. This assumption is based on the one hand on the accepted yearly percentage mentioned under EED article 5, and on the other hand the goals for 2050, which imply an almost completely (95%) renovated stock by 2050. Energy savings are calculated as FhG energy consumption multiplied by the renovated stock fraction multiplied by the relative reduction in energy consumption due to improved energy standards. In the case of office buildings, the savings are equal to that for existing tertiary buildings. The values for both new and existing dwellings and buildings are compiled into a composite savings figure.

This calculation provides estimates of energy savings in each Member State. The total is then scaled to be consistent with the figures for the EU as a whole that were estimated by Ecofys.

3 Economy and labour market

3.1 Overview of the links in E3ME

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.

Further information about E3ME is provided in Appendix A, including a flow chart of the main interactions within the model and how energy efficiency is modelled. Essentially, however, the key relationships are:

- An increase in investment will boost rates of economic activity and create jobs…
- … but 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 national accounting system, allowing quantification of the impacts. As E3ME includes equation sets for labour demand, supply and wage rates, labour market impacts are included as standard in the model results.

3.2 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 to 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. Although this is not a standard output from the E3ME model, it may be inferred easily from the model results. A reduction in energy imports for one country means that it is less exposed to changes in international commodity prices or geopolitical movements.

4 Health and well-being

4.1 Key issues and scope of work

Properly designed actions for improving building energy performance can have major co-benefits for public health, although there are risks involved with the possibility of poorly designed interventions leading to unintended consequences, such as health problems related to ventilation reduction. Most energy efficiency measures will improve indoor temperatures and, by choosing renovation measures that also improve indoor air quality, health benefits can be obtained through fewer incidences of disease, reduced mortality, improved worker productivity and improved overall quality of life. While most of these benefits accrue to society in general, public budgets may also be improved through reduced healthcare expenses, fewer sick days and increased tax revenues resulting from increased economic production. This is discussed further in Section III.7.

Europeans spend on average over 90% of their time indoors[5] – at home, in the office, in school, in kindergarten, etc. Concentrations of indoor pollutants are therefore an important factor in air pollution exposure and associated health effects.

To measure and quantify the major positive and negative impacts of 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

4.2 Literature review and data sources

The results in this study are based on the available literature on the health benefits of energy efficiency and the impacts in terms of physical indicators (e.g. indoor temperature, indoor 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 B.

[5] See references here: http://europa.eu/rapid/press-release_IP-03-1278_en.htm

4.3 Detailed approach

Calculation of healthcare cost savings and mortality and morbidity cost savings

For each scenario, given the energy savings calculated at Member State level, we estimate the total square metres of buildings renovated in each country. The calculation is based on the difference between the mean energy consumption level at EU level of 250 kWh/m^2-yr, and the theoretical energy consumption level of renovated buildings (0 kWh/m^2-yr). Using the total area of residential and non-residential buildings renovated each year, we estimate the cost savings by multiplying the total square metres renovated by the ratios drawn from the literature review.

As described in Appendix B, previous studies have shown that total morbidity & mortality costs and healthcare costs can be estimated at €139bn for the EU28, for a total of 25bn m^2 of buildings. The mean cost saving per renovated building can be estimated at €5.60/m^2, and we assume that the costs are divided by two in renovated buildings (a cost saving of €2.80 per renovated m^2), given that the main health risks are reduced by more than half in the most representative illness cases related to cold, damp and low ventilation[6].

Calculation of productivity gains related to better indoor air quality

Using the total area of non-residential buildings renovated each year, we estimate the productivity gains by multiplying the total square meters renovated by the ratios drawn from the literature review (cost savings between €0.60 and €1.00 per m^2 renovated). This leads to a minimum and a maximum value for the productivity gains.

5 Environmental impacts

5.1 Background

Energy efficiency improvements can positively affect the environment in several quite different respects. Focusing our attention on the EU's Sustainable Development Indicators (SDIs), 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 gasses.
- Sustainable, consumption and production (SCP) - This category comprises items such as the emission of local air pollutants and material consumption. Energy efficiency could potentially reduce the level of emissions of sulphur, particulates and other pollutants that are damaging to human health[7]. Energy Efficiency measures may also imply changes in Domestic Material Consumption (DMC) when measures such as building retrofitting 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.

[6] See the detailed literature review in Appendix B (Fraunhofer, 2014, Towards an Identification of European indoor environments' impact on health and performance; UCL institute of Health Equity, 2011, The health impacts of cold homes and fuel poverty).

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

5.2 Output indicators for energy consumption and emissions

The assessment of energy efficiency measures on the themes discussed above is carried out using the E3ME model. In terms of energy and climate, the main quantitative output indicators that E3ME can provide are listed below:

- final energy consumption (total and by the buildings sector)
- primary consumption of fossil fuels
- CO_2 and greenhouse gas emissions

The direct changes are largely given by the energy savings that are estimated, but the results from the modelling exercise also include rebound effects. For this the energy demand equations in the model are important, in particular the relationship between levels of economic activity and energy consumption – in E3ME it is not assumed that this relationship is one-to-one, i.e. there may be economies of scale in production, which is determined by the econometric equation sets. The model also accounts for the energy consumption required to produce energy-efficient equipment and materials.

Total final energy consumption is disaggregated by carrier using a further set of econometric equations. This allows for fuel switching, although limited fuel switching is expected in the energy efficiency scenarios. Results for CO_2 and other emissions are derived using fixed coefficients that are calibrated using the last year of available data. The main data source in the model is the EDGAR database[8].

The power generation submodel

One important aspect of the modelling is the choice of power mix used to generate electricity. If energy efficiency reduces electricity demand then the choice of plant that is closed (or not built in the first place) is important for determining both environmental results (e.g. CO_2 emissions) but also some of the economic results (e.g. through international trade in fuels). The FTT power generation sub-model in E3ME (Mercure, 2012) uses a behavioural approach to make these estimates; the choice of technology used depends partly on costs but also on how well the technology is already established (following previous literature on technology diffusion). Thus, reductions in generation capacity could lead to lower gas or coal consumption, but could also lead to reduced renewables deployment.

5.3 Material consumption

The E3ME model includes estimates of the consumption of raw materials (biomass and non-energy minerals). The structure of the materials sub-model is very similar to that of the energy modelling; there is a set of demand equations with feedbacks to the primary producers (for materials these are agriculture, forestry and non-energy mining).

In the materials demand equations, the dependent model variable is DMI (Direct Material Input) although this is translated to DMC for presentation of results. DMC is the indicator used in the EU's Resource Efficiency Roadmap.

Demand for materials is determined by rates of economic production, price and technology. Higher rates of production will increase demand (although not necessarily linearly, economies of scale are possible), prices will reduce demand and technology will reduce demand. Demand for seven materials types is estimated for around 20 different sectors.

5.4 Land and water requirements

Land and water requirements are the only indicators in this section that are not estimated using the E3ME model. A supplementary calculation is performed here for the

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

power sector (impacts on other sectors should be very limited). However, it should be noted there is quite a wide range of uncertainty around these results because a substantial share of the demands depends on local geography and the technologies used. As such, land use coefficients in particular should be treated carefully as they represent a single example or broad average of a certain type of energy user's land requirements.

6 Social aspects

Table III.1 gives an overview on the types of direct social impacts that could be assessed (taken from the literature review in Appendix B). In this study we focus on energy poverty. However, we also cover some of the indirect impacts from enhanced energy efficiency, using the results from the E3ME model. Unemployment and income distribution are covered in this way.

Table III.1 Overview of direct social impact assessment approaches

Social impact	Analytical approach	Details
Energy poverty	Quantitative	Analysis of different energy poverty indicators (EU-SILC data)
Social inclusion	Qualitative	
Green gentrification	Qualitative	

6.1 Energy poverty

The main issue regarding the quantitative assessment of the prevalence of energy poverty (and the impact of policies in addressing it) is the lack of a common definition within the EU[9] and the consequential lack of coordinated data collection efforts (apart from very basic data within the EU-SILC database). In general, the debate about how to identify and measure energy poverty centres around two different approaches: an expenditure-based approach using actual or required fuel spend (e.g. Hills, 2012) or a consensual approach that utilises subjective indicators (Healy, 2002; Thomson and Snell, 2013). While there are merits from using either approach, harmonised micro data on household energy-related expenditure are not available for all EU Member States. Accordingly, in the present study we rely on the more subjective approach, using different proxy indicators of energy poverty to create a composite measure.

For this purpose, we use data from the EU-panel on "Social Income and Living Conditions" (EU-SILC). The EU-SILC is a longitudinal study that includes indicators on income, poverty, social exclusion and other living conditions for all EU Member States on a common methodological basis. It is administered by Eurostat (for more information see Eurostat, 2015[10]). We employ data from the waves 2004-13 for the analysis in this study. In total, the database includes 1,919,732 observations. We analyse energy poverty operationalised by the following indicators in EU-SILC:

- leaking roof, damp walls/floors/foundation, or rot in window frames or floors[11]

[9] Of the 28 Member States only three (UK, Ireland and France) have an official definition of fuel poverty or energy poverty, none of which are the same.
[10] http://ec.europa.eu/eurostat/web/income-and-living-conditions/overview
[11] The variable HH040 contains answers to the question "Do you have any of the following problems with your dwelling / accommodation? – a leaking roof – damp walls/floors/foundation – rot in window frames or floor" in the format yes/no.

- ability to keep home adequately warm[12]
- arrears on utility bills[13]

These indicators are deemed suitable to sufficiently capture the presence of energy poverty as they reflect different symptoms experienced or characteristics demonstrated by fuel poor households (EPEE, 2009) and have been used in prior research to assess the prevalence of energy poverty across the EU (Healy and Clinch, 2002; Thomson and Snell, 2013).

In order to facilitate interpretation of the results, we have slightly transformed the variables.

Table III.2 Variable transformations

Variable	EU-SILC code	Study code	Transformation
Presence of leaks, damp, rot	hh040	hh040	-
Ability to keep home adequately warm	hh050	hh050i	Recoded to NOT able to keep home adequately warm
Arrears on utility bills	hs021	hs021a	recoded to ANY arrears on utility bills (3-scale to yes/no)

For this study, we follow a two-step approach: 1) analysis of descriptive assessment of the three proxy indicators over time and 2) analysis of potential impacts of an EPBD recast on energy poverty.

6.2 Historical development of energy poverty levels

As a first step, we analyse 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 (see Figure III.2, Figure III.3 and Figure III.5).

[12] The variable HH050 contains answers to the question "Can your household afford to keep its home adequately warm?" in the format yes/no.

[13] The variable HS021 contains answers to the question "In the last twelve months, has the household been in arrears, i.e. has been unable to pay on time due to financial difficulties for utility bills (heating, electricity, gas, water, etc.) for the main dwelling?" in the format yes, once/yes, twice or more/no.

Figure III.2 Historical development of arrears on utility bills by residential building type and Member State

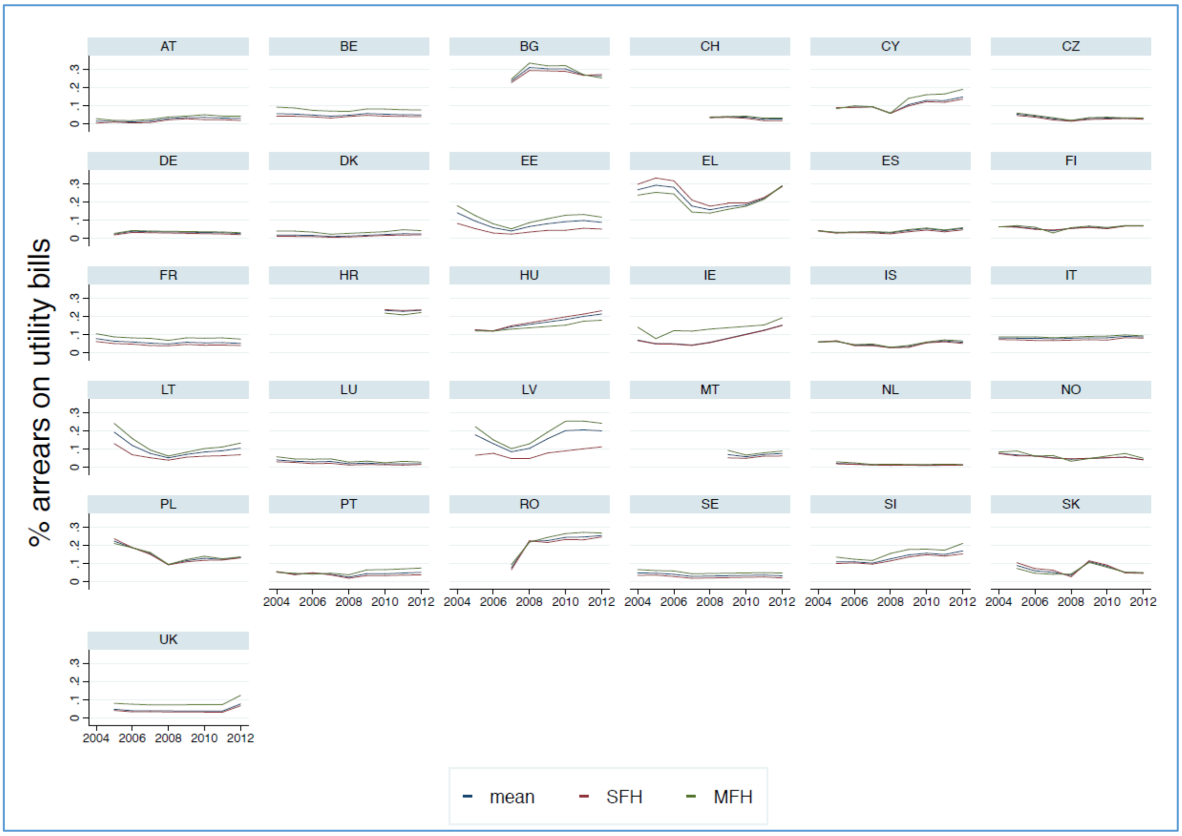


Figure III.3 Historical development of presence of leaks, damp, rot by residential building type and Member State

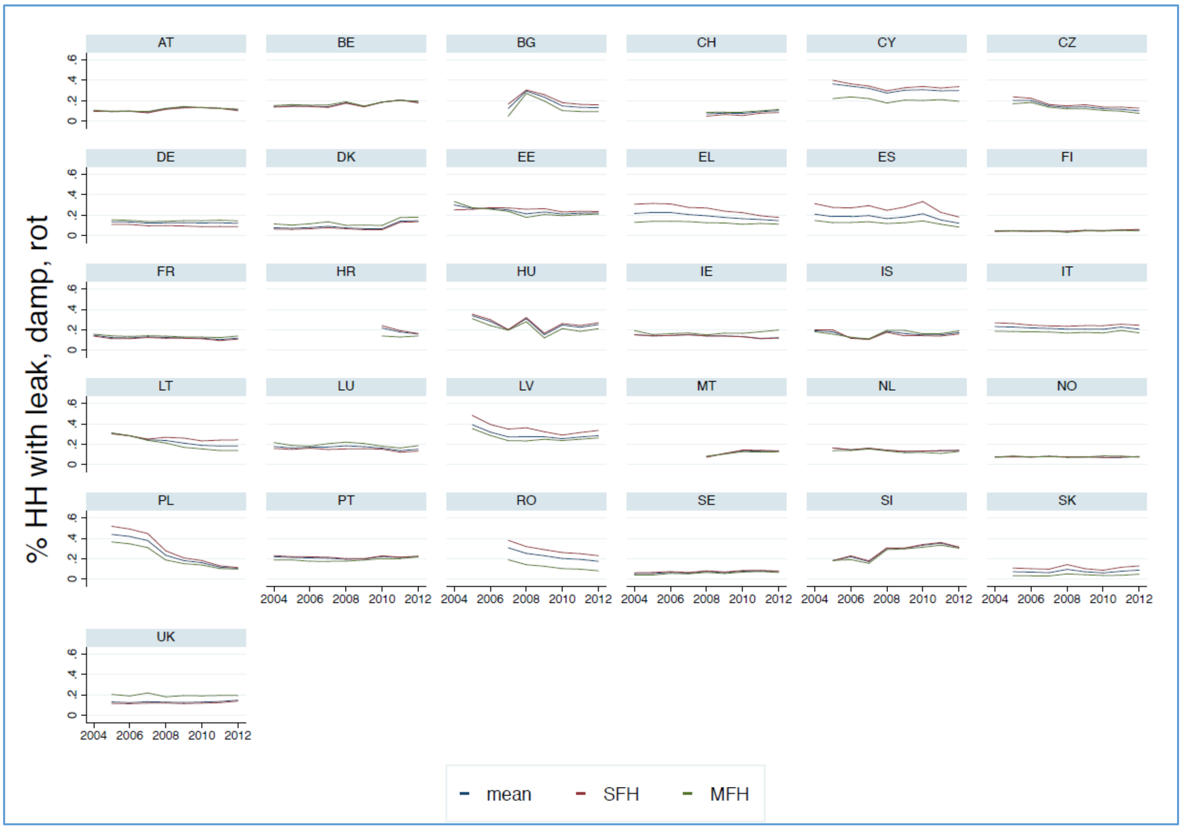
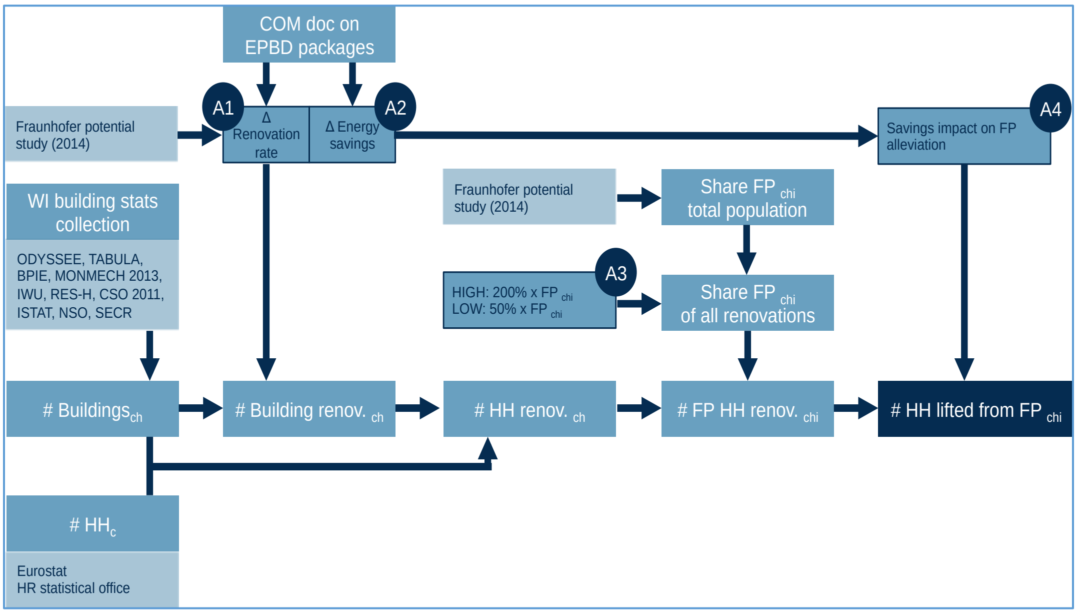


Figure III.5 Historical development of ability to keep home adequately warm by residential building type and Member State

Figure III.4 Framework for assessing EPBD effects



Note(s): light blue denotes external sources, A # denotes central assumptions.
Indices:
c = by country (EU)
h = by housing type (SFH/MFH)
i = by energy poverty indicator

Analysis of possible EPBD effects

In order to quantify the impact of the different scenarios in terms of energy poverty alleviation, we start from a trend projection based on historical energy poverty development by country. This approach accounts for the effect of existing policies including those targeting poverty and social inequality in general. We expect that with a positive trend (i.e. decreasing numbers of energy poor households), it gets increasingly difficult to reach households that have not yet been reached by the same policy instrument up to a certain point and that the trend thus slows down. For a negative trend (i.e. increasing numbers of energy poor households) we expect that it will be increasingly offset by the implementation of targeted policies flanking the EPBD recast transposition and therefore equally expect it to slow down. We therefore assume that the historical trend effect diminishes by 50% pa[14]. From the resulting projected number of households living in energy poverty according to the respective indicator, the policy impact is deducted.

The policy impact is quantified based on the share of energy poor households affected by additional renovation activity multiplied with an impact factor reflecting uncertainties with regards to renovation depth, the degree to which the actually implemented policies target energy-poor households, as well as different levels of energy poverty among households not reflected by the binary indicators. Finally, the annual impact figures have been aggregated to reflect the total impact of the different scenarios by 2030.

[14] The share of households living in energy poverty for each year has been adjusted based on the results for the previous year including policy impact and overall trend.

Assumptions

Table III.3 Basic assumptions

Package	No-policy change	Scenario S1: Enhanced implementation and soft law, including clarification and simplification of the current Directive	Scenario S2: Enhanced implementation, including targeted amendments for strengthening current provisions	Scenario S3: Enhanced implementation and increased harmonization
A1: EPBD impact on annual renovation rate (% points)	**0**	**0.15**	**0.4**	**1.15**
A2: EPBD impact on annual additional savings in existing buildings (%)	**0**	**0.04**	**0.4**	**1.5**
A3: Share of energy-poor households affected by renovations (% relative to share of energy poor/total households per country) LOW–HIGH	**50–200**	**50–200**	**50–200**	**50–200**
A4: Impact of additional energy savings in existing buildings on energy poverty alleviation (% additional households)	**0**	**0.04**	**0.4**	**1.5**

A1: EPBD impact on renovation rate (in % points)

Impact on renovation rates are assumed 0% for no change, +0.15% for scenario S1, +0.4% for scenario S2 and 1.15% for scenario S3 (see Table III.3, based on information provided by the European Commission and the Fraunhofer ISI potential study, Braungardt et al. 2014).

A2: EPBD impact on additional energy savings (in %)

Additional annual energy savings in existing buildings as a result of policy implementation are assumed 0% for no change, 0.04% for scenario S1, 0.4% for scenario S2 and 1.5% for scenario S3, based on calculations by ECN.

A3: Share of fuel-poor households affected by renovations

The share of renovations implemented in buildings inhabited by energy-poor households is highly uncertain and depends strongly on the specific policy design, as well as its implementation. One proxy is the share of energy-poor households relative to the total number of households. We use a LOW to HIGH uncertainty corridor ranging from 50–200% of this proxy value by country and energy poverty indicator. These values assume that policy packages have either no, low or high specific sub-targets to address energy poverty, whereby in the first case still some collateral policy impact is assumed. This broad range also covers other uncertainties related to the policy implementation impact e.g. with regards to differing levels of energy poverty households' experiences, which are not reflected in the binary energy poverty indicators but will affect the impact in terms of number of households actually lifted from energy poverty.

A4: Impact of additional energy savings in existing buildings on energy poverty alleviation

Deeper renovations resulting in higher energy savings can be expected to have a positive impact on energy poverty alleviation. Accordingly, we assume that a 1% increase in additional energy savings (according to A2) results in a 1% increase of household numbers lifted from energy poverty.

6.3 Real disposable income

Impacts on real disposable income are available for each Member State at aggregate level and by income quintile from the E3ME modelling. These estimates make use of the Eurostat data on household expenditure patterns by the different income groups, and combine the data with the impacts on prices of each type of product defined in the data (further details are provided in the E3ME model manual).

6.4 Unemployment

Impacts on unemployment are available at Member State level from the E3ME modelling. Unemployment is modelled as the difference between labour supply and labour demand; supply would not be expected to change by much in the EPBD scenarios but there are likely to be impacts on labour demand (see Part III Section 3).

7 Public budgets

7.1 Background

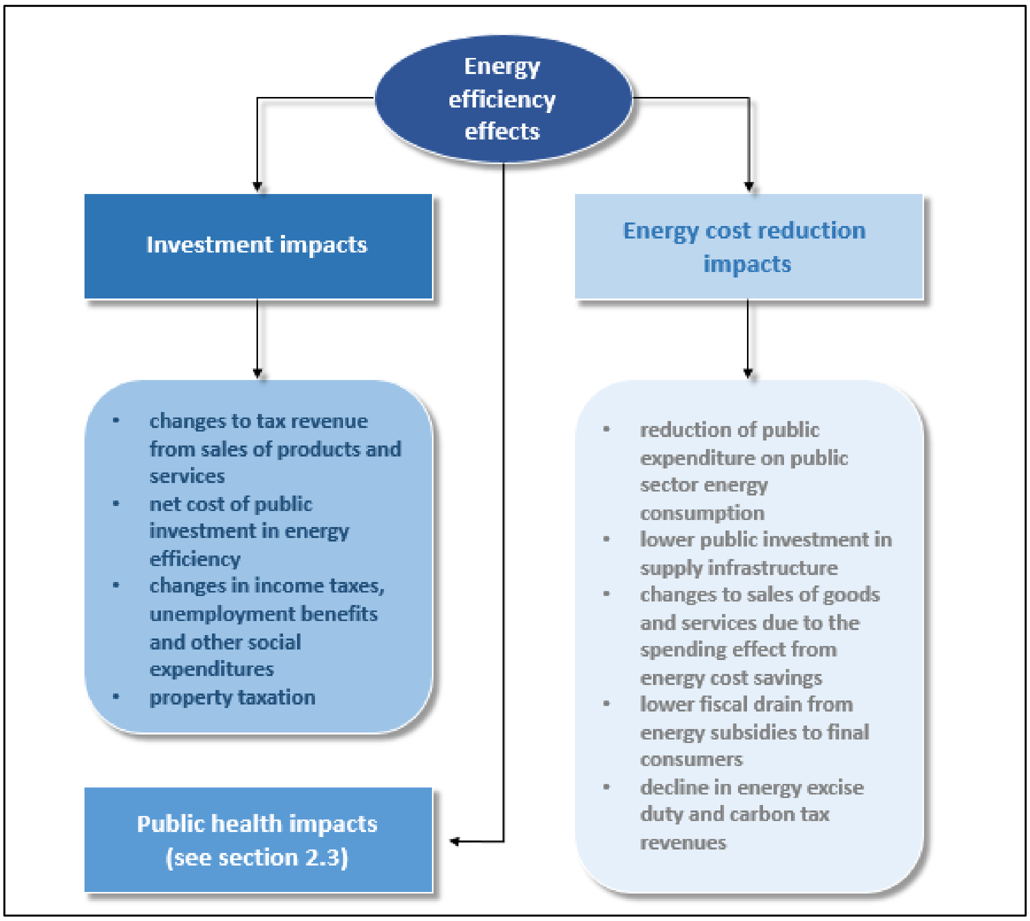
As has been discussed in the existing literature, the effects of energy efficiency on public budgets are complex (IEA, 2014). Quantifying some of the effects could be very difficult due to a high degree of uncertainty, e.g. impacts on public health budgets[15].

Other effects could be derived directly from the bottom-up estimate of energy savings, for example:

- public expenditure on energy saving equipment

[15] Warming homes could potentially affect public health budgets through two different channels, although the sign of the net impact remains unclear. Specifically, an increase in the life expectancy of a person who lives in a warmer home could be assumed. However, this effect could be translated into an increase in healthcare later in life for other reasons.

Figure III.6 The effects of energy efficiency on public budgets



- the value of energy savings to the public sector

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.6.

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

7.2 Our approach

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 analysis. However, the macro modelling cannot cover all relevant aspects and therefore the model results need to be extended. Our estimates therefore build on the results from E3ME, expanding the model results to take into account certain specific factors.

Table III.4 summarises the main factors that are accounted for in our estimates.

Table III.4 Factors in the budget calculations

Factor	Availability
Factors affecting 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
Property tax receipts	Not estimated
Other tax receipts	Not estimated
Factors affecting expenditures	
Public sector energy expenditure	Estimated off-model
Social benefits	Estimated using E3ME results
Public sector support	Assumed to be zero
Public health expenditure	Not included to avoid double counting
Public investment in energy efficiency	Estimated off-model
Other public expenditure	In the E3ME results

7.3 Tax revenues from E3ME

E3ME provides estimates 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 each scenario it is assumed that the tax rates remain unchanged, so direct tax revenues will vary according to levels of wages or profits. A single rate is used, meaning that, for example, movements between income tax bands will not be 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. The key question is whether the composition of jobs in the scenario affects 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 play a higher average tax rate. However, there is little evidence to suggest that the assumption of an unchanged tax rate is unreasonable, as the jobs that are being created directly from the energy efficiency measures are a mix of high and low skilled positions, while the indirect changes in employment affect the whole economy anyway.

Social contributions, both from employees and employers, are estimated in the same way based on fixed rates in relation to wages. The approach for corporation tax is also similar in that a fixed rate is applied, although this time it is in relation to company profits.

Indirect taxes

The treatment of VAT in E3ME is to assign a rate to each of the 43 product groups (as defined by Eurostat) in the model. Energy products are distinguished in the categories so, 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.

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. We have assumed no auctioning of ETS allowances outside the power sector.

Property taxes

As discussed in Part III Section 9, increased rates of energy efficiency could potentially lead to slightly higher buildings values. This would be expected to lead to higher tax receipts from taxes that are linked to building values, for example taxes paid by property owners, taxes linked to rental yields or taxes on buildings transactions.

However, it is difficult to quantify the impacts within this category. First, as discussed in Part III Section 9, it is highly uncertain what the impact on the value of buildings would be. The situation becomes even more complicated when attempting to estimate the impact of increased energy efficiency on tax receipts and it is necessary to make additional assumptions. For example, one of the main increases in tax receipts could be through inheritance taxes, but an increase in housing values could lead to pressure to raise inheritance tax thresholds.

Property taxes can be important for local government but the OECD reports that the UK is the only EU OECD country in which property taxes account for more than 10% of total revenues[16].

We therefore proceed with conservative assumptions and do not account for property taxes in the analysis. We are likely to be missing a contribution to public budgets from increased property tax receipts, but the impact is likely to be small, as:

- only some buildings are affected
- the increase in value would not be large
- property taxes make a relatively small share of total tax receipts

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 our assumptions are conservative.

7.4 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

[16] See https://data.oecd.org/tax/tax-on-property.htm

the model and, to avoid double counting, we do not account for induced changes in healthcare costs (see Section 4). The only impacts are therefore through changes in prices. For example, if inflation increases then public sector wage demands are also likely to increase.

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, while other payments are adjusted in line with rates of unemployment and labour market inactivity. 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 3). 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. However, in the scenarios this level of support is assumed to be zero.

7.5 Interaction with the economic results

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

In the analysis we have held all tax rates constant so that government receipts and expenditures change in line with wider economic conditions. Or to put it another way, changes in GDP growth rates will affect government incomes and expenditure, but we have not entered any changes to E3ME where changes in government budgets will affect the economic results. The economic and public budgets results presented in Part IV are thus additional.

8 Industrial competitiveness

Industrial competitiveness is a key issue for European policy makers. In this study we define competitiveness at the sectoral level, with a focus on international trade (see below).

Efficiency and competitiveness go hand in hand, and energy efficiency is no different. However, the focus in this study is on energy efficiency in buildings, which has little direct impact on competitiveness. Improved energy efficiency in dwellings does not have any direct effect on industrial competitiveness. Improved energy efficiency in commercial properties has only a limited impact on competitiveness as the cost reductions are small and are often focused on services companies that do not trade internationally.

Competitiveness effects may therefore be more likely in the sectors that produce energy efficient equipment. For example, if these firms 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.

8.1 Key issues and scope of work

European energy efficiency improvement objectives for buildings may have several effects on industrial competitiveness, among which four main topics have been identified:

- *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 production to meet increased domestic demand, while still producing competitive exports.
- *Global market shares of European Industries*: The macroeconomic effects of energy efficiency improvements go beyond GDP and employment growth. In particular, European energy-intensive industrial sectors that are particularly exposed to international competition, such as steel, pulp & paper, aluminium, cement, glass or chemicals may benefit from new opportunities arising from the shift in demand towards more efficient and higher quality building 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 example, innovation on energy-saving building materials, new efficient cooling and heating technologies, or even smart meters for energy-consumption regulation, will contribute to improving energy efficiency in buildings in Europe and in the rest of the world. European industries may be able to position themselves on disruptive innovation and gain competitiveness in fledgling markets.
- In addition, European economic competitiveness in general may be impacted by an *increase in productivity due to enhanced energy efficiency*: Workers' productivity is closely tied to their indoor work environment; thus, health effects of improved energy efficiency in buildings may result in better productivity and, ultimately, affect competitiveness. This aspect is of particular interest in the context of this study, since it combines health and well-being considerations with competitiveness issues. The approach for quantifying health effects is provided in Section 4.

8.2 Literature review and data sources

We analyse these four main aspects, based on a combination of interviews and the literature review. The interviews covered both exports and industrial actors and are described (with the literature review) in Appendix B.

8.3 Output indicators

The analysis of industrial competitiveness is both qualitative and quantitative. The analysis criteria are based on the questions asked during the interviews that are detailed above. Given that the majority of companies in the construction sector are SMEs, particular attention is given to their weaknesses and strengths regarding energy efficiency improvements.

Investment attractiveness of the European construction sector

The analysis of the increase in demand is based on the expert interviews. The objective is to provide both quantitative and qualitative outputs:

- Quantitative output: estimation of the demand volume towards 2030 and 2050 for construction, rehabilitation and renovation.
- Qualitative output (with supporting figures): given the quantitative results, we provide details on the main competitiveness issues linked to increased construction demand. These relate to human capital and training, upgrading and modernising production equipment and industry fragmentation.

Global market shares of European Industries

The output on this topic is also both qualitative and quantitative. In particular, we analyse the price and non-price competitiveness factors that most affect European industries, and the extent to which European energy efficiency policies on buildings may affect them.

Regarding disruptive technologies and innovation, we focus on the most promising sectors and technologies related to buildings and energy efficiency. It is possible to classify the different industry segments related to energy efficiency in buildings. An example (based on US data) is provided in Table III.5.

Table III.5 Jobs in key industry segments in the US, 2010

Activity segment	2010 jobs
Energy-saving building materials	161,896
HVAC and building control systems	73,600
Green architecture and construction services	56,190
Professional energy services	49,863
Appliances	36,608
Energy-saving consumer products (e.g. smart meters)	19,210
Lighting	14,298

Source: Brookings Institute (2011).

Given the employment potential and the relative exposure to international competition of these different activity segments, our analysis mostly focuses on energy-saving building materials (e.g. insulating materials), in so far as this represents more than one third of the total employment in the relevant key industry segments. For these activity segments, we aim to provide the following output indicators:

- Quantitative output: growth potential of the innovation markets for energy efficiency in buildings.
- Qualitative output (with supporting figures): competitive advantage of European industries (e.g. first-mover advantage in innovative solutions) compared to non-EU players.

Increase in productivity linked to energy efficiency

The assessment of the increase in labour productivity linked to energy efficiency is based on the analysis described in Section 4. As labour accounts for a large share of the total cost base of companies in most European sectors, changes in labour productivity could have a substantial impact on overall rates of productivity across Europe.

9 The value of buildings

Of the seven impact areas, the value of buildings is perhaps the most difficult of all to quantify impacts for. Most of the previous studies that have been carried out have relied on large-scale econometric estimates that require substantial data collection exercises. For practical reasons, they are often carried out at city level and none of the studies that we reviewed estimated impacts for more than one country.

The assessment of the impacts of energy efficiency on the value of buildings in this report is based on the findings of the literature review (see Appendix B). It essentially extrapolates the results from previous studies in order to make an estimate of impacts at European level. We assessed the relevance of each study that was reviewed, for example taking into account:

- the degree of energy savings
- geographical location
- type of building

We describe below some of the key studies. The results presented in Part IV Section 8 provide a range of possible impacts, based on these findings.

9.1 General findings

As stated by European Commission (2013), many actors expect the energy performance of buildings to affect the value of buildings as reduced energy consumption saves money and is also in line with changing social norms vis-à-vis the environment. The energy performance of buildings is also expected to affect the value of property for other reasons, such as providing a greater level of services (Ürge-Vorsatz et al., 2009). Information provision through energy performance labelling can help render the differences between otherwise comparable properties more readable, enabling market actors to act on this information where relevant (European Commission, 2013).

As RICS (2010) points out, many surveys show that there is some willingness to pay a premium for labelled buildings, but it is really only in the transaction data (whether rental or sales figures) that a positive link between energy performance certification of a property and its exchange value can be shown. RICS (2010) points out in some detail that market values are only one definition of value and that value in its wider sense can reflect a number of characteristics that can be said to provide value (monetary or psychological) to people. Although value may exist for one party, it will not always be fully reflected in transaction data.

European Commission (2013) provides an analysis of 22 papers in which hedonic regression has been applied to determine the relationship between energy performance certificates and exchange value of both residential and commercial real estate (both rental and sales values), in a period from 1995 to 2012. In 19 of the 22 reports, a positive relationship on either rental and/or sales value was identified: the labelled buildings (e.g. Energy Star or LEED) have an increased price compared to non-labelled buildings.

Within this research, the existing (scientific) literature regarding the relationship between energy efficiency labels and transaction prices (rental and sales values) is divided into residential real estate and commercial real estate. More detailed information regarding the impact of energy labels on the rental and/or sales values of real estate in each of these categories is provided below, based on European Commission (2013) and extended with additional literature.

9.2 Residential

Most relevant studies of residential real estate focus on the effect of improved energy efficiency on transaction prices. Based on the literature we reviewed, some conflicting results are observed. In some cases, studies focusing on the transaction prices of residential real estate show evidence that a positive relationship exists between energy efficiency labels and transaction prices. However, these studies do not investigate occupancy premiums and only three studies investigate rental premiums. Regarding these factors and the effect of improved energy efficiency on time to sale the existing literature is thin.

Two of the studies reviewed in our literature study focus on the price premium in Tokyo. Three studies focus on the US and one of the studies is conducted in Australia. The remaining studies focus on European countries.

9.3 Commercial buildings

Our review showed that there are more relevant studies available for the commercial segment of the property market than for residential buildings. However, the studies on commercial property were geographically much more homogeneous, with the majority focusing on the United States. One study covered the Netherlands and two studies covered the UK.

Of the studies examining the impact of energy efficiency on sales values, 90% found that the presence of energy/environmental labelling had a positive impact (European Commission, 2013). Only Fuerst and McAllister (2011) found that there was no evidence of an impact, either positive or negative. However, this study was based on appraised values and not on transaction values; appraised values are retrospective and lag transacted values: a weak signal from a (so far) weakly implemented EPC would be further weakened by using appraised values. One study (Eichholtz et al., 2010a) found evidence of a positive link for Energy Star but not for LEED.

Of the studies examining the impact on rental values, again 90% concluded that the presence of energy/environmental labelling also had a positive impact on the rental value and only one (Fuerst and McAllister, 2011) found that there was no evidence of an impact, either positive or negative.

Kok and Jennen (2012) and Fuerst and McAllister (2011) were the only studies identified that addressed the link between energy/environmental performance certification and the rental values of commercial property outside the United States. However, the two studies reported quite different findings.

The study of Fuerst and McAllister found no evidence that the EPC was yet having the kind of impact that would be expected. Based on a recent publication in the 'Financieel Dagblad' (Financial Newspaper in the Netherlands), dated 4 November 2015, Nils Kok (CEO GRESB and Professor of Real Estate at the University of Maastricht) quotes his research that the rents of 'energy efficient' buildings are on average approximately 6% higher than rental levels of buildings that are designated as 'inefficient'. It should be noted that Kok and Jennen's study (2012) is based on a much larger sample of properties and is based on transacted values. On this basis it may be considered as more robust.

We carried out a short interview with Mr. Kok and it appears, following his study, that tenants and investors increase the pressure on building owners to further invest in energy efficiency. For instance, the Dutch Government solely wants to rent energy efficient buildings and pension fund manager PGGM demands from companies in which it invests that the CO_2 emissions of the entire real estate portfolio need to be reduced by 50% in a five-year timespan. This finding is consistent with the conclusion of the real estate study that states: *The international real estate markets embraced sustainability and are aware of the fact that it can be a distinctive factor.*

The finding applies mainly for measurable aspects of sustainable buildings, such as energy efficiency, that translate into greater value in the form of higher rental rates, increased sale prices, increased occupancy rates and lower capitalisation rates. It also benefits the end user due to lower operating expenses, improved indoor climate and increased worker productivity.

Kok also states that investing in energy efficient real estate has positive effects on an organisation's image, the climate and investment returns. Nevertheless, real estate owners are still not investing en masse. This is partly because energy savings need to be passed on to the tenant (which leads to negotiations) and also because investments in sustainability often pay out in the medium to long term, because, for example, vacancy rates are lower.

9.4 Appraisers view

We also consulted EY's real estate team. They stated that as a result of the financial crisis a visible upward impact of energy performance on building values is hard to quantify due to the sharp drop in real estate values. However, it is evident that sustainable buildings show shorter vacancy periods, have a lower loss of rental income due to changing tenants and, as such, show a more positive operating impact for the owner, if compared to the 'same' energy inefficient building. Notwithstanding these positive impacts, it must be noted that a high 'green' label comes with higher and more frequent (re-)investment and maintenance costs. As such it is still unclear if energy performance is positively reflected in the internal rate of return for the investor. Now that the real estate market is coming back on track and the real estate values are 'reset', appraisers expect an acceleration in the value impact on sustainable buildings.

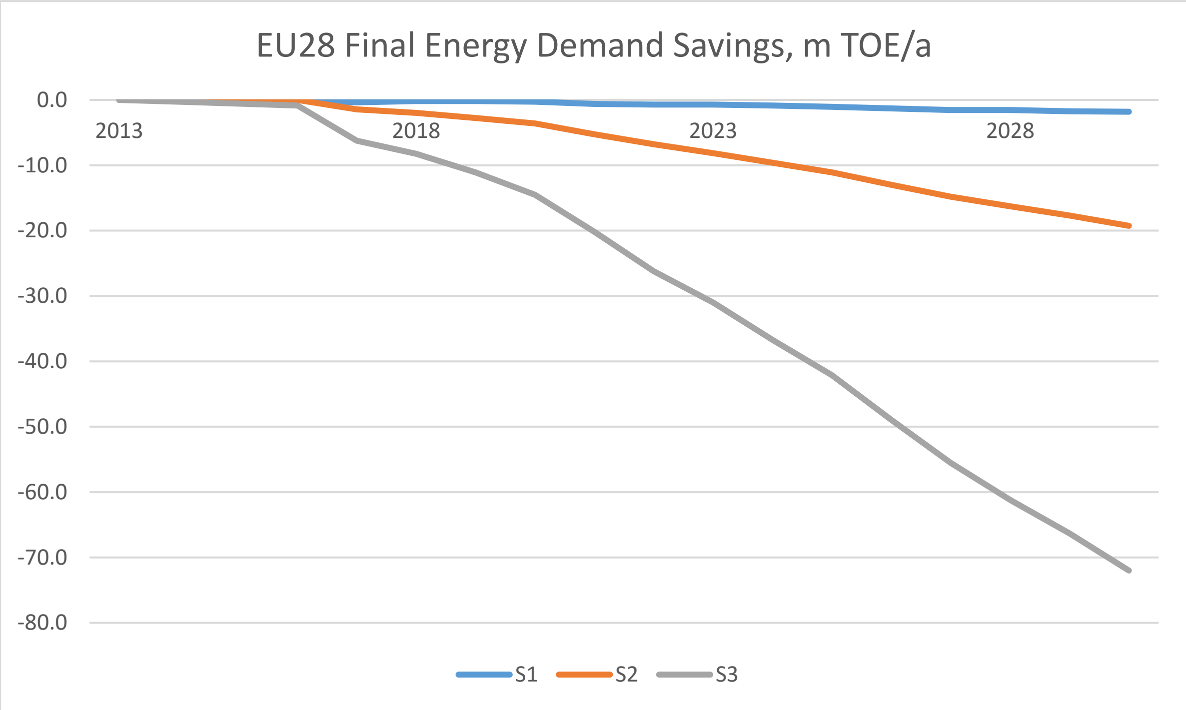
Part IV. Results

1 Introduction

This chapter presents the quantitative results from the analysis. It is split into the seven impact areas, which are discussed in turn.

To put the impacts into context, Figure IV.1 shows the energy savings that are achieved in each scenario, compared to the reference case. The figure shows that the level of ambition is much higher in S3 than in the other cases. We would expect the results across each of the seven impact areas to reflect this.

Figure IV.1 EU28 final energy demand savings, m toe per annum, compared to reference scenario



Source(s): Ecofys and European Commission[17].

2 Economy and labour market

2.1 Macroeconomic impacts at EU level

The economic and labour market impacts largely come from the E3ME model results. Table IV.1 and Table IV.2 summarise the macroeconomic results for 2020 and 2030, respectively.

Overall, the magnitude of the impacts is fairly small throughout. This partly reflects the scale of the inputs, but also the relatively small size of the energy sector in the total economy. However, there is also a clear trend that the impacts are positive, both for GDP and employment. The pattern of results is the same for 2020 and 2030, with the scale of impacts in 2030 slightly larger. The maximum increase in GDP is in the range

[17] Boermans, T, Grözinger, J, von Manteuffel, B, Surmeli-Anac, N, John, A (Ecofys) Leutgöb, K and Bachner, D (e7) (2015) 'Assessment of cost optimal calculations in the context of the EPBD' (ENER/C3/2013-414) Final report. 19 November 2015, Project number: BUIDE13705.

of 0.6%, while employment is likely to increase by up to 0.25% (568,000 jobs). Unemployment falls by a comparable amount (see Section 5).

The positive economic impacts are largely driven by higher levels of investment. For example, in scenario S3 where the EE investment is the largest, additional investment in 2030 for the EU28 countries is €101bn. The investment is paid for through a redistribution of consumer expenditure made by households, so the effects on consumption are modest at best and may be slightly negative.

The effects on international trade are ambiguous. On the one hand a reduction in energy consumption leads to lower fossil fuel imports. However, a higher level of GDP tends to lead to a higher demand for imports as well (e.g. for energy-efficient goods). So, while imports of energy goods fall in all cases, it is not necessarily the case that a more ambitious level of energy efficiency leads to a lower total volume of imports. There is little impact on exports.

Table IV.1 EU28 Summary of results in 2020, % difference from reference scenario

	S1	S2	S3
GDP	0.08	0.11	0.26
Employment	0.01	0.02	0.06
Consumer expenditure	0.02	0.01	-0.10
Investment	0.11	0.20	0.80
Extra-EU exports	0.02	0.02	0.03
Extra-EU imports	-0.10	-0.17	-0.36
Employment (thousands)	32	46	126
Consumer price index	-0.07	-0.11	-0.25

Source(s): E3ME, Cambridge Econometrics

Table IV.2 EU28 Summary of results in 2030, % difference from reference case

	S1	S2	S3
GDP	0.12	0.29	0.61
Employment	0.04	0.10	0.25
Consumer expenditure	-0.03	-0.01	0.06
Investment	0.38	0.84	1.82
Extra-EU exports	0.02	0.05	0.12
Extra-EU imports	-0.11	-0.20	-0.08
Employment (thousands)	93	220	568
Consumer price index	-0.14	-0.41	-0.88

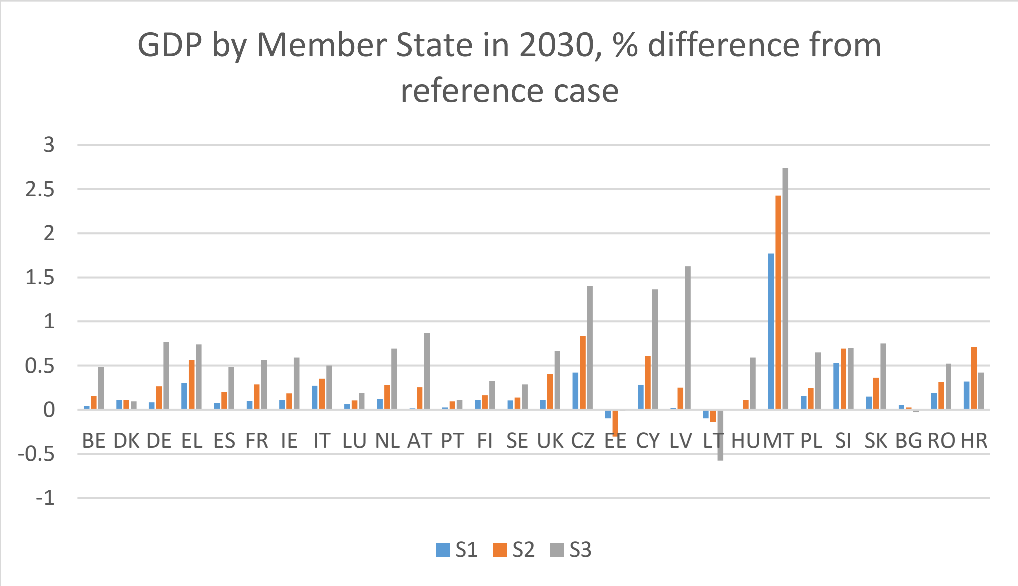
Source(s): E3ME, Cambridge Econometrics

2.2 Macroeconomic impacts at Member State level

The Member State level impacts of energy efficiency on GDP and employment are shown in Figure IV.2 and Figure IV.3, respectively. The national results largely reflect shares of energy-efficiency investment (relative to GDP). Countries with large investment goods sectors are also expected to see larger increases in both output (GDP) and employment.

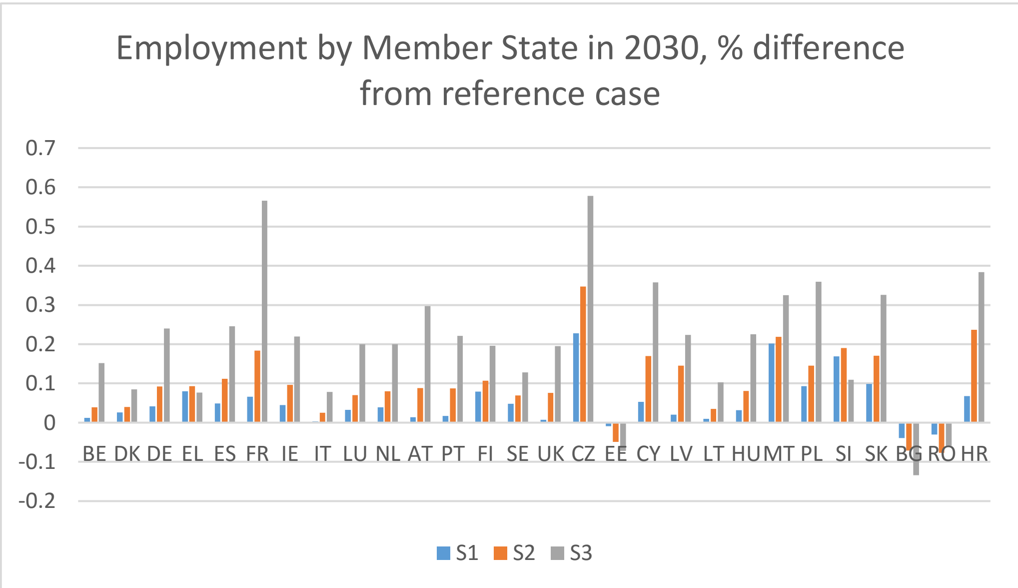
In terms of GDP (Figure IV.2), countries that produce energy domestically and/or export energy suffer from reductions in energy demand, while countries that are energy intensive and/or import energy benefit from reductions in energy demand.

Figure IV.2 GDP by Member State in 2030, % difference from reference case



Source(s): E3ME, Cambridge Econometrics

Figure IV.3 Employment by member state in 2030, % difference from reference case



Source(s): E3ME, Cambridge Econometrics

Countries with economies that are focused more towards consumer goods and services are likely to see smaller increases in employment (Figure IV.4) than those that produce capital equipment. In some cases, there is a small decrease in employment as households reduce current consumption to pay for investment in the short run.

However, in the longer term (after the period of the model simulations) when the investment has already been made, consumption would be expected to recover.

Most Member States show positive impacts from the three scenarios when compared to the reference case; however, there are a few notable exceptions. GDP is lower in the scenarios than in the reference case in 2030 in Estonia and Lithuania, reflecting their high levels of trade. In these countries the investment in energy efficient equipment creates domestic activity in the construction sector but spending in other sectors is diverted to pay for the equipment. As most of the equipment is imported, there is a short-term negative effect.

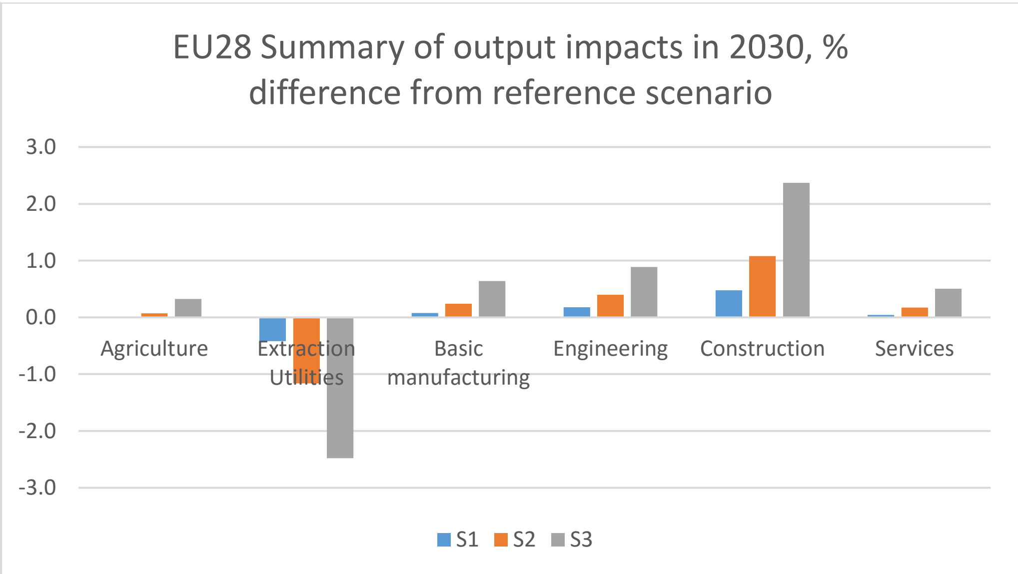
Employment is lower in the scenarios in Estonia, Bulgaria and Romania; in the latter pair of countries (where GDP did not fall), this is reflecting a shift in economic activity away from agriculture (as consumer expenditure on food decreases) and towards construction (to implement the energy efficiency measures). As construction has a higher average level of productivity than agriculture, this shift in economic activity generates fewer jobs in construction than those that are lost from agriculture.

It should also be noted that there are some endogenous wage responses in the modelling, which can explain some of the employment impacts (both positive and negative). Changes to productivity, consumption patterns and aggregate inflation rates can lead to changes in the wage bargaining process and a different outcome for average wage rates.

2.3 Impacts at sectoral level

The E3ME model results for output and employment, split by different sectors of the economy, are displayed in Figure IV.4 and Figure IV.5. These results show a reduction in output and employment in the utilities and extraction sectors due to the energy saving measures. However, small rebound effects and reductions in imports limit the overall impacts on the extraction sectors.

Figure IV.4 EU28 Summary of output impacts by sector in 2030, % difference from reference case

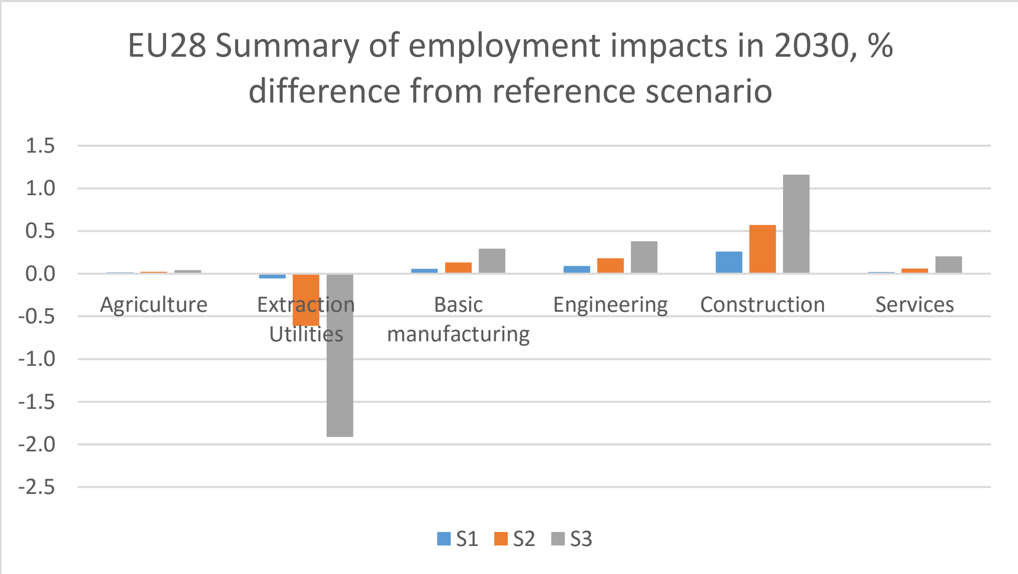


Source(s): E3ME, Cambridge Econometrics

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 reference case. Because these positive economic impacts are driven largely by higher levels of investment, the impact is greatest in scenario S3 where the energy efficiency investment is the largest.

Employment results at sectoral level follow the same pattern as output, although the magnitude of the impacts is smaller (Figure IV.5). The only sector that is expected to see a decline in employment is extraction and utilities. Construction and engineering will be the two sectors experiencing most significant increases in employment, although these are still moderate.

Figure IV.5 EU28 Summary of employment impacts by sector in 2030, % difference from reference case



Source(s): E3ME, Cambridge Econometrics

2.4 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.3.

The measure shows some small improvements in energy security in the scenarios. However, in all the scenarios these impacts are quite small in magnitude.

Table IV.3 Energy imports as a share of GDP

	Ref case	S1	S2	S3
BE	0.092	0.091	0.091	0.090
DK	0.015	0.014	0.014	0.014
DE	0.031	0.031	0.030	0.029
EL	0.045	0.043	0.041	0.039
ES	0.025	0.025	0.024	0.023
FR	0.040	0.039	0.038	0.038

	Ref case	S1	S2	S3
IE	0.020	0.020	0.020	0.020
IT	0.029	0.027	0.027	0.027
LU	0.033	0.033	0.033	0.033
NL	0.092	0.091	0.091	0.089
AT	0.033	0.033	0.032	0.030
PT	0.051	0.051	0.050	0.049
FI	0.013	0.012	0.012	0.011
SE	0.036	0.036	0.035	0.034
UK	0.024	0.023	0.021	0.020
CZ	0.028	0.025	0.023	0.021
EE	0.057	0.057	0.055	0.053
CY	0.054	0.052	0.051	0.047
LV	0.174	0.173	0.173	0.160
LT	0.293	0.294	0.294	0.295
HU	0.032	0.031	0.030	0.028
MT	0.047	0.034	0.029	0.028
PL	0.046	0.045	0.045	0.043
SI	0.044	0.040	0.038	0.036
SK	0.069	0.066	0.065	0.063
BG	0.045	0.044	0.044	0.043
RO	0.059	0.058	0.058	0.058
HR	0.057	0.054	0.051	0.050
EU	0.037	0.036	0.035	0.034

Source(s): E3ME, Cambridge Econometrics

3 Health and well-being

The results for healthcare cost savings, mortality and morbidity costs savings and productivity gains resulting from energy efficiency measures that improve indoor thermal comfort and air quality are displayed in Table IV.4 to Table IV.6. The results for healthcare, mortality and morbidity cost savings are derived from an estimate of the square meterage of building area that will be renovated under each scenario based on the estimated energy savings at the Member State level (see Table IV.7 for details). An annual cost-saving estimate of €2.80 per renovated square metre, derived from the existing literature (see Appendix B), has been used in the final calculations. A more detailed overview of the methodology is provided in Part III Section 4 of this report.

As the results in the tables show, 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 level of investment: greater savings are derived from greater levels of investment. The benefits also accumulate over time. The cost savings related to healthcare costs, mortality and morbidity range from €2m pa for the EU28 in S1 (Table IV.4) to €367.6m pa in S3 (Table IV.6) for the period of 2015-2020 and from €24m pa in scenario S1 (Table IV.4) to €925.9m pa in scenario S3 (Table IV.6) for the period 2020-2030.

The estimates of productivity gains are derived using the total area of non-residential buildings renovated each year and an estimated annual cost saving of between €0.6 and €1.0 per square metre of renovated floor space. These estimates provide a minimum and maximum value for the productivity gains.

As is the case with healthcare cost, mortality and morbidity, the extent of impacts varies between scenarios and the benefits accumulate over time. The absolute values of the productivity gains are not as significant as the other health-related cost savings, but are nevertheless considerable at the EU28 level. The estimated productivity gains for the EU28 range from €0.1m to €0.2m pa (S1, Table IV.4) in 2015-2020 to €53.4m to €88.9m pa (S3, Table IV.6) in 2020-2030.

The variation in the scale of impacts at Member State level is considerable and reflects different types of public health coverage and scope for improvements in building quality.

Table IV.4 Change in health-related costs, scenario S1, m€ per year

	2015 - 2020			2020 - 2030		
	Cost savings - morbidity, mortality & healthcare	Prod. gains minimum	Prod. gains maximum	Cost savings - morbidity, mortality & healthcare	Prod. gains minimum	Prod. gains maximum
BE	-0.1	0.0	0.0	-0.7	0.0	-0.1
DK	0.0	0.0	0.0	-0.2	0.0	0.0
DE	-0.4	0.0	0.0	-4.1	-0.2	-0.3
EL	0.2	0.0	0.0	-0.1	0.0	0.0
ES	-0.1	0.0	0.0	-1.2	-0.1	-0.1
FR	-0.3	0.0	0.0	-3.5	-0.2	-0.3
IE	0.0	0.0	0.0	-0.2	0.0	0.0
IT	-0.2	0.0	0.0	-2.4	-0.2	-0.3
LU	0.0	0.0	0.0	-0.1	0.0	0.0
NL	-0.1	0.0	0.0	-0.8	-0.1	-0.1
AT	0.0	0.0	0.0	-0.5	0.0	0.0
PT	-0.1	0.0	0.0	-1.3	-0.1	-0.1
FI	0.0	0.0	0.0	-0.4	0.0	0.0
SE	0.0	0.0	0.0	-0.4	0.0	0.0
UK	-0.4	0.0	0.0	-4.8	-0.2	-0.3
CZ	-0.1	0.0	0.0	-0.6	0.0	-0.1
EE	0.0	0.0	0.0	-0.1	0.0	0.0
CY	0.0	0.0	0.0	0.0	0.0	0.0
LV	0.0	0.0	0.0	-0.1	0.0	0.0
LT	0.0	0.0	0.0	-0.1	0.0	0.0

	2015 - 2020			2020 - 2030		
HU	-0.1	0.0	0.0	-0.6	0.0	-0.1
MT	0.0	0.0	0.0	0.0	0.0	0.0
PL	0.0	0.0	0.0	-0.3	0.0	0.0
SI	0.0	0.0	0.0	-0.2	0.0	0.0
SK	0.0	0.0	0.0	-0.1	0.0	0.0
BG	0.0	0.0	0.0	-0.2	0.0	0.0
RO	-0.1	0.0	0.0	-0.7	0.0	-0.1
HR	0.0	0.0	0.0	-0.3	0.0	0.0
EU	-2.0	-0.1	-0.2	-24.0	-1.4	-2.3

Source(s): E3ME, Cambridge Econometrics

Table IV.5 Change in health-related costs, scenario S2, m€ per year

	2015 - 2020			2020 - 2030		
	Cost savings - morbidity, mortality & healthcare	Prod. gains minimum	Prod. gains maximum	Cost savings - morbidity, mortality & healthcare	Prod. gains minimum	Prod. gains maximum
BE	-2.6	-0.1	-0.2	-5.8	-0.3	-0.4
DK	-0.6	0.0	-0.1	-1.6	-0.1	-0.2
DE	-15.1	-0.7	-1.2	-41.2	-2.0	-3.3
EL	-1.8	-0.1	-0.1	-5.0	-0.3	-0.4
ES	-4.5	-0.3	-0.6	-12.2	-0.9	-1.6
FR	-13.2	-0.8	-1.3	-35.8	-2.1	-3.5
IE	-0.9	0.0	-0.1	-2.5	-0.1	-0.2
IT	-9.1	-0.8	-1.3	-24.7	-2.1	-3.4
LU	-0.2	0.0	0.0	-0.6	0.0	0.0
NL	-3.2	-0.2	-0.4	-8.6	-0.6	-1.1
AT	-1.9	-0.1	-0.1	-5.3	-0.2	-0.4
PT	-5.0	-0.3	-0.5	-13.5	-0.7	-1.2
FI	-1.3	-0.1	-0.2	-3.6	-0.2	-0.4
SE	-1.4	-0.1	-0.1	-3.7	-0.2	-0.4
UK	-17.7	-0.7	-1.2	-48.3	-2.0	-3.3
CZ	-2.4	-0.2	-0.3	-6.6	-0.4	-0.7
EE	-0.3	0.0	0.0	-0.8	-0.1	-0.1
CY	-0.1	0.0	0.0	-0.4	0.0	-0.1
LV	-0.5	0.0	-0.1	-1.5	-0.1	-0.2
LT	-0.5	0.0	-0.1	-1.3	-0.1	-0.2

	2015 - 2020			2020 - 2030		
HU	-2.2	-0.1	-0.2	-6.0	-0.3	-0.5
MT	0.0	0.0	0.0	-0.1	0.0	0.0
PL	-0.9	-0.1	-0.2	-2.6	-0.3	-0.5
SI	-0.9	-0.1	-0.1	-2.5	-0.2	-0.3
SK	-0.4	0.0	0.0	-1.1	-0.1	-0.1
BG	-0.8	-0.1	-0.1	-2.2	-0.2	-0.4
RO	-2.6	-0.2	-0.3	-7.0	-0.4	-0.7
HR	-1.0	0.0	-0.1	-2.6	-0.1	-0.2
EU	-91.1	-5.2	-8.7	-246.8	-14.2	-23.7

Source(s): E3ME, Cambridge Econometrics

Table IV.6 Change in health-related costs, scenario S3, m€ per year

	2015 - 2020			2020 - 2030		
	Cost savings - morbidity, mortality & healthcare	Prod. gains minimum	Prod. gains maximum	Cost savings - morbidity, mortality & healthcare	Prod. gains minimum	Prod. gains maximum
BE	-10.5	-0.5	-0.8	-21.3	-1.0	-1.6
DK	-2.3	-0.2	-0.3	-5.9	-0.4	-0.6
DE	-61.1	-2.9	-4.9	-154.7	-7.4	-12.3
EL	-6.8	-0.3	-0.5	-18.5	-0.9	-1.5
ES	-18.1	-1.4	-2.3	-45.9	-3.5	-5.8
FR	-53.2	-3.1	-5.2	-134.5	-7.9	-13.2
IE	-3.7	-0.2	-0.3	-9.3	-0.4	-0.7
IT	-36.7	-3.1	-5.1	-92.7	-7.7	-12.9
LU	-0.8	0.0	-0.1	-2.1	-0.1	-0.2
NL	-12.7	-0.9	-1.6	-32.2	-2.4	-4.0
AT	-7.8	-0.4	-0.6	-19.8	-0.9	-1.5
PT	-3.8	-0.4	-0.7	-9.6	-1.1	-1.8
FI	-5.4	-0.4	-0.6	-13.6	-0.9	-1.5
SE	-5.5	-0.3	-0.5	-13.8	-0.8	-1.3
UK	-71.6	-2.9	-4.9	-181.2	-7.4	-12.4
CZ	-9.8	-0.6	-1.1	-24.7	-1.6	-2.7
EE	-1.2	-0.1	-0.1	-3.0	-0.2	-0.4
CY	-0.6	-0.1	-0.1	-1.5	-0.2	-0.3
LV	-2.2	-0.1	-0.2	-5.5	-0.3	-0.6

	2015 - 2020			2020 - 2030		
LT	-1.9	-0.1	-0.2	-4.8	-0.4	-0.6
HU	-8.9	-0.5	-0.8	-22.6	-1.2	-1.9
MT	-0.1	0.0	0.0	-0.3	0.0	0.0
PL	-20.1	-1.1	-1.9	-50.9	-2.8	-4.7
SI	-3.6	-0.3	-0.5	-9.2	-0.8	-1.3
SK	-1.7	-0.1	-0.1	-4.2	-0.2	-0.4
BG	-3.2	-0.3	-0.5	-8.2	-0.8	-1.4
RO	-10.4	-0.6	-1.0	-26.3	-1.6	-2.7
HR	-3.9	-0.2	-0.3	-9.8	-0.4	-0.7
EU	-367.6	-21.2	-35.3	-925.9	-53.4	-88.9

Source(s): E3ME, Cambridge Econometrics

4 Environmental impacts

4.1 Impacts on energy consumption

The impacts of energy efficiency on final energy consumption come largely from the E3ME model results, which are based on the initial energy savings but also take into account rebound effects and energy consumption required to produce energy-efficient equipment and materials. The E3ME model results for final energy consumption are shown in Table IV.7. These figures include both the direct energy savings from the bottom-up analysis and any indirect effects.

As can be seen in Table IV.7, most of the changes in final energy demand are in the buildings sector, which is to be expected considering the focus of all three scenarios on energy efficiency improvements in buildings. The changes in energy consumption in other sectors are the result of indirect impacts (e.g. rebound effects).

Both the reductions in final energy consumption for buildings and for the whole economy are driven by the level of investment in energy efficiency in the different scenarios. The impact on final energy consumption by buildings in the EU28 ranges from -0.7% in scenario S1 to -14.8% in scenario S3, while for the whole economy the range is from -0.4% in S1 to -6.9% in S3. Even when rebound effects and the energy consumption required to produce energy efficient equipment and materials are taken into consideration, all scenarios show a reduction in final energy consumption, although the magnitude of this reduction varies.

The magnitude of the impacts also varies considerably between countries, reflecting differences in the current quality of the building stock and the potential for energy efficiency improvements. The reductions in final energy consumption, most notable in the high investment scenario (S3), are smaller for countries where the building stock is known to be relatively energy efficient already (such as Sweden, Denmark and the Netherlands).

4.2 Impacts on greenhouse gas and other air-borne emissions

The impacts on greenhouse gas (GHG) and CO_2 emissions (Table IV.8) are taken from the E3ME results and are consistent with the results for primary fuel consumption.

As can be seen in Table IV.8, both CO_2 and GHG emissions decrease in all scenarios. Again, the magnitude of the impact is driven by the level of investment and energy savings, with the change in CO_2 emissions in the EU28 ranging from -0.5% in S1 to -7.8% in S3. The change in GHG emissions ranges from -0.4% in S1 to -6.0% in S3.

At Member State level, the magnitude of the impacts varies considerably, largely due to the varying potential to further improve energy efficiency in buildings at the national level.

The results from the E3ME model also include estimates of several more localised air pollutants. These results are used as inputs to the calculations of impacts on human health (see Section 3 above). Full tables of results are provided in Appendix C.

Table IV.7 Final energy consumption in 2030, % difference from reference case

	For buildings			For the whole economy		
	S1	S2	S3	S1	S2	S3
BE	-0.3	-2.7	-10.0	-0.3	-1.6	-5.4
DK	-0.4	-2.3	-7.9	-0.2	-1.0	-3.4
DE	-0.9	-4.1	-14.3	-0.4	-1.8	-6.2
EL	-0.7	-4.3	-15.9	-1.0	-3.4	-10.0
ES	-0.6	-4.0	-13.2	-0.3	-1.5	-4.9
FR	-0.8	-4.9	-17.2	-0.4	-2.1	-7.1
IE	-0.6	-5.8	-21.9	-0.3	-2.1	-7.3
IT	-0.6	-3.0	-10.0	-0.4	-1.8	-6.0
LU	-1.2	-7.2	-25.7	-0.2	-1.0	-3.6
NL	-0.2	-1.6	-6.1	-0.3	-1.5	-5.5
AT	-1.1	-5.9	-20.4	-0.3	-1.8	-6.5
PT	-1.1	-3.3	-10.0	-0.3	-1.3	-4.3
FI	-0.3	-2.7	-10.1	-0.1	-1.1	-4.3
SE	-0.3	-2.6	-9.6	-0.1	-0.9	-3.4
UK	-1.1	-8.9	-32.2	-0.6	-3.6	-12.4
CZ	-0.7	-4.8	-15.8	-0.5	-2.6	-8.2
EE	-0.6	-3.6	-13.4	-0.7	-2.9	-9.1
CY	-0.6	-5.6	-21.0	-0.8	-2.5	-7.3
LV	-0.9	-5.2	-19.6	-0.3	-2.2	-8.9
LT	0.5	-1.0	-5.3	0.1	-1.0	-4.3
HU	-0.9	-5.0	-17.2	-0.5	-2.7	-9.5
MT	-0.4	-3.9	-14.5	-0.6	-1.7	-4.9
PL	-0.3	-3.0	-11.2	-0.2	-1.4	-5.1
SI	-1.1	-11.0	-41.4	-0.8	-4.8	-16.7
SK	-0.5	-2.5	-8.8	-0.1	-0.9	-3.2
BG	-0.7	-3.7	-11.6	-0.9	-3.1	-8.2
RO	-1.1	-4.2	-14.0	-2.9	-7.4	-13.5
HR	-1.5	-8.3	-28.4	-0.8	-3.7	-12.1
EU	-0.7	-4.2	-14.8	-0.4	-2.1	-6.9

Source(s): E3ME, Cambridge Econometrics

Table IV.8 Impact on CO_2 and GHG emissions in 2030, % difference from reference case

	CO_2 emissions			GHG emissions		
	S1	S2	S3	S1	S2	S3
BE	-0.4	-2.5	-8.8	-0.4	-2.0	-7.0
DK	-0.3	-1.4	-4.7	-0.2	-0.8	-2.9
DE	-0.4	-1.9	-6.5	-0.4	-1.6	-5.4
EL	-1.0	-3.1	-9.2	-0.9	-2.7	-7.9
ES	-0.4	-1.7	-5.0	-0.4	-1.6	-4.5
FR	-0.8	-3.4	-11.2	-0.6	-2.4	-7.7
IE	-0.3	-2.1	-7.6	-0.2	-1.1	-3.9
IT	-0.5	-2.0	-6.2	-0.5	-1.8	-5.3
LU	-0.3	-1.5	-5.3	-0.2	-1.3	-4.8
NL	-0.4	-2.2	-7.7	-0.3	-1.7	-6.1
AT	-0.4	-1.8	-6.5	-0.3	-1.6	-5.6
PT	-0.5	-1.5	-4.7	-0.4	-1.3	-3.9
FI	-0.3	-1.8	-5.7	-0.2	-0.8	-2.5
SE	-0.4	-1.3	-2.4	-0.2	-0.8	-1.4
UK	-0.5	-3.9	-13.2	-0.4	-2.9	-10.2
CZ	-0.5	-2.9	-8.0	-0.5	-2.7	-7.6
EE	-0.7	-2.8	-8.1	-0.4	-1.6	-4.7
CY	5.5	2.8	-5.2	5.2	2.6	-5.0
LV	-0.9	-4.3	-11.7	-0.1	-0.1	-0.3
LT	-0.3	-2.3	-7.8	-0.2	-1.1	-3.7
HU	-0.4	-3.2	-11.2	-0.3	-2.5	-8.7
MT	3.7	1.9	-3.8	3.1	1.6	-3.2
PL	-0.1	-0.9	-3.3	-0.1	-0.7	-2.7
SI	-1.2	-6.2	-18.8	-1.0	-5.3	-15.5
SK	-0.1	-0.7	-2.6	-0.1	-0.8	-2.9
BG	-1.5	-4.5	-11.9	-1.0	-3.1	-8.3
RO	-2.9	-7.4	-13.0	-2.2	-5.8	-10.7
HR	-0.9	-3.6	-11.1	-1.4	-3.6	-10.0
EU	-0.5	-2.5	-7.8	-0.4	-1.9	-6.0

Source(s): E3ME, Cambridge Econometrics

4.3 Impacts on material consumption

The impacts of energy efficiency on material consumption come from the E3ME materials sub-model, which estimates the demand for seven different materials across 20 sectors of the economy. The interaction between energy and materials demand is known to be complex: the production of materials like steel and cement is known to be energy intensive, but many energy savings measures are also known to be quite material intensive.

The demand for materials in the E3ME materials sub-model is determined by rates of economic production, price and technology. Feedbacks to the primary producers (agriculture, forestry and non-energy mining) are included in the demand equations. In the materials demand equations, the dependent model variable is DMI (Direct Material Input) although this is translated to DMC (Direct Material Consumption) for presentation of results here.

Table IV.9 gives the results for the impact of energy efficiency on material consumption. The demand for materials in the EU28 increases due to higher buildings investment, as well as rebound effects from higher economic activities. As a result, material consumption is higher in S3 than in S1 and S2. It is worth noting, however, that the increase in material consumption relates only to the initial investment that is being made. Once the investment is completed, material consumption will return close to baseline values in the reference case.

Table IV.9 DMC in 2030, % difference from reference case

	S1	S2	S3
BE	-0.03	-0.03	-0.02
DK	0.42	0.65	1.34
DE	-0.02	-0.03	-0.04
EL	0.20	0.38	0.70
ES	0.09	0.20	0.31
FR	0.05	0.16	0.48
IE	0.11	0.24	0.51
IT	0.17	0.48	0.73
LU	0.16	0.36	0.77
NL	0.02	0.09	0.25
AT	0.02	0.10	0.38
PT	0.59	1.28	1.77
FI	0.01	0.03	0.07
SE	1.70	3.06	5.37
UK	-0.02	-0.06	-0.13
CZ	0.46	0.98	1.63
EE	0.42	0.89	2.07
CY	0.21	0.50	1.08
LV	0.30	0.75	1.28
LT	-0.03	0.34	1.24

	S1	S2	S3
HU	1.08	2.20	4.29
MT	0.09	0.16	0.29
PL	0.25	0.57	1.30
SI	2.44	5.29	10.40
SK	0.37	0.83	1.68
BG	-0.76	-1.56	-3.17
RO	8.22	28.11	38.16
HR	-0.07	-0.19	-0.29
EU	0.26	0.81	1.21

Source(s): E3ME, Cambridge Econometrics

4.4 Impacts on water and land use by the power sector

The impacts of energy efficiency on water and land use by the power sector are shown in Table IV.10. These estimates are the result of a supplementary calculation that builds on the outputs of the E3ME model.

The results in Table IV.10 only cover requirements by the power sector, as it is assumed that in other sector changes in land and water use would be fairly minor (although this does not mean that other sector change would be zero – for example, if material consumption grows, the land required for mining activities may increase).

As shown in Table IV.10, both water consumption and land use for the power sector in the EU28 are expected to decline in S2 and S3, with the impacts of S1 on both land use and water consumption being negligible. The impact on both water and land use is greatest in the high investment scenario (S3), which shows an estimated reduction of 2.8% for water consumption and 4.5% for land use in the EU28.

However, there is quite a wide range of uncertainty around these results, because a substantial share of the demands depends on local geography and the technologies used (the uncertainty surrounding water and land use coefficients is discussed in greater detail in Part III Section 5). As such, the results in Table IV.10 should be treated with caution.

Table IV.10 Changes in water and land consumption by the power sector in 2030, % difference from reference case

	Water consumption			Land use		
	S1	S2	S3	S1	S2	S3
BE	-0.1	-1.0	-2.7	-0.6	-5.2	-14.1
DK	0.0	-0.6	-2.0	0.0	-0.6	-1.7
DE	0.2	-0.8	-3.1	0.3	-0.6	-2.6
EL	-1.9	-5.1	-18.0	-1.6	-4.6	-17.2
ES	0.1	-0.1	-1.4	0.4	-0.3	-4.0
FR	0.0	-0.5	-1.8	1.0	-5.8	-21.1
IE	0.0	-1.1	-2.2	0.0	-1.0	-2.0
IT	1.1	-0.2	-2.4	1.3	0.2	-1.7

	Water consumption			Land use		
LU	0.6	-1.5	-5.6	0.4	-1.2	-4.7
NL	-0.2	-1.8	-5.7	-0.2	-2.0	-6.6
AT	-0.1	-1.2	-3.8	0.0	-1.1	-3.6
PT	1.0	0.1	-5.7	1.6	0.8	-4.7
FI	0.0	-1.0	-4.4	0.1	-2.5	-10.8
SE	0.0	-0.2	-1.1	0.1	-1.2	-5.6
UK	0.0	-1.4	-2.1	0.2	-2.0	-2.7
CZ	0.0	-0.8	-2.7	0.2	1.6	-1.6
EE	-0.7	-2.4	-8.6	-0.5	-1.8	-7.2
CY	12.5	12.5	0.0	13.1	8.4	-5.1
LV	0.7	-2.2	-12.1	0.7	-2.0	-11.4
LT	0.3	-0.7	-3.7	3.6	-6.1	-30.5
HU	0.1	-0.8	-2.5	0.6	-3.2	-9.7
MT	0.0	0.0	0.0	0.0	0.0	0.0
PL	0.5	-0.1	-1.3	0.7	0.2	-0.6
SI	-0.3	-2.7	-14.6	0.1	-7.7	-41.1
SK	0.0	-0.2	-0.9	0.2	-1.3	-5.1
BG	-1.2	-3.5	-10.1	-2.4	-6.9	-19.7
RO	-2.6	-6.7	-9.6	-4.5	-11.4	-17.5
HR	0.4	-3.6	-15.8	0.8	-3.4	-16.4
EU	0.0	-0.9	-2.8	0.3	-1.1	-4.5

Source(s): E3ME, Cambridge Econometrics

5 Social impacts

The most relevant social impact included in our analysis on the impacts of energy efficiency in buildings is the change in number (or proportion) of households in energy poverty. In the absence of a shared and agreed definition (and 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 comprising measures that target existing buildings (and preferably that induce deep renovations, such as potentially measure 1B in scenario S3) 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 (indicated by the LOW/HIGH impact scenarios).

Table IV.11 displays a summary of the results for six proposed policy scenarios for the EU28. The number of households (HH) that may be lifted from energy poverty across the EU according to the above points lies between 194,000 and 310,000 (LOW impact scenario/scenario S1) and between 5.17m and 8.26m (HIGH impact scenario/scenario S3), depending on the energy poverty indicator considered (see Table IV.11 and Figure IV.15 to Figure IV.17).

The results for the indicators AUB, LDR and AKW are also presented separately by Member State for all three policy scenarios. In these figures (Figure IV.6 to Figure IV.14), the results are disaggregated by housing type (multi-family homes, MFH; and single-family homes, SFH).

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.

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

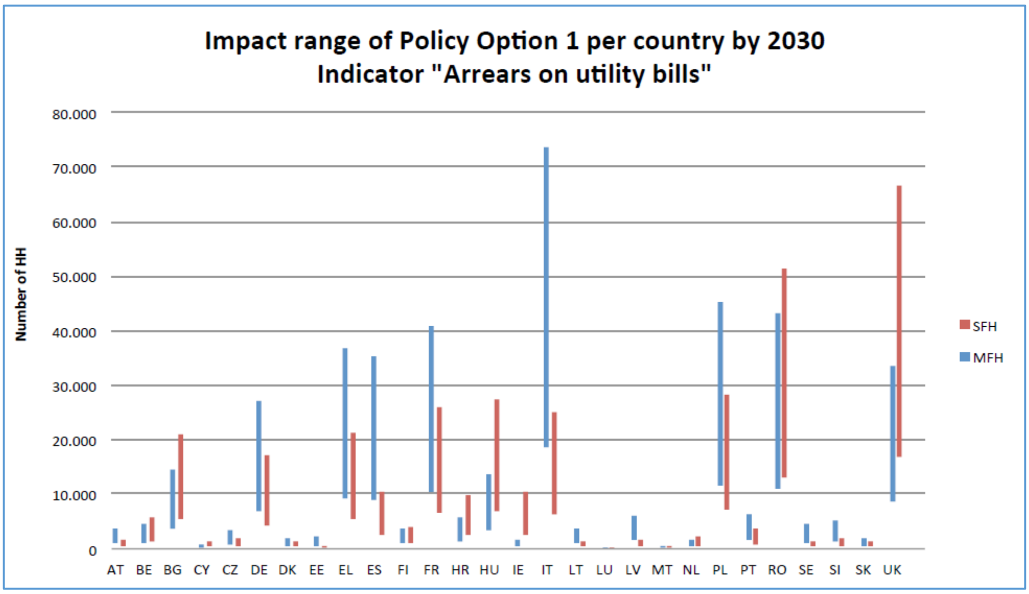
Figure IV.15 to Figure IV.17 illustrate the potential of different policy scenarios (high and low-impact versions of S1, S2 and S3) to reduce energy poverty at the EU level over time using the three key indicators (AUB, LDR and AKW).

Table IV.11 Total EU reductions in energy poverty in 2030 (in 1000 HH)

	LOW				**HIGH**			
	No change	**S1**	**S2**	**S3**	**No change**	**S1**	**S2**	**S3**
AUB SFH	0	87.4	231.9	656.5	0	344.2	889.8	2331.2
AUB MFH	0	106.5	282.6	799.9	0	419.5	1084.3	2840.1
AUB Total	**0**	**193.9**	**514.5**	**1456.4**	**0**	**763.7**	**1974.1**	**5171.3**
LDR SFH	0	160.3	425.1	1203	0	630.9	1630.4	4267.2
LDR MFH	0	149.7	396.9	1124.4	0	589.7	1523.9	3988.6
LDR Total	**0**	**310**	**822**	**2327.4**	**0**	**1220.6**	**3154.3**	**8255.8**
AKW SFH	0	105	278.5	788.1	0	413.3	1068.2	2796.1
AKW MFH	0	127.9	339.2	960.3	0	503.6	1301.5	3407.7
AKW Total	**0**	**232.9**	**617.7**	**1748.4**	**0**	**916.9**	**2369.7**	**6203.8**

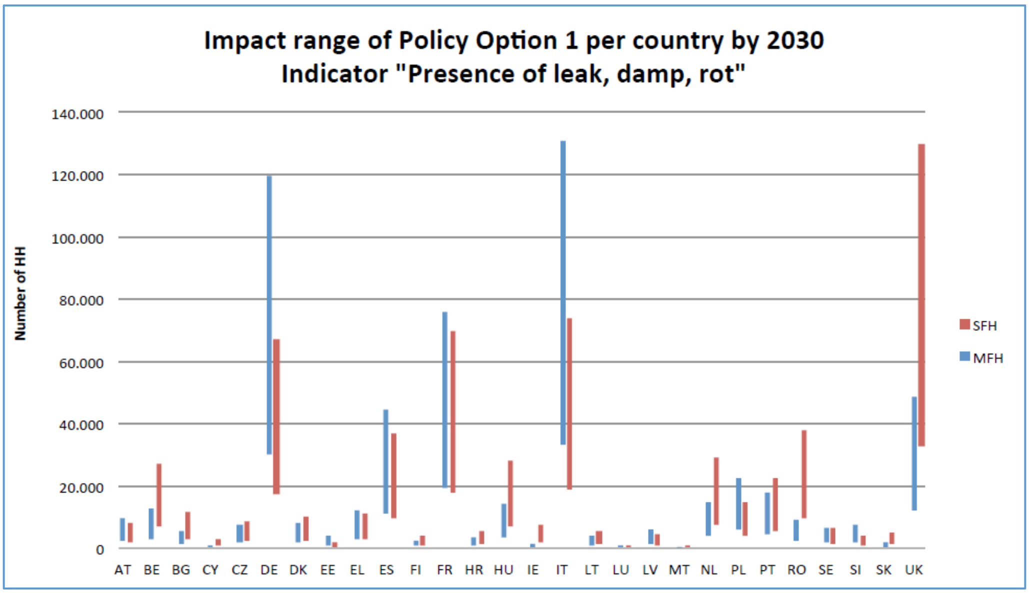
Source(s): Wuppertal Institut.

Figure IV.6 Energy poverty alleviation impact of policy option 1 in SFH and MFH using AUB as indicator



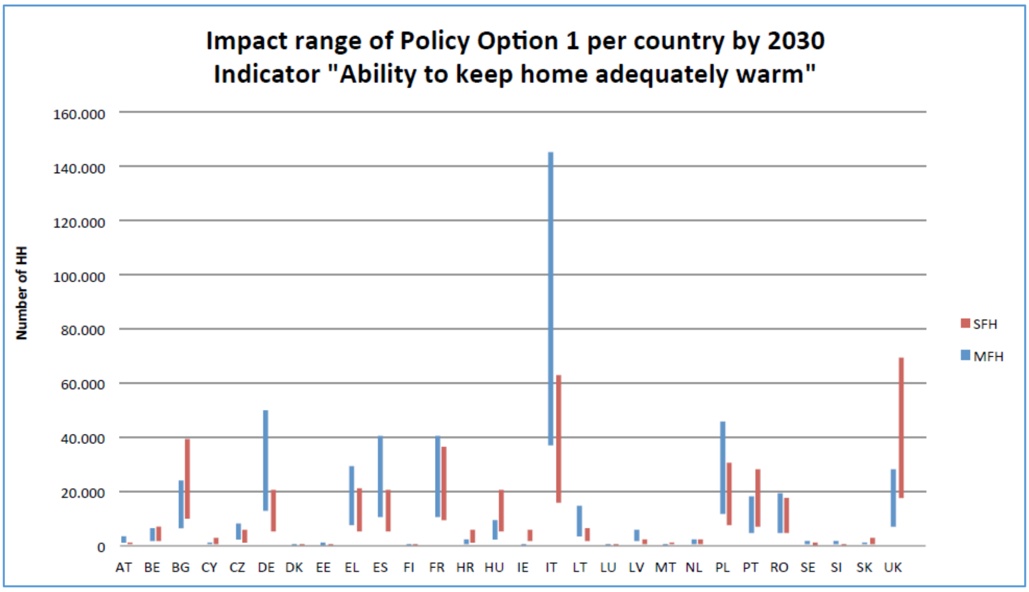
Source(s): Wuppertal Institut.

Figure IV.7 Energy poverty alleviation impact of policy option 1 in SFH and MFH using LDR as indicator



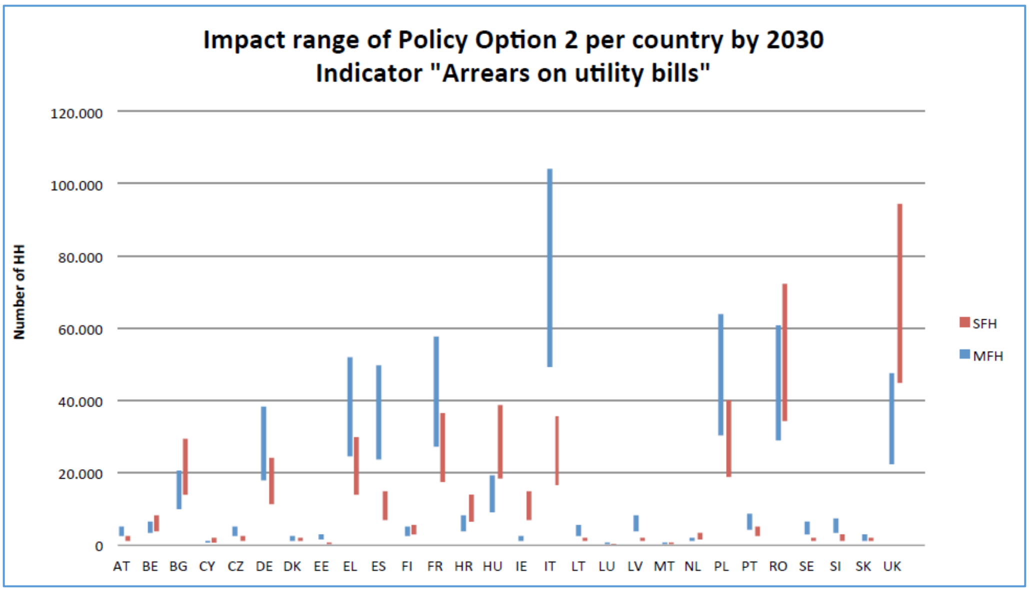
Source(s): Wuppertal Institut.

Figure IV.8 Energy poverty alleviation impact of policy option 1 in SFH and MFH using AKW as indicator



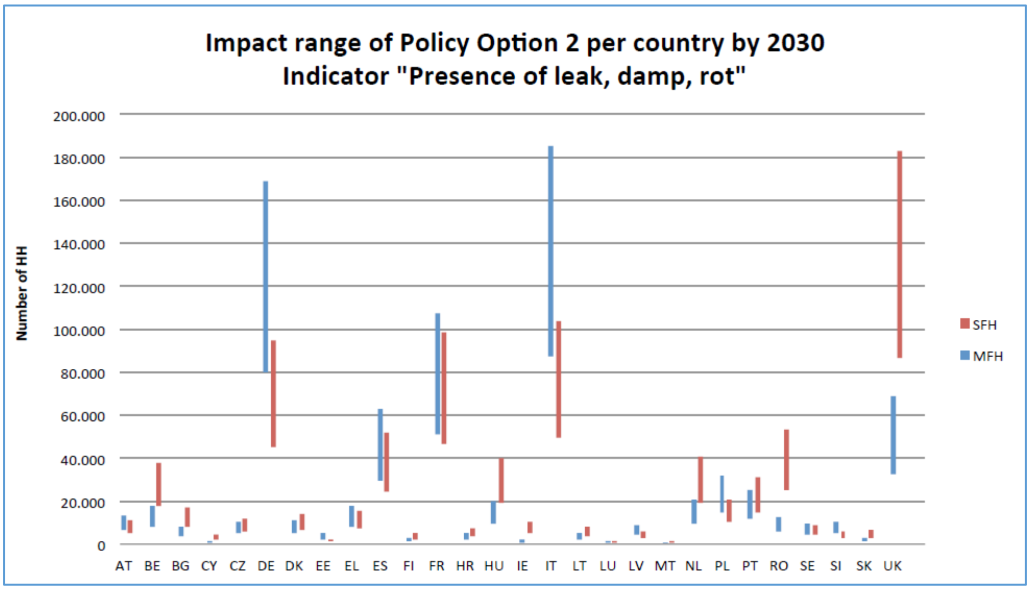
Source(s): Wuppertal Institut.

Figure IV.9 Energy poverty alleviation impact of policy option 2 in SFH and MFH using AUB as indicator



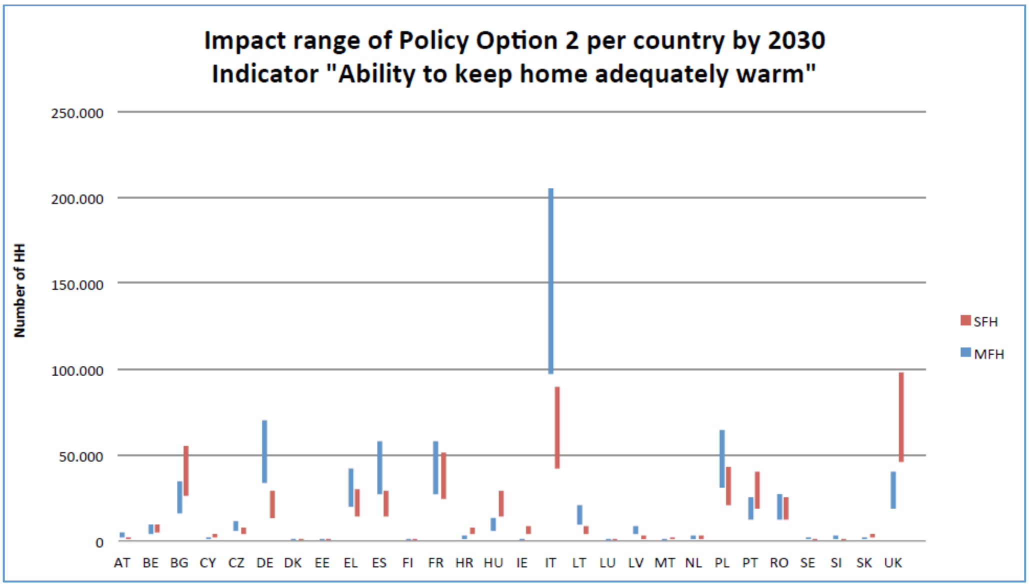
Source(s): Wuppertal Institut.

Figure IV.10 Energy poverty alleviation impact of policy option 2 in SFH and MFH using LDR as indicator



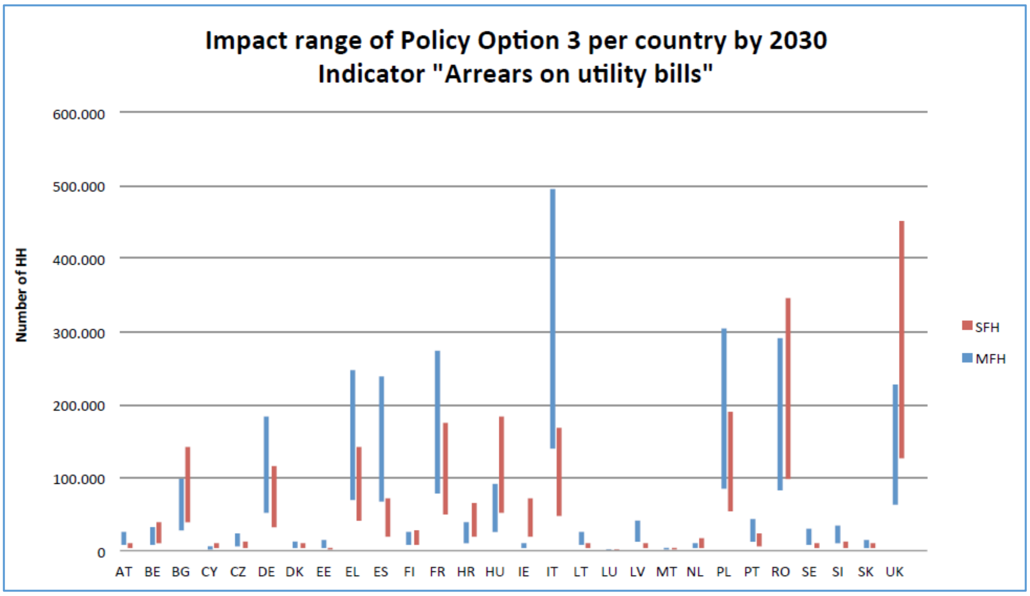
Source(s): Wuppertal Institut.

Figure IV.11 Energy poverty alleviation impact of policy option 2 in SFH and MFH using AKW as indicator



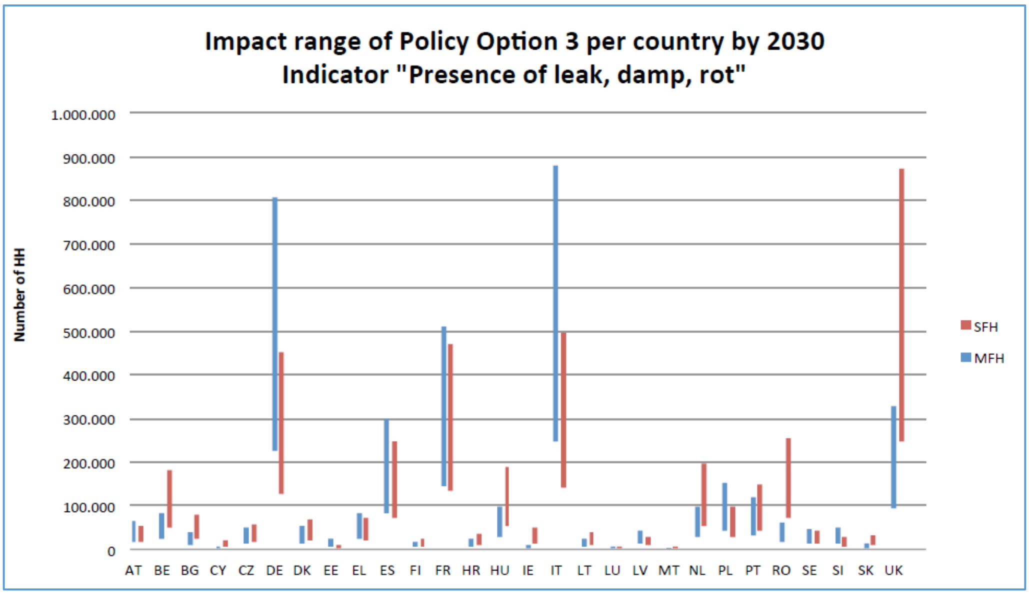
Source(s): Wuppertal Institut.

Figure IV.12 Energy poverty alleviation impact of policy option 3 in SFH and MFH using AUB as indicator



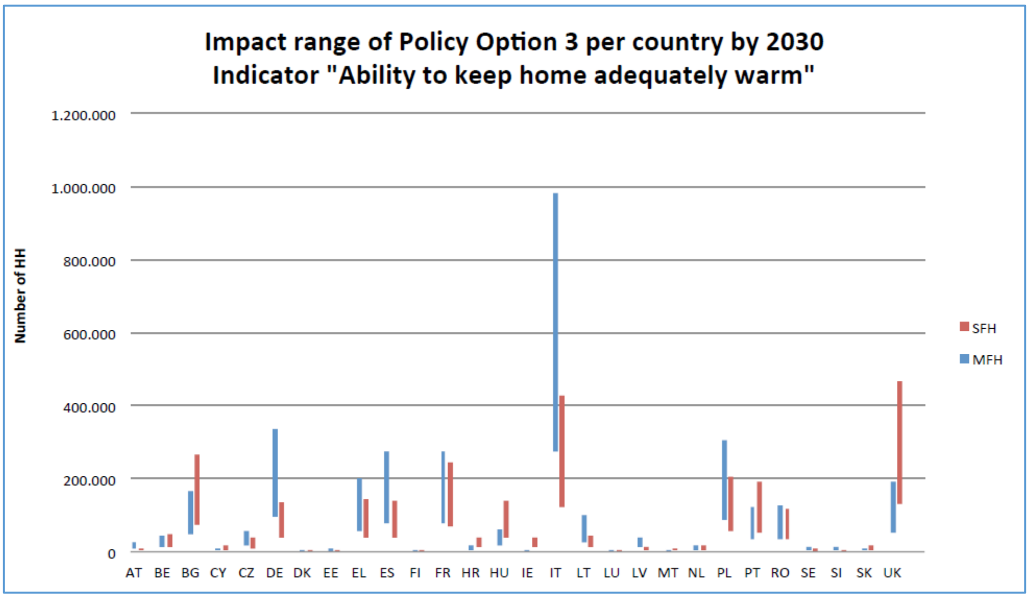
Source(s): Wuppertal Institut.

Figure IV.13 Energy poverty alleviation impact of policy option 3 in SFH and MFH using LDR as indicator



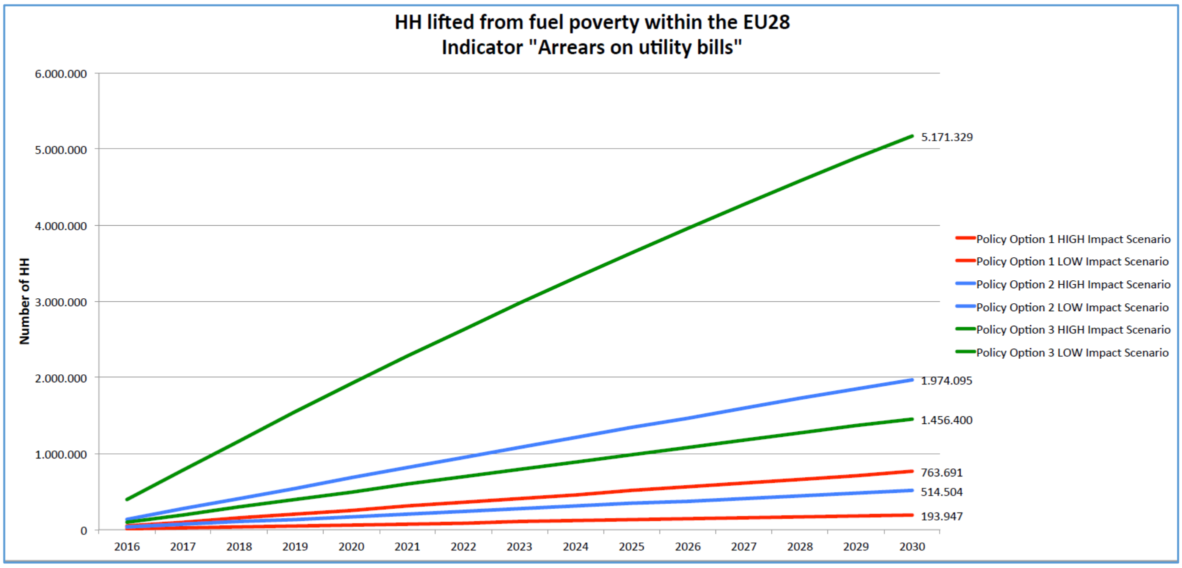
Source(s): Wuppertal Institut.

Figure IV.14 Energy poverty alleviation impact of policy option 3 in SFH and MFH using AKW as indicator



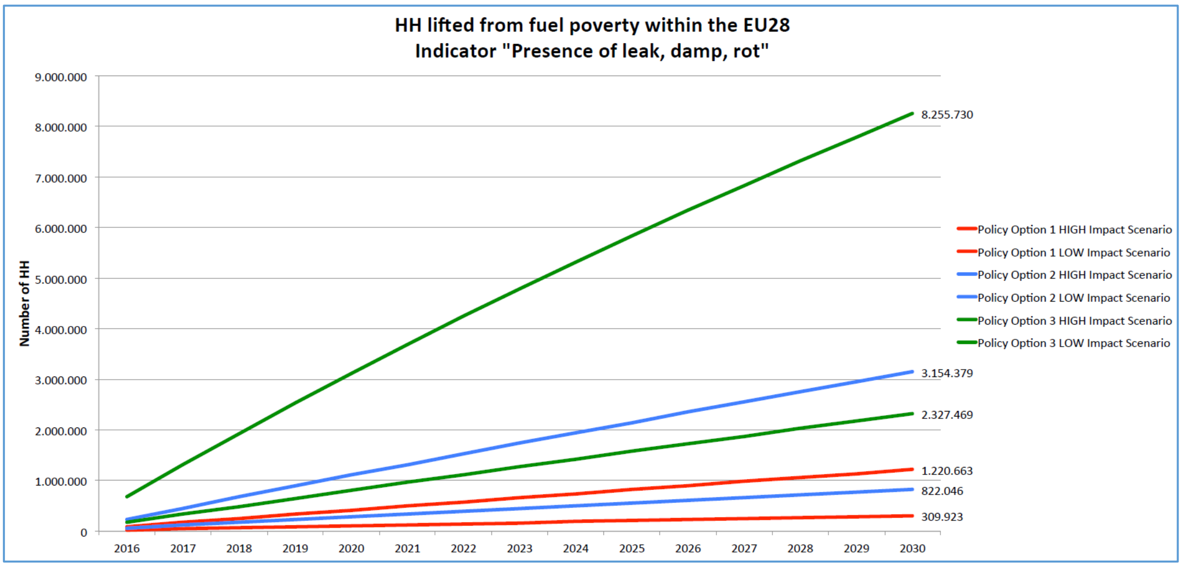
Source(s): Wuppertal Institut.

Figure IV.15 Energy poverty alleviation impact of the different policy options in residential buildings using AUB as indicator



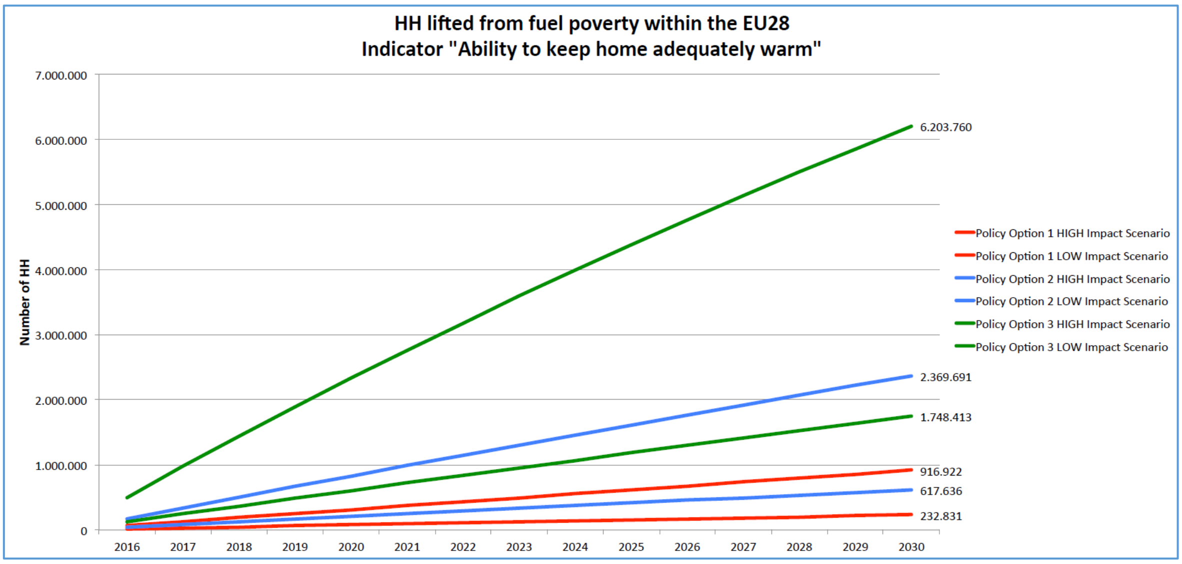
Source(s): Wuppertal Institut.

Figure IV.16 Energy poverty alleviation impact of the different policy options in residential buildings using LDR as indicator



Source(s): Wuppertal Institut.

Figure IV.17 Energy poverty alleviation impact of the different policy options in residential buildings using AKW as indicator



Source(s): Wuppertal Institut.

6 Public budgets

6.1 Impacts at European level

The estimated impacts of energy efficiency in buildings on public budgets are shown in Table IV.12. The figures in the table are based on the results from E3ME together with expansion of the model results to take into account certain specific factors (see Section 3.7 for a detail description of the methodology).

The results in Table IV.12 are displayed in current prices so many of the negative figures reflect price reductions (a lack of inflation) due to reductions in expenditure on expensive energy products in the scenarios. The impacts include a mixture of public sector savings (reduced expenditure) and costs (reductions in revenue).

On the income side, there are small reductions in energy excise duty and VAT revenues (including VAT from energy), and revenues from auctioned ETS allowances. Deflationary impacts in the scenarios also result in a small reduction in income tax revenues and both employers' and employees' social contributions (in current prices). However, revenues from corporation tax increase as firms make profits from cutting energy costs.

On the expenditure side, governments will spend less on energy after implementing energy efficiency measures, meaning that investment in energy efficiency is essentially paid for from reductions in government energy spending. There are also reductions in other expenditures due to deflationary impacts in the scenarios and changes in social transfers in the form of benefits. 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.

As shown in Table IV.12, the overall budget change at EU level is positive for all policy scenarios, ranging from €4,443m in scenario S1 to €28,104m in scenario S3 in monetary terms. However, as many reductions in Table IV.12 reflect price reductions, it is better to look at budget impacts as % of GDP (bottom line of Table IV.12). This shows an estimated budget change of 0.02% of GDP in S1, ranging to 0.11% of GDP in S3 at EU level.

Table IV.12 Impact on public budgets, €m difference from Reference case at EU level, 2030 (current prices)

	S1	S2	S3
Taxation (revenue)			
Income taxes	-1,424	-4,064	-5,700
Employees' social	-398	-1,115	-1,072
Employers' social	-1,039	-2,524	-3,506
Corporation tax	1,849	4,595	10,121
VAT	-1,471	-4,983	-10,622
Energy excise	-1,098	-4,573	-13,288
Auctioned ETS	64	-803	-2,568
Property taxes	0	0	0
Other taxes	0	0	0
Expenditure			

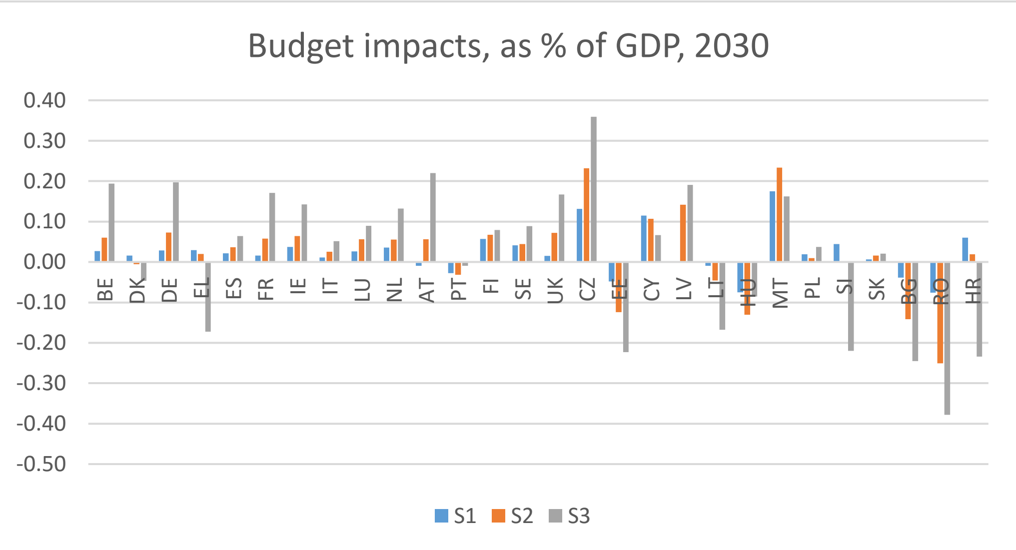
Energy purchases	-225	-1,442	-4,433
Social benefits	-22	-109	-482
Support for EE	0	0	0
Health benefits	0	0	0
Investment in EE	1,454	3,213	6,786
Other expenditure	-9,169	-26,760	-56,609
Overall budget change	**4,443**	**11,632**	**28,104**
EU28 budget change/GDP (pp)	**0.02**	**0.05**	**0.11**

Source(s): Cambridge Econometrics

6.2 Impacts at Member State level

Figure IV.18 shows the estimated public budget impacts at Member State level. For most Member States, the budget position improves due to higher levels of energy efficiency, although the extent of these impacts varies. For most countries, the extent of the impact is linked to the level of investment in the three policy scenarios.

Figure IV.18 Public budget impacts by Member State in 2030, as % of GDP



Source(s): Cambridge Econometrics

7 Industrial competitiveness

The quantification of energy efficiency impacts on competitiveness is difficult due to confidentiality issues. As noted in Part III Section 8, however, the competitiveness impacts within industrial sectors are likely to be small as long as the focus of the energy efficiency measures is on buildings.

The key sectors that are likely to be affected by an increase in energy efficiency are insulation and flat glass. The size of each sector will depend on the demand for their products, which is in turn dependent on the policies implemented. In estimating the future size of the sectors, the key assumptions are those made on the renovation market growth rate for each scenario (see below).

Scenario S1

Assumption / renovation market growth rate: steady market (€55bn-€83bn per year)

Results / insulation industry market: steady market (approx. €7.5bn at EU level / 26% of the global market (source: Eurima))

Results / flat glass industry market: steady market (approx. €10.8bn at EU level / 15% of the global market (source: Glass for Europe[18]))

Scenario S2

Assumption / renovation market growth rate: market multiplied by 1.45 by 2030 (€80bn-€120.3bn)

Results / insulation industry market: market multiplied by 1.45 by 2030 (approx. €10.9bn)

Results / flat glass industry market: market multiplied by 1.18 by 2030 (approx. €12.8bn)

Scenario S3

Assumption / renovation market growth rate: market multiplied by 2 by 2030 (€167bn-€250bn)

Results / insulation industry market: market multiplied by 2 by 2030 (approx. €15bn)

Results / flat glass industry market: market multiplied by 1.4 by 2030 (approx. €15.1bn)

8 The value of buildings

Estimating the impact of energy efficiency on the value of buildings is also difficult, as both sale and rental prices are influenced by a multitude of endogenous and exogenous factors (e.g. location), as well as market conditions and general supply-demand balance.

There is, however, some evidence to suggest that better energy performing buildings show shorter vacancy periods, have a lower loss of rental income due to changing tenants and, as such, show a more positive operating impact for the owner. In the commercial sector, buildings that fail to keep up with technological advances, including widespread advances in energy efficiency, risk becoming obsolete, especially in unfavourable market conditions (such as periods of low or negative economic growth).

The impact of this scenario in the value of buildings is at lower end of the scale, with our estimates based on the findings of the literature review (see Part III Section 9 and Appendix B).

Increased sale value of better performing buildings, 2030, compared to the reference case:

- Service: +5.2% to +35.0%
- Residential: 0.0% to +14.0%

[18] Figures reported by the interviewed experts from Glass for Europe

Increased rental value of better performing buildings, 2030, compared to the reference case:

- Service: +2.5% to +11.8%
- Residential: +1.4% to +5.2%

Part V. Conclusions

The IEA (2014) has identified a range of multiple benefits that may result 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 study 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 focus of the analysis is energy efficiency in buildings and, in particular, the EPBD. The focus on buildings is partly because of the large potential energy savings that exist across Europe, but also the direct relevance of many of the benefits (e.g. in health and social welfare) that were recognised by the IEA and the wider research community. Three scenarios of possible future outcomes for energy efficiency were assessed, based on different implementations of a future EPBD. These scenarios are:

- Scenario S1 (Option I): Enhanced implementation and soft law, including clarification and simplification of the current Directive
- Scenario S2 (Option II): Enhanced implementation, including targeted amendments for the strengthening of current provisions
- Scenario S3 (Option III): Enhanced implementation and increased harmonization, while introducing substantial changes

In each case the inputs to the scenarios have been derived from other EC studies, in particular a study led by Ecofys[19], providing consistency with other reports. The scenarios have been compared to a reference case in which there is no policy change. Seven impact areas have been covered:

- economy and labour market
- health and well-being
- environmental impact
- social aspects
- public budgets
- industrial competitiveness
- the value of buildings

It should be noted that there is potentially considerable cross-over and interaction between the different categories, some of which is captured in our assessment framework. However, most important is to note that we avoid double counting of impacts between the different categories[20].

Table V.1 summarises the key findings from each impact area. The table uses results from scenario S3 as it has the largest impacts; for other scenarios the direction of results is the same but the magnitude is less. The table shows that mainly positive impacts were found in all impact areas[21]; there could be a combination of economic, social and (mainly) environmental benefits.

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[19] Boermans, T, Grözinger, J, von Manteuffel, B, Surmeli-Anac, N, John, A (Ecofys) Leutgöb, K and Bachner, D (e7) (2015) 'Assessment of cost optimal calculations in the context of the EPBD' (ENER/C3/2013-414) Final report. 19 November 2015, Project number: BUIDE13705.

[20] 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.

[21] For the value of buildings the findings are positive in terms of values. It is noted that this is a positive result for existing owners of buildings but not for renters or new entrants to housing markets.

Table V.1 Key results from the analysis (EU level, scenario S3)

	Direction of impact	Key results, difference from no-change scenario in 2030
Economy and labour market	Positive	GDP increases by up to 0.6% Employment increases by up to 0.25% Substantial negative impact upon extraction utilities (and those Member States where this sector is largest)
Health and well-being	Positive	Annual health cost savings of €180m Annual productivity gains around €10m
Environmental impact	Mostly positive	Energy consumption reduced by 7% GHG emissions reduced by 6% Material consumption increased by 1.2% Land and water use reduced slightly
Social aspects	Positive	Potentially 1.5m-8m households removed from energy poverty depending on the extent to which Member States adapt energy poverty alleviation as a specific policy target.
Public budgets	Slightly positive	Increase in annual public balances of 0.1% of GDP
Industrial competitiveness	Positive	Potential increase in annual output of insulation and flat glass sectors, €5-10bn
The value of buildings	Positive	Potential increase in sales values (up to 35%) and rental values (up to 12%)

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 EPBD and related policies must be implemented and properly enforced; otherwise results will be weaker across all impact areas.
- There is an important question about how energy efficiency investment will be financed. In the scenarios presented in this report it is mainly self-financed by households. Other possibilities, for example linked to a revised Energy Efficiency Directive, could result in greater economic benefits.
- Competitiveness and economic benefits will be maximised if the energy efficient equipment and materials are manufactured domestically.
- Benefits for social welfare will be increased greatly if the EPBD recast includes requirements to improve the energy performance of existing buildings and if these improvements to buildings are targeted at households that suffer from energy poverty.

In conclusion, the results from this study outline many potential benefits of improving energy efficiency in Europe, and improving energy efficiency in buildings in particular. The challenges for policy makers relate to an efficient implementation of an enhanced EPBD and ensuring enforcement.

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.

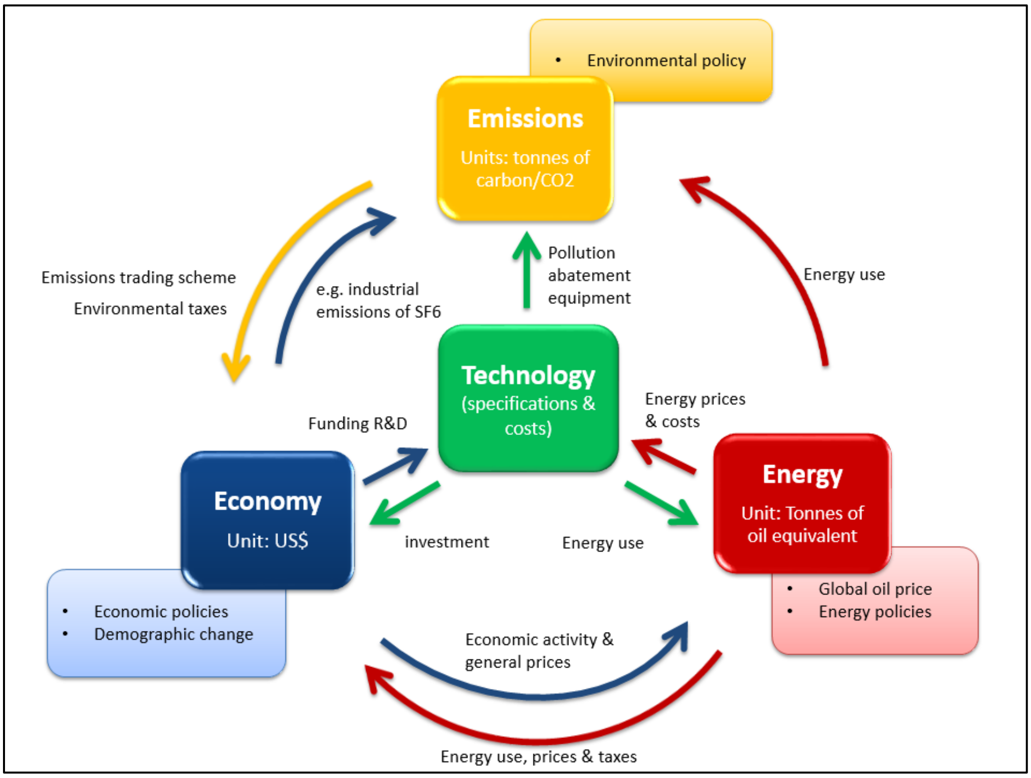
E3ME's historical database covers the period 1970-2014 and the model projects forward annually to 2050. The main data sources for European countries are Eurostat and the IEA, supplemented by the OECD's STAN database and other sources where appropriate.

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[22] (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.

[22] 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 assessment of the Energy Efficiency Directive. The inputs to the model are:

- estimates of energy savings (see Part III Section 2)
- estimates of the cost of these savings (also in Part III Section 2)

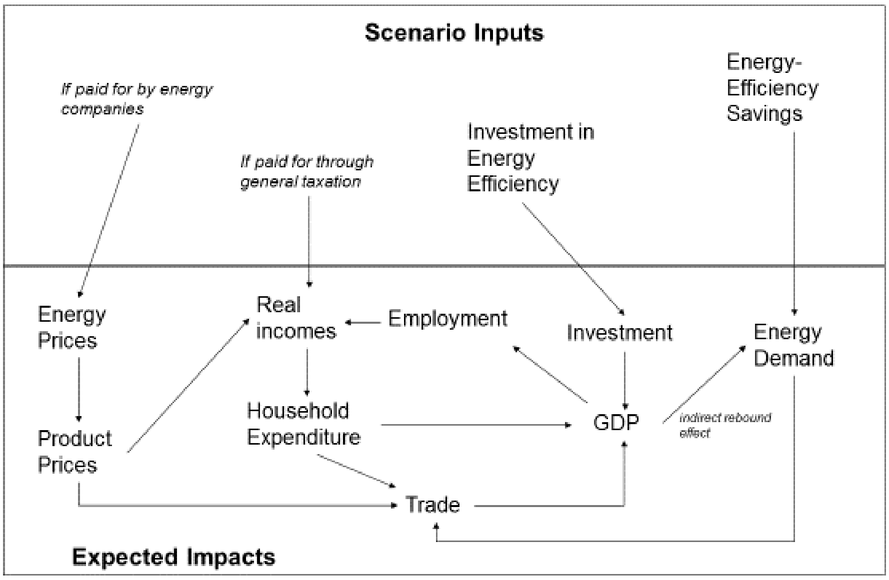
- information about which energy carriers have been displaced (mainly gas or electricity for buildings, forming part of the estimates above)
- an assumption about how the energy efficient goods are financed

The first two of these inputs are derived from the results from the study carried out by Ecofys[23], further disaggregated using the approach described in Part III Section 2.

The assumption about financing is determined as part of the scenario design. In general, it is assumed that the investment is made by the occupants of buildings, reflecting the revised and better enforced regulation. 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. At present the measures are financed privately so it is household real incomes (net of the investment costs) that are affected.

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

[23] Boermans, T, Grözinger, J, von Manteuffel, B, Surmeli-Anac, N, John, A (Ecofys) Leutgöb, K and Bachner, D (e7) (2015) 'Assessment of cost optimal calculations in the context of the EPBD' (ENER/C3/2013-414) Final report. 19 November 2015, Project number: BUIDE13705.

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 early 2014 used a different approach to assess the effects of energy efficiency. In the previous exercise the PRIMES energy systems model was used to assess the consequences of energy efficiency programmes on Europe's energy system.

While this approach was able to take advantage of the detailed representation of the energy system in PRIMES, it meant that in the economic analysis there was no endogenous treatment of energy demand, i.e. the indirect rebound effect was not included in the analysis. As the rebound effect is the source of some of the multiple benefits of energy efficiency, this approach is less appropriate for the current study. For example, if lower energy bills lead to 'comfort taking' and homes being heated to higher temperatures, this will have a positive social impact but will lead to higher levels of energy consumption.

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). However, we do not impose 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 case 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 sets E3ME apart from the more common CGE macroeconomic modelling approach, where crowding out is strictly enforced and outcomes are determined by supply-side factors.

2.1 Representation of buildings in E3ME

E3ME does not have a 'buildings' sector represented explicitly. Its energy-using categories are based on the sectors distinguished in the IEA energy balances. Most of the use of energy in buildings is covered by the categories 'Residential' and 'Commercial and public services'. The latter includes both retail and office premises.

The sectoral linkages are important in determining economic effects. Reduced spending on energy allows households to spend more on other products, potentially boosting the domestic economy. Likewise, reduced spending on energy by the offices and retail premises will lead to lower bills for service companies which could be reflected in lower prices for final goods across the economy.

Modelling changes to the EPBD

Changes to regulations on efficiency are modelled in the same way as other improvements to energy efficiency (see sections above). The main inputs to E3ME are estimates of the energy savings, cost, the displaced fuel and an assumption about who pays. The energy savings (in mtoe)[24] and costs (in m euros) are derived from the bottom-up analysis and the database of savings potentials, following the assumptions of the defined scenarios.

2.2 The seven impact areas in E3ME

The results from E3ME are fed into the analysis for each of the seven 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.

2.3 The reference scenario

In this study the E3ME reference case was calibrated to match the PRIMES 2015 Reference case. 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 case 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[25] and have not been revised from previous studies. We do not describe the process further here.

[24] Million tonnes of oil equivalent.

[25] '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 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 Background

The assessment of the macroeconomic effects of energy efficiency programmes in this report builds on earlier work undertaken for DG ENER for the project 'Assessing the Employment and Social Impact of Energy Efficiency'. The findings of the study are summarised in Box 0.1.

Box 0.1 Assessing the Employment and Social Impact of Energy Efficiency

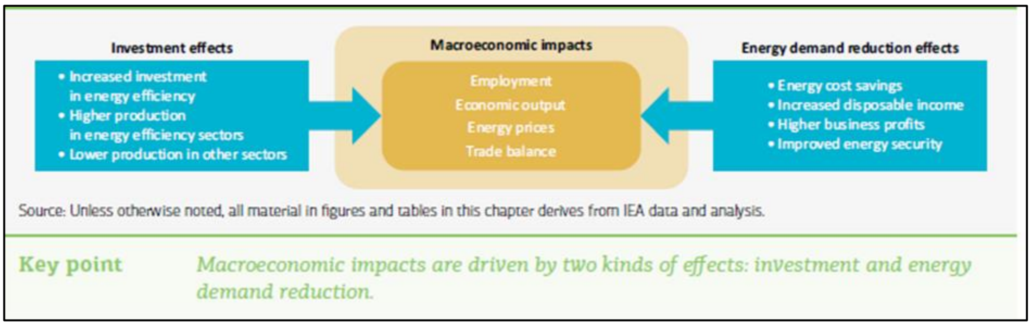
Some of the main findings of this study in terms of economy and labour market outcomes are summarised as follows:

- The 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) 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 could produce an increase in employment at EU level of 0.7-4.2m by 2030.

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

The report includes a list of indicators that is expanded considerably from standard economic analyses. The choice of indicators accounts for some of the main elements that are included in the conceptual framework developed by IEA (2014) to analyse the multiple benefits of energy efficiency.

Figure 0.3 Summary effects macroeconomic impacts energy efficiency



Source(s): Reproduced from IEA (2014).

2.2 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 0.1 provides some references, along with a description of their main findings.

Table 0.1 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 a 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.

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

2.3 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 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[26].

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

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

- 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 – 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.

Box 0.2 provides an overview of the different methodological approaches that could be employed to assess the rebound effect.

Box 0.2 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'
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 0.2 provides an overview of some previous assessments of the rebound effect across various economies.

Table 0.2 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 Effects for UK Households	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 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	Netherlands	Based on a sample of 560,000 households, this paper reports the existence of a rebound effect

	Household Behaviour: The Rebound Effect in the Residential Sector		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%.

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 that could be available 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.

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 capacity will be delayed or cancelled. However, usually this effect is smaller than the investment in energy efficiency.

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.

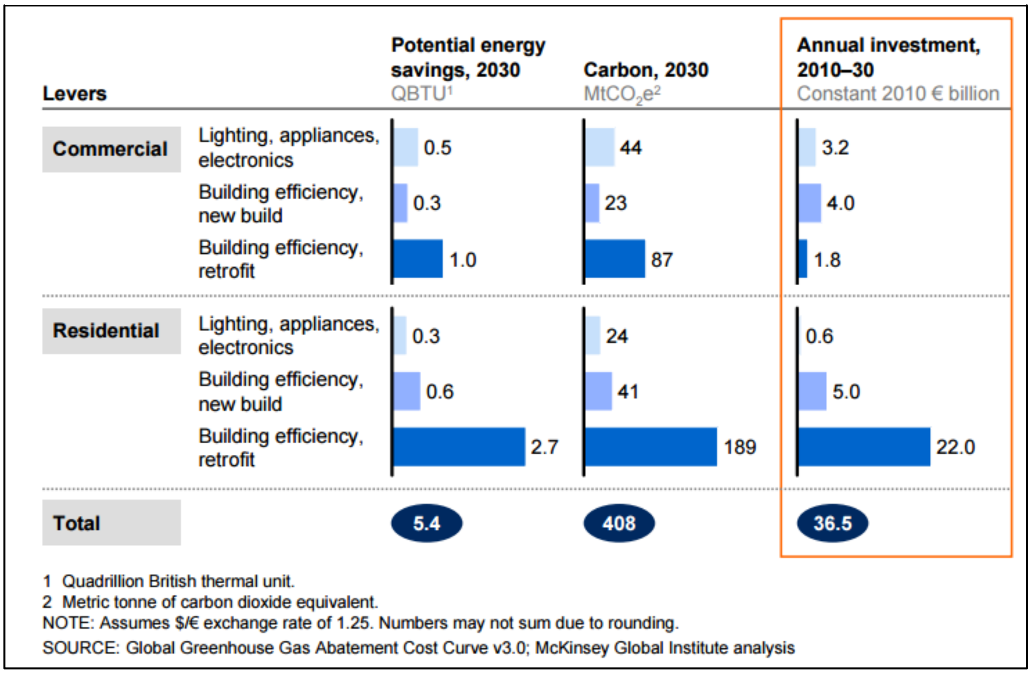
Crowding out of investment

However, the study also outlines the importance of the assumption about how capital markets work. Although the direct investment in energy efficiency is funded through higher taxes, the modelling by Cambridge Econometrics (using E3ME) allows for additional lending to take place as well, meaning that additional investment can boost economic activity. In contrast, the CGE modelling approach, represented by the GEM-E3 model in the same report, assumes full capacity in capital markets, meaning that higher investment in energy efficiency must be at the expense of investment elsewhere in the economy. Under CGE conditions therefore, investment and GDP would not be expected to increase.

Bottom-up assessment of investment requirements

Separate research undertaken by the McKinsey Global Institute (2012) concludes that increasing energy efficiency globally holds the potential to generate up to €37 bn of annual investment over the period 2010-2030. Further details are provided in Figure 0.4.

Figure 0.4 Potential increases in investments related to energy efficiency



Source(s): Reproduced from McKinsey Global Institute (2012).

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, we can expect an improvement in the trade balance of those countries that produce and export the equipment which is needed for the transformation of current infrastructure and buildings into more efficient ones. Moreover, energy efficiency improvements will produce a decline in the amount of fuel / energy which is required and imported. These two elements could impact on international trade. Another element that will reinforce this 'circuit' is the subsequent effect of changes in energy demand on prices (see below). The issue of energy security is clearly linked to international trade.

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[28]. 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 costed €300 bn to the EU (IEA, 2014).

[28] See, also, IMF (2014), for further discussion and examples of the effects of a decline in oil prices. However, when considering energy efficiency in buildings it is gas prices that are more likely to be affected.

Additionally, low domestic energy prices could contribute to improved competitiveness by reducing production costs[29] if they are not reflected in other countries. Such a result is perhaps most likely for electricity.

2.4 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).

Typology of effects

In terms of job creation, Box 0.3 elaborates on the two dimensions that need to be addressed when analysing employment effects.

Box 0.3 Employment effects of energy efficiency policies

As explained in the proposal, the employment effects that result from energy efficiency can be categorised according to the following typology:

- Gross/net effects – Gross effects represent the number of jobs created in the sector. They could be obtained for example by estimating the number of jobs associated with fitting insulation to a house and then multiplying by the number of houses. Net effects also take into account jobs that are displaced from elsewhere in the economy. For example, if a house consumes less energy, then there may be fewer jobs in the energy supply sector.

- Direct/indirect effects – Direct effects include only the energy efficiency sector in question. Indirect effects also include the supply-chain effects and jobs that are created (or lost) in the wider economy.

Source: Authors' elaboration.

Some empirical evidence

To illustrate this point, Table 0.3 summarises some of the findings of previous research on the impact of energy efficiency improvements 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

[29] 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.

			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. employment, income, and investment	US	The fiscal Year 2005 Building Technologies programme could create 446,000 jobs by 2030 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. €301 bn 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.

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

2.5 Other labour market indicators

When studying the employment impacts of investing in energy efficiency in buildings it is important to analyse the quality and the sustainability of the jobs that are created. A quantitative assessment of job quality can be estimated, based on the model results by means of two indicators:

- sectoral employment
- sectoral wages

This can be supplemented by additional information from the EU LFS, which could address some of the factors outlined in the Laeken indicators[30]. It is possible to develop an index of job quality by combining the available information. Factors that could be included (assuming data availability) are:

- educational attainment (high medium or low)
- permanency of job (temporary/permanent)
- type of Job (full time/part time)
- hours worked (up to 47/48 or more, derived variable)
- non-standard hours of work
- atypical Work (yes/no – never)
- receipt of education / training over the past four weeks

A key contribution to the issue of job creation is Meijer et al. (2012). This report explores the job creation that could result from energy renovation of the EU housing stock. It also pays special attention to the case of the Netherlands, Germany, the United Kingdom and Ireland. In general terms, the literature review conducted for that report finds that employment creation varies between six new jobs per €1 million investment (in the Netherlands) to 16/17 new jobs (in Germany and Ireland). Moreover, this report discusses the issue of qualifications and skills mismatches. It has been acknowledged in the existing literature that employers face difficulties in finding employees who have the appropriate skills to develop certain occupations (see, Meijer et al., 2012 for further details).

[30] See ec.europa.eu/social/BlobServlet?docId=2267&langId=en

Box 0.4 Are energy efficiency jobs ´good´ jobs?

The ACEEE factsheet 'Energy Efficiency and Economic Opportunity' provides some insights on the issue of the quality of the jobs that were created in the US related to energy efficiency improvements. The document provides key messages that were identified in some relevant literature in the field:

- In the US case, $1 of avoided utility bill costs is found to have 2.24 times the effect on domestic employment and wages compared to $1 spent on utility bills.
- On average 4% of households' income is spent on home energy costs; however, this proportion goes up to 17% in the case of low-income families.
- Investments in energy efficiency have an immediate impact on employment. However, there is stronger job creation from the additional consumption of energy which is related to savings on energy bills.
- The vast majority of the jobs that are created are local. In other words, many of them consist of installation or maintenance of equipment locally.
- Energy efficiency programmes should include formally an evaluation of non-energy benefits, such as job creation and the development of new local business.
- Energy efficiency generates jobs that are available for workers without higher education. For example, a higher percentage of energy efficiency jobs can be taken by low-skilled workers in the energy efficiency sector than in the fossil fuel and utility sector (48% versus 42%).
- Specifically, energy efficiency programmes generate more jobs with above-average earnings potential for low-credentialed employees (29% versus 13% for the fossil fuel sector). Moreover, research reveals that 49% of clean energy jobs are developed by workers who hold a high school diploma or lower qualification.
- Another important issue to consider is remuneration. ACEEE reports that the average wage is $4,900 above the national median and 75% of employees have middle-wage employment (compared to 20% of the national median).

Source(s): Authors' elaboration based on ACEEE. The relevant factsheet is available at: http://aceee.org/files/pdf/fact-sheet/ee-economic-opportunity.pdf

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 actively 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.

2.6 Energy security

Another important area to monitor the impact of energy efficiency investments is energy security. Improvements in energy efficiency could lead to a reduction of energy imports which make a country less vulnerable to international shocks in energy prices or disruptions to energy supply. As suggested by European Commission (2013), three broad areas of energy dependence need to be considered:

- Security of energy supply – which traditionally is defined as follows: 'Energy security means uninterrupted availability of energy sources at an affordable price while respecting environmental concerns' (European Commission, 2000; IEA)[31].
- Energy and carbon intensity – energy intensity is defined as the amount of energy used per unit of GDP.
- Contribution of energy products to trade – the share of energy products which are traded and the existence of current account imbalances requires detailed analysis.

Empirical evidence

The European Commission (2013) report also explores the issue of energy dependence in the context of each Member State and reports several energy dependence indicators related to security of energy supply. A summary of the relevant indicators is shown in Table 0.3.

[31] The report 'Building Efficiency. Reducing Energy Demand in the Commercial Sector' also supports the argument that energy efficiency improvements in the commercial sector contributes to reduced energy dependency. This report is available at: http://www.policyconnect.org.uk/wsbf/sites/site_wsbf/files/report/403/fieldreportdownload/wsbfreport-buildingefficiencypdf.pdf

Table 0.3 Energy dependence indicators related to the security of energy supply

Energy dependence indicators related to the security of energy supply dimension*

	Import dependency				HHI energy imports			Non-EEA share of imports			Gross inland energy consumption, shares by fuel					
	Gas (%)	Oil (%)	Solid fuels (%)	**Total Primary (%)**	Gas	Oil	Solid fuels	Gas (%)	Oil (%)	Solid fuels (%)	Gas (%)	Oil (%)	Nuclear (%)	Renewables (%)	Solid fuels (%)	HHI energy sources
	2006-2010	**2006-2010**	**2006-2010**	**2006-2010**	**2006-2010**	**2006-2010**	**2006-2010**	**2006-2010**	**2006-2010**	**2006-2010**	**2006-2010**	**2006-2010**	**2006-2010**	**2006-2010**	**2006-2010**	**2006-2010**
AT	83	92	97	67	0.40	0.13	0.37	86	54	10	22	40	0	25	11	0.28
BE	100	98	96	78	0.28	0.17	0.22	25	56	90	26	41	21	3	7	0.29
BG	94	100	34	47	1.00	0.46	0.42	100	87	98	14	24	22	6	37	0.27
CY		101	95	99		0.11	0.94		52	100	0	96	0	3	1	0.92
CZ	97	97	-16	27	0.66	0.29	0.72	78	72	8	16	22	15	5	44	0.29
DE	84	95	38	60	0.32	0.13	0.13	45	56	82	23	34	11	8	24	0.24
DK	-97	-64	94	-24		0.18	0.24		21	90	21	39	0	17	22	0.27
EE	100	66	0	22	1.00	0.28	0.91	100	55	100	12	19	0	12	59	0.42
ES	100	100	78	80	0.20	0.07	0.19	92	81	99	23	48	11	8	10	0.31
FI	100	95	65	53	1.00	0.54	0.42	100	79	91	10	29	16	24	17	0.21
FR	98	98	100	51	0.18	0.07	0.15	52	72	84	15	33	42	7	5	0.31
EL	100	100	4	71	0.52	0.16	0.44	100	90	85	10	55	0	6	27	0.39
HU	83	81	42	61	0.61	0.67	0.27	93	85	57	39	28	15	6	11	0.27
IE	92	99	63	88	1.00	0.49	0.32	0	7	86	28	53	0	4	15	0.38
IT	90	92	100	85	0.23	0.13	0.18	82	94	95	38	43	0	8	9	0.34
LT	100	95	91	63	1.00	0.88	0.81	100	98	97	30	32	23	12	3	0.28
LU	100	100	100	97	0.25	0.57	0.38	50	0	100	25	63	0	3	2	0.46
LV	93	98	100	57	1.00	0.26	0.88	100	48	97	30	32	0	32	2	0.29
MT		100		100							0	100	0	0	0	1.00
NL	-64	95	112	36	0.35	0.08	0.20	18	63	94	42	42	1	3	9	0.36
PL	69	99	-11	28	0.62	0.60	0.40	91	83	76	13	26	0	6	56	0.39
PT	100	99	100	81	0.47	0.07	0.35	100	80	95	16	52	0	18	10	0.35
RO	25	50	24	26	0.92	0.31	0.22	100	91	72	32	26	7	14	23	0.24
SE	100	99	89	37	1.00	0.23	0.19	0	37	83	2	28	32	32	5	0.28
SI	100	99	21	51	0.37	0.23	0.56	81	11	80	12	36	20	12	21	0.25
SK	100	91	84	65	0.99	0.67	0.29	100	84	41	28	20	23	6	22	0.23
UK	25	8	70	24	0.44	0.22	0.27	16	34	97	38	36	8	3	16	0.30
EA											24	39	15	8	13	0.26
EU27	62	83	41	54	0.18	0.09	0.13	60	66	86	24	36	14	8	17	0.25

*For sources and indicators, see Annex 1. Please note that colours only indicate top and bottom values and have no qualitative assessment attached.

**Total import dependency does not include electricity. Data for import dependence in solid fuels come from DG ENER's Country Factsheets, while all the other data come from Eurostat.

Source(s): Reproduced from European Commission (2013).

Some highlights of the analysis undertaken by European Commission (2013) are listed as follows:

- Greece is one of the most vulnerable countries in the EU since half of its energy consumption relies on imported oil from outside the EEA.
- Ireland is included among one of the five most vulnerable countries of the EU due to its high import dependency and its reliance on oil.
- Malta and Cyprus rely heavily on oil imports and are therefore quite vulnerable to external shocks. Another small country that could face important concerns to secure energy access is Luxembourg, which lacks domestic energy sources.
- The Czech Republic and Romania are among the least dependent countries on external energy supply.
- Portugal has reduced substantially its energy dependency through investing in renewables.

Linking to a macroeconomic model

The following indicators may be derived from the results of a macroeconomic model such as E3ME:

- import dependence (Total TJ imported / total TJ used) = (%)
- total energy used / GDP
- value of energy imports or exports (in USD terms) / GDP

These could be combined into a single index but it may be worthwhile maintaining different measures so as not to hide the complexity of the issue. In addition, it is necessary to consider qualitative factors when assessing energy security. Box 0.5 provides an example on how European energy supply could change in the future.

Box 0.5 How EU energy security could change in the future*

- In September 2014 several European countries suffered restricted gas supply from Russia. These included Austria, Poland, Romania, Slovakia and Ukraine.
- The EU could replace Russian gas with Algerian, Norwegian and Qatari gas. However, a change in gas suppliers would require additional spending on new infrastructure.
- In the long run, potential new EU suppliers could be Azerbaijan, the United States, Iran, Mozambique, Australia, Israel and Turkmenistan.
- Any measures to reduce gas consumption in buildings would contribute to improved energy security. Reductions in electricity consumption in buildings would also improve energy security if it displaces power generation from gas.
- Shale gas reserves across Europe could contribute to reducing energy dependency.

* See, also, European Commission (2014a) for further details on the impact of the Ukraine crisis and European energy reliance on Russian gas.

Source: European Commission (2014a).

2.7 Spill-over effects

Energy efficiency programmes can lead to so-called spill-over effects. These are secondary effects that may be far removed in time or space from the initial or intended outcomes of the energy efficiency programmes. To conclude the discussion of the impacts of energy efficiency measures on the economy, some insights on the existence of spill-overs among individuals and sectors that result from energy efficiency are provided in Box 0.6.

Box 0.6 Spill-over effects and energy efficiency programmes

- Spill-overs result from customers (households, firms, etc.) that invest in energy efficiency measures, even though they were not a targeted group by the energy efficiency programme under consideration. In other words, their motivation to invest in energy efficiency comes from programme-related information and marketing campaigns (EPA, 2008).
- Research carried out by Bosetti et al. (2007) suggests that international knowledge spill-overs have a negative impact in energy efficiency R&D. This effect is found to be more intense in the case of high-income countries.
- The initial effect of energy efficiency improvements may be either reinforced or partly offset by the presence of positive or negative behavioural spill-overs that result from individual behavioural responses. Positive spill-overs occur when the utilisation of a particular technology that is less energy-intensive induces further investment to adopt another energy-saving technology. For example, a homeowner who improved the insulation of his home may then decide to undertake further investment to replace the heating system. Alternatively, it is possible that an individual who has modernised their heating system considers that there is no need to make further improvements and does not modify behaviour (see, Thøgerson and Crompton (2009) who have explored the issue of spill-overs in the case of pro-environmental behaviours).
- Further spill-over effects from the buildings sector (both residential and commercial) to other sectors such as transportation or industry could be generated if suitable energy programmes are implemented, e.g. through developing technologies such as batteries that can be applied in different settings. An example of this type of comprehensive measure is the ecoENERGY Efficiency programme implemented in Canada (Natural Resources Canada, 2012). Other examples of programmes that have been implemented and have a multi-dimensional focus are the 20-Year Energy Efficiency Development Plan for Thailand and the National Green Technology Policy 2009 in the case of Malaysia (see, OECD (2014) for further details on these programmes).

Source: Authors' elaboration.

3 Health and well-being

3.1 Key issues and scope of work

Properly designed actions to improve building energy performance can have major co-benefits for public health. Living in cold and poorly ventilated homes is linked to a range of health problems, and retrofits that improve indoor temperatures may have positive impacts on mental health and incidences of cardiorespiratory diseases. However, there are risks involved with the possibility of poorly designed interventions leading to unintended consequences. Energy efficiency retrofits that alter the fabric heat loss can also increase the air tightness of the dwelling and can 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 improved housing energy performance, we focus on two main issues that particularly impact public health:

- indoor air quality, resulting of a variety of parameters; among which VOC pollutants (such as benzene) and air tightness are key parameters
- temperatures and ability to keep homes adequately warm

3.2 Literature review and data sources

The literature review focuses on existing literature on the health benefits of energy efficiency and impacts in terms of physical indicators and monetary indicators. The main sources reviewed in detail are synthesised in Table 0.4. Table 0.4 also gives a brief summary of the type of information provided by each source and its key findings.

Table 0.4 Data sources for health and well-being

	Reference	Type of information / data to collect / findings
1	UCL institute of Health Equity, 2011, The Health Impacts of Cold Homes and Fuel Poverty	Direct and indirect health impacts of cold homes. Examples are provided below: * Excess winter deaths are almost three times higher in the coldest quarter of housing than in the warmest quarter. * More than 1 in 4 adolescents living in cold housing are at risk of multiple mental health problems compared to 1 in 20 adolescents who have always lived in warm housing.
2	International Energy Agency, 2014, Capturing the Multiple Benefits of Energy Efficiency	* Mapping of the diverse impacts of energy efficiency on health & well-being and their links with other macroeconomic effects. * Ratios about health benefits of energy efficiency. For example, the report highlights several studies that quantified total outcomes found benefit/cost ratios as high as 4:1 when health and well-being impacts were included, with health benefits representing up to 75% of overall benefits.
3	UCL institute of Health Equity, 2014, How to Improve Health and Well-being through Action on Affordable Warmth	* Health and well-being impacts of affordable warmth (physical health, mental health). * Ratios and figures at UK level, e.g. investing £1 in improving affordable warmth delivered a 42 pence saving in health costs for the healthcare system. * List of outcome indicators linked to action on energy poverty and cold homes.
4	NHBC foundation, 2009, Indoor Air Quality in Highly Energy Efficient Homes – a Review	* Review of current research and state of the art for ventilation performance in dwellings and of construction and ventilation provision in highly energy efficient homes. * Impacts of energy efficiency on indoor air quality. * Influence of air quality and other factors on occupant well-being.
5	Fisk, 2000, Health and Productivity Gains from Better Indoor Environments and their Relationship with Building Energy Efficiency	* Quantification of health effects due to better indoor environments in terms of productivity.
6	Bone, 2010, Will Drivers for Home Energy-efficiency Harm Occupant Health?	Review of the influence of energy efficiency on health, mainly due to insufficient indoor air quality if ventilation is insufficient.
7	World Health Organization, 2011, Environmental Burden of Disease	A method guide to the quantification of health effects of selected housing risks in the WHO European Region.

	Associated with Inadequate Housing	
8	CSTB, Anses, 2014, Étude exploratoire du coût socio-économique des polluants de l'air intérieur	Socio-economic valuation of the health impacts of indoor air pollutants in France.
9	University of Florida, 2015, Energy Efficient Homes: Indoor Air Quality and Energy	Links between energy efficiency and indoor air quality.
10	Cambridge Econometrics, 2015, Assessing the Employment and Social Impact of Energy Efficiency	Qualitative and quantitative analysis assessing some economic and health effects of energy efficiency in Europe.
11	Gonand, 2015, La bataille de l'air pur, nouvel enjeu écologique et économique du siècle	* Productivity gains linked to better indoor air quality (productivity increased by 3%-8% due to indoor air quality). * Statistical value of life (mean value of €3 million).
12	Ürge-Vorsatz, 2009, Counting good: quantifying the co-benefits of improved efficiency in buildings	* Review of existing literature on health benefits of energy efficiency and main results in terms of physical indicators and monetary indicators. * Effects of better indoor air quality on productivity in monetary terms.
13	Šadauskienė, 2014, Impact of Air Tightness on the Evaluation of Building Energy Performance in Lithuania	* Methodology for the calculation of energy efficiency of buildings, while taking into account the air tightness of the buildings. * Estimation of the air tightness level of different energy classes of buildings.

The literature review provides figures, ratios and statistics on the relationships between energy efficiency improvement scenarios and physical outcomes such as the rate of mortality, morbidity, etc. and the monetary valuation of these outcomes.

Its key objectives are to:

- Identify and quantify causal effects between energy efficiency and selected technical parameters (temperature, air tightness level, VOC concentrations, mould and dampness and daylight).
- Identify and quantify causality effects between selected technical parameters (temperature, air tightness level, VOC concentrations) and health outcomes.
- Identify and select ratios for the monetary valuation of health and well-being effects of improved indoor air quality.

Quantifying the effects of energy efficiency on technical parameters

Several sources in Table 0.4 provide data on the relationship between buildings energy efficiency improvement and physical parameters that directly influence health and well-being. The relationship between energy efficiency and air tightness is very well documented. Regarding VOC concentrations, fewer studies have been identified at this stage, although some indirect links are well documented (e.g. impact of air tightness level on pollutant concentrations). The analysis of such indirect impacts helps to overcome the potential lack of data regarding any direct relationship between energy efficiency and VOC emissions / concentrations.

Monetary valuation of health and well-being effects

Literature is widely available on the monetary/economic valuation of health effects of outdoor air pollution. However very few publications carry out the valuation of health effects of indoor air pollution, for which no recognised and well-tested methodology exists. Sources 7 and 8 in Table 0.4 have served as a starting point to select and design the most appropriate methodology for evaluating the monetary benefits of reduced morbidity and mortality due to energy efficiency.

We also analyse the effects of health and well-being improvement on productivity. Sources 5, 11 and 12 in Table B.4 provide ratios and evaluations that can be collected and synthesised so as to define an empirical ratio of rate of productivity increase per percentage improvement of indoor air quality improvement.

The linkages between the data sources listed in Table 0.4 and the modelling carried out for this study are shown in Figure 0.5.

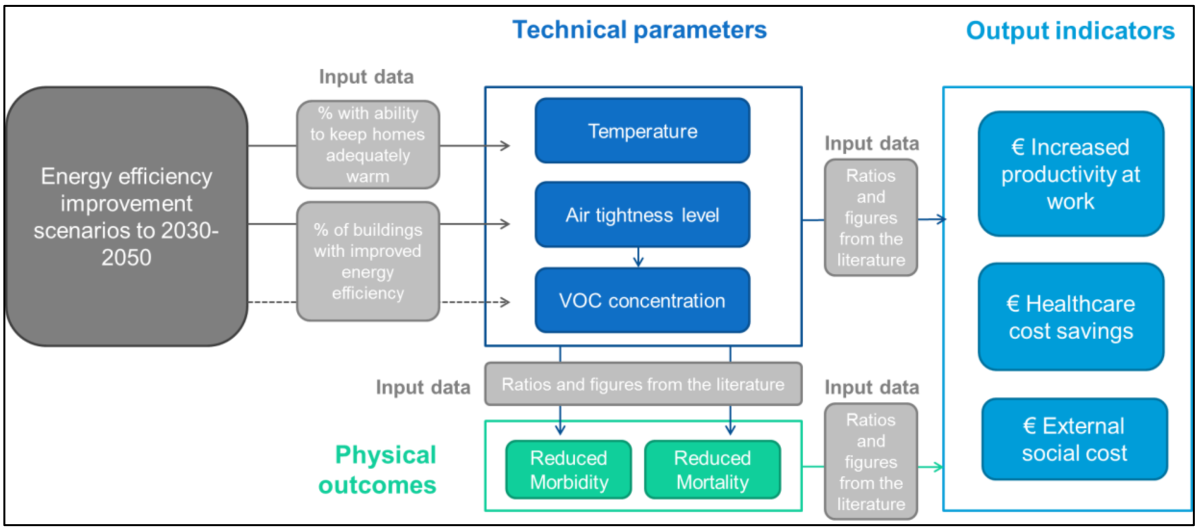
4 Environmental impacts

4.1 Key issues and scope of the work

Energy efficiency improvements can positively affect the environment in several respects. Focusing our attention on the EU's Sustainable Development Indicators (SDIs), the following three themes are relevant:

- Energy and climate change – energy efficiency measures are likely to contribute to

Figure 0.5 Health and well-being indicators



reducing greenhouse gas emissions. An important issue to be addressed is how energy efficiency improvements can alter the path of deployment of different fuels, which eventually affects the overall level of emissions[32]. Focusing on the case of

[32] Emission savings related to natural gas (and other primary fuels) can be estimated by means of coefficients (e.g. from the IPCC). In the case of electricity, emission savings need to be modelled or given by assumption about which type of generation is displaced. It may be reasonable to assume that the marginal fuel is replaced in existing capacity, but lower rates of electricity consumption will also influence future capacity decisions. In addition, it is necessary to take into account feedback from the ETS, as a lower demand for allowances from the power sector will lead to a lower carbon price and greater demand from elsewhere (i.e. a 100% rebound effect).

buildings (both residential and non-residential), investment in energy efficiency could produce a switch between different energy carriers, mainly gas and electricity.
- Sustainable consumption and production (SCP) - this category comprises items such as the emission of local air pollutants, material consumption and waste generation. Energy efficiency measures can potentially reduce the level of emissions of sulphur, particulate matter and other 'local' pollutants (see previous section). The extent to which energy efficiency improvements impact on local air quality depends, at least partially, on subsequent changes in the energy mix, in particular any reduction in the level of coal consumption[33].
- Natural resources – this theme refers to land use, eco-systems and biodiversity. However, the impact of energy efficiency measures in buildings on these indicators is likely to be fairly weak, unless greater energy efficiency leads to a reduction in the use of bio-energy.

The utilisation of monetary values to estimate the impact of energy efficiency is an issue that deserves careful consideration. This practice has been most commonly applied for assessing the effects of local pollutants and insufficient indoor thermal regime on human health (see previous section for more details) and by economists to estimate the 'social cost of carbon'. The utilisation of monetary values to estimate the 'cost' and 'benefits' of energy efficiency can be controversial as it places estimates on the value of human life and natural habitats. Furthermore, it does not deal well with the geographical, social or temporal distribution of impacts and suggests a false degree of reversibility (a damaged eco-system cannot be always be recovered). Nevertheless, the practice of estimating the monetary value of various impacts of environmental problems and energy efficiency programmes is standard in cost-benefit analysis and can provide a consistent basis for comparing policies.

4.2 Literature review and data sources

The purpose of this literature review is to provide some insights on the impact of energy efficiency on the wider environment. The discussion below is structured around the three themes discussed above.

Climate change

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.

The main sources of the relevant literature and their key findings are synthesised in Table 0.5.

[33] However, two issues need to be explored carefully: a) some energy efficiency measures could increase minerals deployment; and b) waste generation can be boosted if economic activity accelerates as a result of energy efficiency improvements.

Table 0.5 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.
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 emissions 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 equivalents 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 improve energy efficiency could reduce CO_2 emissions.
9	SEAI, 2011, Economic Analysis of Residential	Ireland	The Home Energy Saving (HES) scheme is expected to lead to CO_2 emissions reductions

	and Small-Business Energy Efficiency Improvements		of approximately 1.5 tonnes per dwelling. The SME Programme is expected to result in CO_2 emissions 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 Technology Fund in Renewable Energy and Energy Efficiency Market in Turkey	Turkey	This report presents the main results of an assessment of those investments in energy efficiency which were financed by the CTF 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.

Consumption and production

Resource-energy issues have attracted growing attention in view of several challenges such as water shortages, waste generation, rising energy prices, higher material costs and global warming – now often dubbed the 'nexus' when land use and food production are included as well (see below). All these factors can impose constraints on future consumption and production patterns. The key to understanding the nexus is developing the linkages between the different component parts, as a solution to a problem in one part of the nexus could simply shift that problem elsewhere.

Regarding consumption and production, we are interested in energy efficiency measures that will reduce energy demand as well as the demand for water, materials, and other resources. Subsequently, a reduction in the generation of by-products such as waste and pollutants which are associated with production processes will also likely take place. In many cases (e.g. behavioural change) the relationship is obvious but it may be less clear-cut in cases where energy efficiency measures require investment in material-intensive products. In addition, the final impact remains unclear in view of a potential rebound effects that may alter consumption and production, as discussed in Appendix B Section 2.

Table 0.6 provides an overview of a selection of studies that have contributed to the debate.

Table 0.6 Selection of reports on energy and SCP

	Reference	Scope	Main findings
1	EPA, 2007, Guide to Resource Planning with Energy Efficiency	US	This report discusses the effects of energy efficiency in terms of GHG reductions. Specifically, positive effects can be expected from a more efficient deployment of energy.
2	Rio Cariillo and Frei, 2009, Water: A key resource in energy production	Spain	This paper explores the two-way relationship between water and energy. This research suggests that the energy mix of the current economy is likely to be more water consumptive in 2030 compared to 2005 levels.
3	Shenot, 2013, Quantifying the Air Quality Impacts of Energy Efficiency Policies and Programs	US	This study attempts to quantify the impacts of energy efficiency in terms of air quality. It calls for more attention to energy efficiency policies to improve air quality.
4	SEAI, 2011, Economic Analysis of Residential and Small-Business Energy Efficiency Improvements	Ireland	This study suggests that the estimated savings from reduced levels of local air pollutants (NOx, SOx, VOCs and particulate matter) will be around €71 bn by 2030.
5	DEFRA, 2014, Energy from Waste. A Guide to the Debate	UK	This document emphasises the potential of waste as another source of energy and encourages energy recovery.
6	IRENA, 2015, Renewable Energy in the Water, Energy & Food Nexus	Global	This report focuses on the potential benefits from large-scale renewable energy generation in terms of reduced demand for water and increased food security.
7	FAO, 2014, The Water-Energy-Food Nexus: A new approach in support of food security and sustainable agriculture	Global	This study highlights the interlinkages between energy generation and water and food supply.
8	IISD, 2013, The Water–Energy–Food Security Nexus: Towards a practical planning and decision-support framework for landscape investment and risk management		This paper sets out the key role that land use has in determining outcomes for the water, food and energy systems.

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

Natural resources

As noted previously, a possible link between energy efficiency improvements and the deployment of natural resources occurs in terms of land use. Despite the complexity of this relationship (that runs both ways), we have identified two main issues that have been covered in the existing literature.

Specifically, there is a branch of the literature that focuses on how urban planning can contribute to reducing automotive transport which will affect energy consumption and, subsequently, emissions. Higher density buildings development will not only lead to lower direct land use requirements, but also to lower demand for transport fuels and (assuming a fixed biofuel share greater than zero) a lower demand for land for energy crops.

Some contributions that have focused on the relationship between energy and land use are listed in Table 0.7.

Table 0.7 Literature review on energy efficiency and land use

	Reference	Scope	Main findings
1	Sharpe, 1980, Improving Energy Efficiency in Community Land-Use-Transportation Systems	Australia	Adequate planning could lead to 40% energy savings in the case of some large cities. This study also finds that sub-centre developments are preferred to satellite developments from an energy efficiency perspective.
2	GAO, 1981, Greater Energy Efficiency Can Be Achieved Through Land Use Management	US	This report emphasises the role of land use and planning to achieve energy efficiency. Specifically, it highlights the importance of 'smart' land use management that aims to reduce automobile transportation and the construction of energy-intensive infrastructure.
3	World Bank, 2010, ECO_2 Cities: Ecological Cities as Economic cities	Developing countries	This book provides several examples of how some cities in countries such as Brazil and China have implemented measures to promote an efficient use of energy through land use planning. Overall, these measures have also contributed to improved air quality.
4	Malekizadeh et al., 2013, To Improve Energy Efficiency via Car Driving Deduction by Land Use Planning	Malaysia	This study concludes that highly populated areas can benefit from greater utilisation of public transportation services as a way to reduce energy consumption and pollution.
5	Shirgaokar et al., 2013, Integrating Building Energy Efficiency with Land Use and Transportation Planning in Jinan, China	Jinan (China)	This report suggests that energy efficiency can be improved substantially by a more holistic approach to building and urban design, land use and transportation.

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

Energy efficiency can affect land use by influencing the demand for biofuels and, subsequently, the amount of land devoted to biofuels production. The debate on the use of biomass for energy has typically focused on transport applications, but power generation from biomass (including waste) is expected to increase considerably in the coming decades, in part to meet higher electricity demand from buildings. The main concerns regarding biofuel production and consumption are listed below[34]:

- The 'food versus fuel' dilemma – there is no consensus regarding the cause of rising food prices in recent times. However, increasing biofuel production, urbanisation and the process of financialisation of agricultural markets are considered as possible explanatory factors for this trend.
- Land availability – land scarcity could compromise what may be produced and employed for biofuel generation and non-fuel demand.
- Environmental impacts – the utilisation of some modern farming methods are known to have negative impacts on the environment, causing pollution, eutrophication, water shortages and soil erosion as well as other problems.

[34] The European Biofuels Technology Platform website provides more details on the discussion of these issues. Available at: http://www.biofuelstp.eu/sustainability.html#enviro

- 'Indirect Land Use Change (ILUC)' effects – increased demand for biofuels results in cropland being repurposed for the production of biofuels. However, since the agricultural produce is still required, some of this activity is displaced to non-cropland such as grasslands and forests. As a result, the ability of this undeveloped land to absorb and store carbon emissions is lost and, as a result, atmospheric emissions levels may increase.

We have not been able to identify any studies that assess the impact of energy efficiency improvements on biofuel consumption. For a better understanding of this relationship from a descriptive point of view, some background reading that provides insights on this issue are listed below:

- European Commission, 2010, Report from the Commission on Indirect Land-Use Change Related to Biofuels and Bioliquids – this report summarises the results of several modelling exercises of various combinations of bioethanol / biodiesel on emissions.
- WWF, 2006, Sustainability Standards for Bioenergy – this document elaborates on the main drivers of bioenergy generation and provides some insights on the issue of sustainability of biomass production.

5 Social aspects

5.1 Introduction to the literature review

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 buildings' energy efficiency policies or 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. If poverty alleviation and health improvements are the overarching policy targets, positive measurements/estimates on either of these indicators (reduction in energy costs or increase in living comfort) provide evidence for successful energy poverty alleviation. However, studies that aim to assess the impact of non-targeted (building) energy efficiency policies rarely differentiate between household types with regard to incurred costs and benefits, unless low-income households are explicitly specified as a target group. The more common approach is to estimate costs and (monetised) savings for different sectors and/or society as a whole (e.g. Clinch et al. 2001).

In this section we discuss the methodologies and findings from a range of studies that have assessed the social impacts of policies and programmes aimed at improving the energy efficiency of buildings. It should be noted here that the focus is almost entirely on residential buildings, as energy efficiency in non-residential buildings is likely to have limited direct impact on social welfare (although some indirect impact may result from employment effects discussed in Appendix B Section 2).

5.2 Detailed findings

The UK Department of Energy & Climate Change (DECC) estimates annually the impact of energy and climate change policies (including those addressing energy efficiency in buildings) on energy prices and energy bills for the following year and up to the years 2020 and 2030. Results for the household sector are based on a representative average demand level for households, derived from historical total domestic consumption (which is assumed to remain constant over the period 2014 to 2030) divided by estimates of the number of households in the UK. A Distributional Impacts Model for Policy and Strategic Analysis (DIMPSA) is employed to account for household heterogeneity with regards to share of expenditure on energy, household composition and type of heating fuel. The estimates of the savings associated with the different measures vary by year and by household characteristics, and are adjusted for comfort taking[35] (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). These changes occurred alongside the hypothesised health benefits (reduced odds of 'fair' or 'poor' self-rated health).

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 provided similar results (Patterson, 2012). The main objective of the ARBED was to reduce energy consumption, particularly among low-income households, by funding the adoption of energy efficiency measures. 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, with additionally 64% stating that since energy efficiency measures were installed their homes felt warmer.

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

[35] For any heat consumption reduction measure or renewable heat pump or insulation measure the savings are adjusted by 15% to allow for comfort taking.

monthly heating expenses from €96 to €16 per dwelling, demonstrating that heating can be affordable even for the lowest-income Hungarian households.

This corroborates the claims of a recent macroeconomic study on building energy efficiency in Hungary, in which the author uses financial cost-benefit analysis to assess the economic outcomes of implementing different building retrofit scenarios based on a residential building stock model and an expenditure based measure of energy poverty in Hungary (Tirado-Herrero 2011). While his results indicate that it may be possible to eliminate energy poverty in Hungary altogether by implementing the deep building retrofit scenario, the analysis unfortunately lacks elaboration in regard to the impact chain.

In an attempt to comprehensively assess the impact of different energy efficiency retrofit measures on energy poverty alleviation, SEAI/Combat Poverty (2009) compared households who participated in the Irish Warmer Homes Scheme with those who did not participate in the scheme. The study used a broad mix of indicators for energy poverty, including measures of fuel and health expenditure as well as subjective measures of the ability for timely payment of energy bills and the ability to afford to heat one's dwelling during winter. While no statistically significant differences between the groups were found in terms of achieved fuel cost savings (approximately £85/household), households in the participants group showed a significant decrease of respondents finding it difficult to pay their energy bills on time, from 48% before to 28% after the intervention (with no significant effect for the comparison group, i.e. 42% to 40%), although wall insulation was the only statistically significant predictor. However, before the implementation of the energy efficiency measures, only 27% of the families with children were able to keep a comfortable temperature at home, while after the interventions this share increased considerably to 71%.

Overall summary of findings

In summary, 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 who are living in low-quality housing.

5.3 Qualitative assessment of interactions with other benefits and indirect impacts

In addition to energy expenditure savings, improvements to building energy efficiency can have other benefits, which may reinforce the positive effect on household budgets. For example, the biggest 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 positively affect educational achievement or work performance (Thomson et al. 2009), thus enabling the uptake of financially more attractive career paths. Health improvements 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. As several studies have shown, occupants of poor quality housing may suffer from social isolation due to feelings of embarrassment regarding their living conditions (Barton et al. 2004; Bashir et al. 2014). Improving indoor comfort levels through measures such as improved insulation can help low-income households to overcome this obstacle and thus reduce social isolation.

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. Although there is a lack of empirical evidence regarding the scope and severity of social dislocation as a result of energy efficiency programmes, there is a risk of 'green gentrification' if the transformation towards a more energy efficient building stock is not accompanied by appropriate legislation or support measures to protect low-income households from being crowded out. 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 (see Appendix B Section 8 for a detailed discussion of this issue).

5.4 Data Sources

The main issue regarding the quantitative assessment of the prevalence of energy poverty and the impact of policies in addressing it is the lack of a common definition within the EU[36] and the consequential lack of coordinated data collection efforts. In general, the debate about how to identify and measure energy poverty centres around two different approaches: an expenditure based approach using actual or required fuel spend or a consensual approach that uses subjective indicators. While there are merits and downsides to either approach, in the present study data availability is a limiting factor with regard to this respective choice. The most appropriate source providing relevant (micro) data for all EU Member States is the EU Statistics on Income and Living Conditions Panel (EU-SILC).

6 Public budgets

6.1 Background

As has been discussed in the existing literature, the effects of energy efficiency on public budgets are complex (IEA, 2014). Quantifying some of the effects could be very difficult due to a high degree of uncertainty, especially when rebound effects, spill-over effects and indirect effects need to be accounted for, e.g. impacts on public health budgets[37]. Other effects, however, can be derived directly from the bottom-up estimate of energy savings, for example:

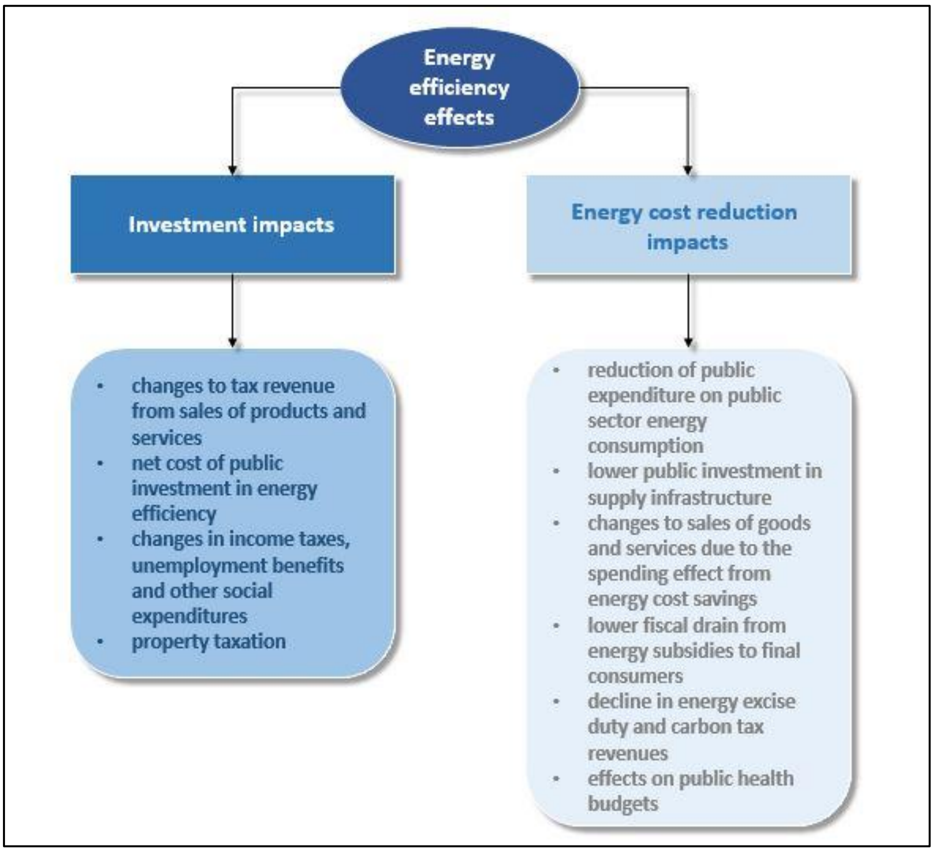
- public expenditure on energy saving equipment
- the value of energy savings to the public sector

Considering IEA (2014) as the starting point for the study of the effects of energy efficiency on public budgets, the main impacts that have been identified in the literature are summarised in Figure 0.6.

[36] Of the 28 Member States only three (UK, Ireland and France) have an official definition of fuel poverty or energy poverty, with all being different from each other.

[37] For example, warmer homes could potentially affect public health budgets through two different channels, although the sign of the net impact remains unclear. Specifically, an increase in the life expectancy of a person who lives in a warmer home could be assumed. However, this effect could be translated into an increase in healthcare later in life for other reasons.

Figure 0.6 The effects of energy efficiency on public budgets



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

6.2 Investment effects

Focusing our attention on the investment impacts of energy efficiency programmes on fiscal budgets, four effects need to be discussed, as shown in the figure above.

Tax revenue from sales of products and services

First, we concentrate on changes to tax revenue from sales of products and services[38]. Energy efficiency improvements often involve the production and purchase of new and more efficient goods. As discussed in Section 2 of this appendix, the transition of the economy towards a more energy efficient path is likely to have a positive impact on consumption as the government, households and businesses invest in new goods and associated services. Although subject to some rebound and crowding-out effects, the sales of new equipment and services will result in changes to tax revenues.

Cost of public investment in energy efficiency

Some energy efficiency measures require public support in the form of financial and fiscal incentives whose overall objective is to stimulate investment in energy efficiency. There are three main types of interventions that can be included in this broad category, including:

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[38] See, also, KfW (2011) for empirical evidence in the case of Germany.

- Grant schemes[39] – grants that cover the total / partial cost of investment in energy efficiency.
- Concessional loans[40] – subsidies that are designed to reduce the cost of finance to households / businesses who invest in energy efficiency measures.
- Guarantees and other mechanisms to expand credit availability.

Income tax, unemployment benefits and social expenditure

A substantial effect of energy efficiency programmes on fiscal budgets results from the associated job creation that is expected to take place. Rising employment would have a positive impact on public finances from a reduction of unemployment and social benefits, as well as from increased income taxes. The extent of employment-related impacts on public budgets depends on various factors, including the net increase in the number of jobs and the nature of these jobs. The employment effects of energy efficiency, including the potential crowding-out effects and skill level of increased employment in certain sectors of the economy, are discussed in detail in Section 2 of this appendix.

Additional public revenues

Investment in energy efficiency can increase the value of commercial and private properties. Any increase in property values will generate further revenues via taxes over immovable properties and levies on property transactions, as long as market activity does not slow down because of the value increase. See Section 8 of this appendix for further discussion on this.

6.3 Energy cost reduction impacts

Energy cost reduction also impacts on public sector finances. We follow the discussion provided by IEA (2014) and concentrate on the effects suggested in Figure 0.6.

Expenditure on public sector energy consumption

Energy efficiency measures affect fiscal balances directly when the policies implemented provoke a reduction in public energy consumption. There are two dimensions that need to be considered:

- Savings arising from reduced spending on energy – for example, reduced heating costs of public buildings as a result of improved insulation.
- The public sector as a potential market for energy efficient goods and services – the investment costs that the public sector must cover in order to purchase and install the equipment.

Public investment in supply infrastructure

Energy generation infrastructure may be owned wholly or partly by the public sector, and the public sector may also oversee its maintenance and repairs. In this context, lowering energy requirements for the economy by increasing the efficiency of infrastructure will reduce pressure on the public sector to expand energy generation capacity and might reduce sales of energy as well. It will also reduce the cost related to the operating and maintenance of the existing infrastructure. As emphasised by Ecofys (2013), countries such as Poland that own old infrastructure will be facing the strongest challenges in this respect.

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[39] See SEAI (2015), for an evaluation of the implementation of a grant scheme in Ireland.
[40] See Kuckshinrichs et al. (2013) for an assessment of the German KfW programme for energy efficient building and refurbishment.

Changes to sales of goods and services

The implementation of energy efficiency measures can impact positively on household disposable income and could also lead to an increase in business profits. This additional income can be reinvested or used to increase consumption, with potential implications on the fiscal balance. Additionally, energy efficiency measures that reduce spending on energy may provoke a switch towards consumption of other goods and services. The exact public budget impacts of any changes to consumption patterns, however, are difficult to estimate and will depend on the tax rate that is applied to the consumption of different goods and services[41].

Fiscal drain from energy subsidies

Many governments around the world pay subsidies for energy production and consumption. In general terms, subsidies to oil products account for half of the total spending related to this category of expenditure[42]. This percentage is substantially higher in the case of developing countries and oil exporters (IEA, 2014). However, in the case of developed countries, government concerns could be also related to energy bill subsidies. In this context, energy efficiency programmes to finance improvements in buildings, such as better insulation or more efficient boilers, could reduce overall government expenditure on energy production and consumption subsidies. However, this type of public intervention can be quite controversial in the sense that it is debatable who should pay for the initial investment in energy efficiency in the case of buildings which are privately owned[43].

Energy excise duty and carbon tax revenues

Taxes on energy are implemented in the vast majority of the economies and in some cases can be linked to CO_2 emissions[44]. As reported by the OECD (2014), energy taxes generate between 1% and 5% of government revenues[45]. In the EU, there are also ETS auction revenues to take into account; a reduction in energy consumption could affect public finances by reducing income from energy taxes and ETS revenue, potentially compelling governments to look for additional sources of revenue to compensate.

Public health budgets

Despite the difficulties in quantifying the impacts of improving energy efficiency on public expenditure on health, this relationship cannot be neglected. Specifically, there is an emerging branch of literature that concentrates on estimating the healthcare cost reductions which result from improving the quality of indoor and outdoor environments (Liddell and Morris, 2010; WHO, 2011). The issue of health, including the potential implications of improved air quality and indoor thermal comfort on health and thus health spending, is discussed in detail in Section 3 of this appendix.

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[41] The existence of several VAT or sales tax regimes for different products will be important in determining the overall impact.
[42] In general, subsidies to oil products are quite low in Europe.
[43] SEAI (2015) presents a modelling exercise in which households were assumed to pay for a particular investment in energy efficiency in the case of Ireland.
[44] See, Energy Taxation Directive, which sets minimum rates for EU countries.
[45] See, also, ACEA (2013) for further details on the role of transport fuel taxes in the EU.

6.4 Some empirical evidence

Previous research undertaken by Verco and Cambridge Econometrics (2014) has assessed the effects of energy efficiency on fiscal budgets in the context of the UK. The key messages of this study are highlighted in Box 0.7.

Box 0.7 Fiscal impacts of making homes energy efficient

Verco and Cambridge Econometrics (2014) estimated the economic, fiscal and environmental impact of the Energy Bill Revolution campaign which was proposed to the UK government.

Focusing our attention on their assessment of the potential effects of the Energy Bill Revolution campaign on UK public budgets, the following main findings are of interest:

- £3.20 will be returned through increased GDP per £1 of government investment.
- £1.27 in tax revenues will be obtained per £1 invested by the government.
- The revenues obtained by increased GDP will enable the scheme to pay for itself by 2024.
- Over the period 2025-2030, the estimated net improvement to the government balance sheet (in real terms) is expected to be £18bn.

Source: Verco and Cambridge Econometrics (2014).

Additional studies that look at the potential impacts of energy efficiency on public budgets are listed in Table 0.8. This table also provides a summary of the key findings of each study.

Table 0.8 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	Czech Republic	This study that finds that every CZK 1m that is invested in enhanced energy efficiency in buildings (dwellings and the public sector)

	Energy Efficiency of Buildings? Macroeconomic Impact Assessment		provokes a direct fiscal effect of CZK 0.967m. This results mainly from increased employment and overall tax income.
6	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 £8.7 bn 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.

6.5 Tax revenue implications

A comprehensive assessment of the effects of investing in energy efficiency in terms of public balances will consist of:

- estimating public sector energy cost reductions
- estimating changes in public revenues

However, the assessment of other costs, and the effects of energy efficiency programmes on the revenue-side of public budgets is more complex and could be carried out using a variety of approaches. Figure 0.7 provides an overview of the main methodologies[46]; while Table 0.9 lists some examples of previous studies that have employed the most relevant approaches.

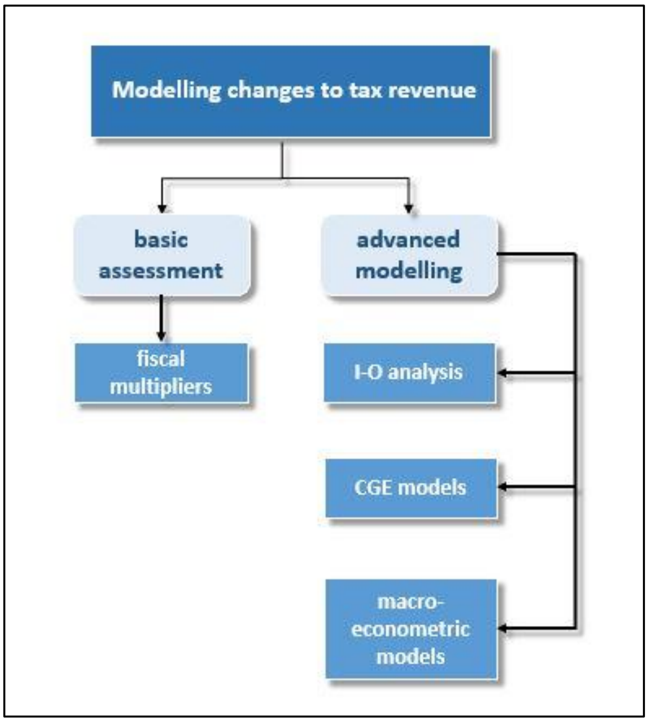
Table 0.9 Examples of previous assessments of changes to tax revenues, by type of methodological approach

Methodology	Scope	Reference
Fiscal multipliers	EU	Copenhagen Economics (2012)
I-O analysis	Germany	KFW (2011)
CGE models	France	ADEME (2014)
Macro-econometric models	UK	Cambridge Econometrics and Verco (2012)

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

[46] See IEA (2014) for further explanations on the different methodological approaches.

Figure 0.7 Methodologies for assessment of changes to tax revenue



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

7 Industrial competitiveness

7.1 Key issues and scope of work

Improvements to energy efficiency in Europe may have several effects on industrial competitiveness, among which four main topics have been identified:

- 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 increased domestic demand and stay competitive compared to external players.
- Global market shares of European industries: Macroeconomic effects of energy efficiency improvement go beyond GDP and employment growth. In particular, European energy-intensive industrial sectors that are particularly exposed to international competition, such as steel, pulp & paper, aluminium, cement, glass or chemicals may benefit from new opportunities arising from the shift in demand towards more efficient and higher quality building materials and processes.
- Emergence and positioning of European firms on breakthrough technologies and innovation in energy efficient products and solutions: new technologies and innovation will 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 for energy-consumption regulation will contribute to improved energy efficiency of buildings in Europe and the rest of the world. European industries may position themselves on disruptive innovation and gain competitiveness on those fledgling markets.

- In addition, European economic competitiveness in general may be impacted by the increase in productivity due to enhanced energy efficiency: Workers' productivity is closely tied to their indoor work environment, and the health effects of improved energy efficiency in buildings may result in better productivity and, ultimately, affect competitiveness. This aspect is of particular interest in the context of the present study, since it combines health and well-being considerations and competitiveness issues, and relates to a major environmental issue (air quality).

7.2 Findings

The importance and potential of reducing CO_2 emissions from buildings are known and rarely questioned. In particular, it has been shown that heating and lighting of buildings **accounts for 40% of Europe's final energy consumption** and **produces almost 30% of CO_2 emissions**.

While new buildings, which are designed to achieve maximum energy performance levels, will globally all reach the near-zero energy requirements in the coming years, the real question arises for the existing stock. Indeed, the vast majority of existing buildings were built before any formal requirements for energy performance were introduced: 50% of buildings date from before 1970 and 40% were built between 1970 and 1999[47]. This means that the energy performance of 90% of the European building stock is well below the rates that are possible to reach today. Thus, there is a large discrepancy between the small percentage of new buildings, which is required to be highly energy efficient, and the rest of the stock, largely old and with a very low energy efficiency rate, which is little or not addressed to date. The existing building stock then represents both a challenge to achieving energy savings, and a very large potential market. However, at the current rate of renovation – about 1% of the stock each year – we may wonder if the expected energy performance will be reached before the end of the century.

Current trends in the European Construction Industry

After seven years of crisis and stagnation, 2014 saw the return of a slight recovery in the European economy. Guided by lower oil prices and a relatively weak euro, this general economic improvement continued in 2015 and the European construction market has also grown. Despite major disparities between north-western and south-eastern countries, the overall growth of the construction sector was expected to reach 2% in 2015 and was expected to stabilise around 2.5% pa by 2017 according to Euroconstruct. The total output for the sector is expected to be €1,360bn in 2016 and €1,436bn in 2017[48].

The renovation market could double in the case of a clear target for renovation

Inside the construction sector, the Renovation and Maintenance (R&M) segment could grow strongly in the near term. It currently represents half of total construction output, (around €680bn) and is expected to grow by about 4.2% between 2015 and 2017. Inside the R&M segment, buildings renovation activities account for €557.6bn.

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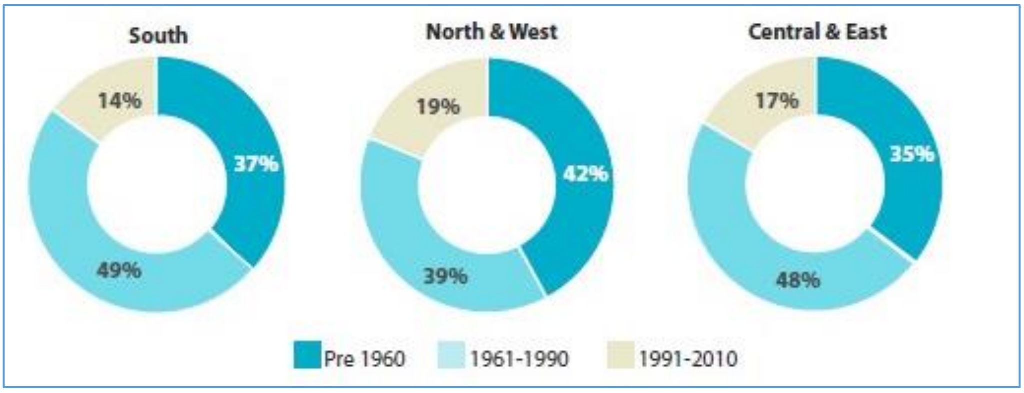
[47] Reside 2015. A baseline scenario for energy efficiency renovations in Europe's Residential buildings.
[48] Euroconstruct. 79th Conference, Warsaw.

Several studies have shown[49] that the European building stock is globally aging and is quite far from the requirements of energy efficiency that apply to new buildings. This is particularly true for the north-western countries such as France, Germany, Netherlands, Sweden, Belgium and the UK.

Figure 0.8 Age categorisation of housing stock in Europe



Source(s): BPIE.

If the enthusiasm about energy efficiency in new buildings was transposed to existing buildings, levels of renovation could become a crucial part of the overall construction market for years to come.

Having said this, it is important to note that operations gathered under the 'renovation' category in construction have two subdivisions: maintenance and renovation. In a broad sense, maintenance and renovation include all work done on an existing building or structure, either to maintain, improve or change its consumer properties. They can be defined as follows:

- Maintenance: Regular activities to keep a building in a normal operating condition and preserve its property value.
- Renovation: Occasional operation to upgrade or reconfigure all or part of the structure and increase its property value.

Maintenance, which aims at improving a building's aesthetics and minimising wear and tear, represents between 20% and 35%[50] of buildings maintenance and renovation operations in Europe. Usually energy performance is only addressed if mandatory and upgraded during a renovation process. For this reason, it only represents between 10% and 15% of the total buildings renovation operations, thus accounting for between €55bn and €83bn pa. The other types of renovations include: modernisation of buildings equipment, extensions and accessibility.

Europe's building stock represents approximately 25 billion square meters of floor area and, as mentioned previously, a large majority of this building stock is not energy efficient. Assuming a new construction rate of 1% pa and a demolition rate of 0.15% pa, this would mean that 68.5% of the 2050 building stock is already built. Figure 0.9 shows the changes in the building stock over time with a constant new construction rate of 1% per annum pa and a demolition rate of 0.15% pa. These values assume some increase in the rate of construction activity in the future compared to today's values.

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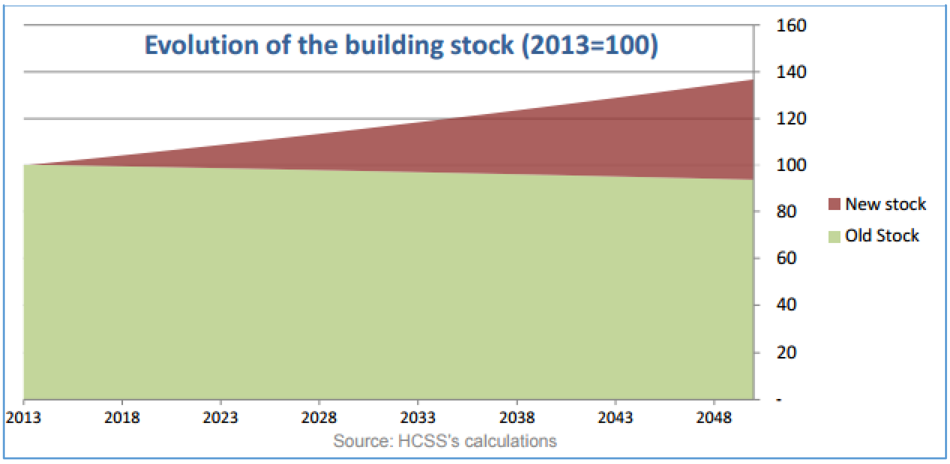
[49] RESIDE, 2015, Boosting innovation in the European building refurbishment sector through roadmaps for demand SIDE policy measures
BPIE, 2011, Europe's buildings under the microscope
Strategy and Change, 2013, Sustainable (Re)Construction - The Potential of the Renovation Market
[50] The Hague Centre for Strategic Studies. 2013. Sustainable (Re)Construction.

This implies that, at the current renewal rate, two thirds of the European stock would still not be energy efficient in 2048.

Figure 0.9 Evolution of the European building stock between 2013 and 2048



Source(s): HCSS.

In order to achieve substantial changes in the building stock's energy efficiency, the renovation rate needs to increase. Article 5 of the EED has set up a 3% annual renovation rate for government owned buildings. If this rate was broadened to the entire stock, it would have a direct impact on the energy efficiency renovation market: if its share remained constant in the R&M operations, **the energy renovation market could nearly double and the corresponding operations would reach 7% to 10% of total construction output (compared to 4% to 6% currently). This would represent €167bn - €250bn of activity (as opposed to €55bn - €83bn today).**

The renovation and construction markets face very large uncertainties

As in every industrial sector that relies on investment demand, the main driver for output in the construction and renovation sector is the wider economic climate. A general and steady economic improvement would directly benefit the construction and renovation sector.

Another key driver would be the development of a strong regulatory framework with a long-term strategy that would send a signal of real engagement to market actors. Such a long-term strategy was partly formulated by the European Commission in its "Roadmap for moving to a competitive low carbon economy in 2050", which suggests decreasing CO_2-emission levels by 88%-91% for the buildings sector by 2050, compared to 1990 levels. Yet **there is a critical need for a long-term vision staggering clear and defined objectives over time; a consolidated and multifaceted policy approach that would include incentives, regulatory elements and financing**. The different actors do not know what the energy efficiency requirements will be by 2050; it is thus difficult for them to predict how much buildings will have to be renovated, or at what speed.

Addressing these two aspects, overall economic trends and regulatory requirements and perspectives, could lead to a climate of increased confidence for investors who would be more inclined to back the sector.

Perspectives for the renovation industry in relation to increased energy efficiency

Depending on the policy options and framework that will be set up, annual market volume for renovation may double or even triple at the European level. This triggers major opportunities for European renovation industries, as well as major challenges such as skills improvement or long-term cost-efficiency of innovative solutions.

The opportunities are substantial: **since small-scale construction is a very local market, overall market growth can benefit European actors**. In addition to not being exposed to international competition, the European construction and renovation industries, mainly composed by local SMEs, are at the forefront of energy-efficient solutions for buildings. Compared to other industrial sectors, the construction sector has not produced high rates of innovation during recent decades and processes have not changed much for the past 20 years, except for energy refurbishment activities. Indeed, different policies for energy performance conducted at the European level have encouraged local industries to develop their expertise and their leadership in this field. Manufacturers have had to develop and offer specific solutions to meet European energy efficiency requirements, and are now considered to be at the cutting edge of technology in this field. Having used Europe as a laboratory for innovation, these industries now design and manufacture a large share of high-tech products available on the global market.

Furthermore, this positioning is growing worldwide and the benefits to European industry may go beyond the European frontiers. The European approach to energy efficiency is seen as potentially at least partially replicable by a growing number of countries outside Europe. Quite often energy efficiency measures are implemented a few years later outside Europe. This gives a considerable advantage to European companies with operations outside Europe, who are already familiar with the requirements of current legislation. European companies may be better prepared to offer appropriate and progressive solutions locally. Maintaining Europe's leading position in energy efficiency legislation is thus important for industrial competitiveness in this sector.

Major challenges linked to production processes, workforce skills and the cost-effectiveness of innovative solutions

First, there is a strong issue regarding the cost-effectiveness of high-tech solutions. The major constraint for energy renovation is not about technology per se, but about its cost-effectiveness. According to the experts who have been interviewed, the technologies in this field are largely mature and correspond to near-term technical requirements. The potential difficulties rather come from the fact that in most cases, the 'cost' criterion prevails on effectiveness. In order to respond to ever-lower prices, building contractors, from property owners to architects and builders, are often constrained to choose the affordable solution rather than the innovative one. If they want to benefit from the potential market of energy renovation, European suppliers for energy-efficient solutions are compelled to make their technological products more competitive by lowering their cost – by becoming mass market products and not luxury options. By fixing mandatory replacement rates and increasing demand, the EPBD could indirectly foster competitiveness which, in the long term, would result in lower production costs.

Second, while innovative technological solutions are already available, innovative production processes have yet to be developed. One of the key developments would be to increase on a large-scale pre-fabrication for refurbishment solutions. There are currently no standards concerning the procedures for renovation: everything is done on a case-by-case basis. Processes are very local and construction methods must be adapted to each site. A standardisation of technical solutions would allow significant time savings and the manufacture of a much more technical products, while reducing danger on site and noise for locals. These solutions would promote the inclusion of energy performance in rehabilitation operations. This requires an initial step to demystify prefabricated homes and buildings so that they gain acceptance by the public.

A second axis of innovation would be to modernise the global process of production itself and *focus on a more interdisciplinary approach*, with more cross-over between the different stakeholders, as one could find in other sectors. This is especially true for the renovation sector where the trades are particularly partitioned. Estimates show that 93%[51] of construction enterprises are small or micro enterprises (with fewer than ten staff), which represent around 6m people in the residential renovation sector. In most rehabilitation operations, business opportunities are missed because the very specific knowledge of these micro-structures does not enable them to understand the intervention of other trades. A better communication process would promote the action of the suitable trade as well as the implementation of energy saving solutions during refurbishment operations.

Last, to address this potential increased market volume, the available labour force needs to be upskilled. Post 2008, the construction of new buildings has declined by around 25% of peak output. This has resulted in many skilled workers being out of work, particularly in hard hit countries such as Spain and Greece. With new construction stagnating, buildings renovation represents a major market where construction workers have directly transferable skill sets. Still, in order to embrace the transformation of the renovation sector and to benefit from all its potential, those skills need to be upgraded to address energy efficiency concerns.

Suppliers' productivity and competitiveness

European energy-intensive industrial sectors that are particularly exposed to international competition, such as steel, pulp & paper, aluminium, cement, glass or chemicals may benefit from new opportunities arising from the shift in demand towards more efficient and higher quality building materials and processes. The interviews conducted with these different industrial suppliers have shown that two areas are particularly related to energy efficiency and may directly benefit from an increased energy renovation market volume: the insulation industry and the flat glass industry. For example, output related to buildings accounts for 80% of the overall output of the flat glass industry. In addition, between 34% and 41% of households' renovation expenditures are aimed respectively at insulation and glazing.

The Flat Glass Industry could benefit substantially from the EPBD

Between 70% and 80%[52] of the Flat Glass Industry's production is directly aimed at the buildings sector, and another 15% is aimed at the car industry. The buildings sector is clearly one of the key clients for most flat glass companies.

The Flat Glass Industry is driven by two factors: the construction of new buildings – to a limited extent and, above all, renovation activity. Rehabilitation operations, both for the service sector and for the housing sector, are usually carried out in order to improve comfort or thermal efficiency. These operations often lead to an upgrade and an expansion of the apertures in the building envelope, which includes a large share of windows and bay windows. Thus, policies which aim to improve energy efficiency indirectly boost glass consumption in the buildings sector which, in turn, contributes to the development of flat glass activity in general. **In that sense the EPBD represents**

[51] FIEC. Annual report 2015
[52] Figures reported by the interviewed experts from Glass for Europe.

a major opportunity for the Flat Glass sector. If the size of the energy renovation market doubled, the Flat Glass sector could increase in size by 40%.

Beyond the practical needs related to renovation, one may also consider the positioning of the European glass companies in the global glass market, to fully understand their competitiveness concerns. European glass manufacturers are mainly focused on high added value glass and processing operations – segments where the most profitable margins are made. They are especially competitive in those two segments, as they have acquired a significant advantage in terms of technology and innovation from their long-standing experience. Until now, this advantage has enabled European companies to distinguish themselves from other international competitors, but new competitors coming from the Middle-East, Morocco, and India are growing. During the past few years, these competitors have become increasingly strong in the export of basic materials (raw materials and semi-finished products) and European exports have slightly decreased in this specific market. However, European assembly lines and their processed operations continue to dominate the market, and it is likely that the future of the European glass economy remains in high performance glass.

As a conclusion, one can assume that, due to these two factors, the European glass industry will directly benefit from the increased rate of energy renovations in the coming years. **If the transformation process remains in Europe and, if the renovation rate keeps growing, increasing demand will benefit above all Europe companies.**

It is important to note that, although international competition is favourable for European actors and should not represent a real threat to European Flat Glass industries in the coming decades, local financing may pose a threat to the development of innovative solutions dedicated to energy-efficient buildings. The real issue for this sector is to convince the different actors of the benefits related to the implementation of high-tech glass. For example, in most cases builders and architects are compelled to choose an affordable opaque wall, rather than glass with electrochromic properties. This means that reaching the objective of zero energy is more a question of funding than one of technique.

The insulation industry will be strongly impacted by the EPBD

As the overall concern for energy savings in buildings has kept rising in Europe over the past decade, the insulation industry has been growing globally despite the adverse economic climate. In 2013, its growth rate was 2 percentage points higher than the rate for general construction activity and the estimated value of the European insulation market was €7.5bn.

Synergies between the building industry and the insulation industry are very strong as insulation is one of the key components of energy efficiency in buildings. An inadequate building envelope, without proper insulation, could result in buildings failing to meet the final energy efficiency targets.

Similarly to the glass industry, the insulation industry is strongly impacted by the market for energy renovation. More specifically, EU regulations are one of the main drivers for the sector. Robust and targeted regulations can increase the demand for insulation solutions. Insulation products are mainly produced and sold locally because insulation is a high volume to value ratio product. Furthermore, the main producers in this market are European multinational companies (Saint-Gobain ISOVER, Rockwool, Knauf Insulation) whose value chains are also local; strong regulation therefore not only benefits the insulation manufacturer's activity, but the whole chain of production as well, and in particular local SMEs. **Even if detailed data on this market are not available due to confidentiality issues, one can reasonably estimate that the insulation**

market would potentially double in size as a result of the energy renovation market doubling, benefiting mainly European industries.

From a broader perspective, the lessons from the European experience, in particular the nZEB implementation, encourage all construction actors to design buildings in a more integrated manner. This approach provides the construction industry and, in particular, the insulation industry, with an advantage at global level. In most cases, European companies are better prepared to offer appropriate and progressive solutions locally. Maintaining Europe's leading position in energy efficiency legislation is thus important for industrial competitiveness in the insulation sector, but also to renewable energy technologies and local SMEs

8 The value of buildings

8.1 The impact of sustainability and energy efficiency on property value

Sustainability and energy efficiency have become increasingly more prominent in real estate markets around the world. Because buildings have a direct and indirect impact on the environment, green building standards, certifications and rating systems, such as BREEAM (Building Research Establishment's Environmental Assessment Method), Energy Star and LEED (Leadership in Energy and Environmental Design), were developed to assess the impact of the buildings on the natural environment. The growing acceptance of sustainability in properties and subsequent interest and demand for sustainable design has led to a proliferation of high-performance buildings worldwide. Also, environmental performance and sustainability metrics are considered as important criteria for property investors, who require information about the costs and benefits associated with developing, managing and investing in buildings with 'superior environmental performance' (Fuerst, 2014). Based on this increasing commitment to more sustainable real estate and aligning organisations' social and commercial responsibilities, it is important to consider if the environmental performance of a building adds value. One would expect that an investor or a tenant is willing to pay a premium for aspects such as financial benefits (energy cost savings), indirect benefits (improved corporate image, worker productivity) and comfort, related to energy efficiency. As a result, energy efficient (or certified) buildings would have higher (rent) values, if compared to non-energy efficient (or uncertified) buildings. In this literature review, we have investigated whether there is a relationship between energy efficiency and the values of properties. Distinction is made between two types of real estate, namely residential and commercial real estate.

Residential real estate

Early sustainability studies published findings on, and insights into, the pricing aspect of sustainable real estate. In 2008, research was performed in Switzerland regarding the willingness to pay for energy-saving measures in residential buildings (Banfi, 2008). This is one of the first studies on the effect of energy efficiency on asset values and the outcome suggests that energy-saving attributes are significantly valued by consumers. The considered energy-saving measures in the study include an air renewal system and different energy-efficiency standards of windows and façades. Both for rental apartments and purchased dwellings, the results from the study show a significant willingness to pay for energy-efficiency attributes. For an enhanced insulated façade (in comparison to a standard insulation) the willingness to pay is circa 3% of the transaction price. For a ventilation system in new buildings or insulated windows in old buildings (compared to old windows), the willingness to pay is 8% to 13% of the transaction price. The energy-saving benefits include, according to the report, '*both individual* *energy savings and environmental benefits as well as comfort benefits namely, thermal comfort, air quality and noise protection*' (Banfi, 2008).

In 2011, a study was performed on the economics of energy labels in the Dutch housing market (Brounen, 2011). Based on the examination of the effect of energy performance certification on the outcome of the transaction process, the researchers conclude that homebuyers are willing to pay a price premium for dwellings that have been labelled as more energy efficient, accounting for thermal and other hedonic characteristics of residential dwellings. This price premium depends and varies with the specific label category of the energy performance certificate (a higher energy label has a greater price impact) and is robust to variations in housing quality (Brounen, 2011). Based on the findings Brounen (2011) concludes that improving the energy efficiency of dwellings not only leads to an immediate financial benefit from lower energy expenses, but also leads to a higher transaction price at the time of sale.

Consistent with the findings of Banfi (2008) and Brounen (2011), Fuerst et al. (2013) find a positive association between price per square metre and energy performance rating in their study on the effect of EPC (Energy Performance Certificate) ratings on house prices in England. Compared to dwellings rated EPC G, dwellings rated F and E are sold for approximately 6% more. Dwellings rated D, C and A/B are sold for 8%, 10% and 14% more, respectively (Fuerst et al., 2013). It is important to note that the differences in price premium were quite large when the sample was categorised by dwelling type.

In their article "Is Energy Efficiency Capitalized into Home Prices?", Walls et al. (2012) examine the premium paid for dwellings with an Energy Star certificate for different periods in the US. Their study shows that, for dwellings built in the period 1995 to 2006, dwellings with an Energy Star certificate have a higher sales price than uncertified dwellings. The results, however, are not quantified, and no evidence is found that dwellings with an Energy Star certificate built in the period after 2006 have a higher sales price than uncertified dwellings. The absence of a price premium on more recently built dwellings is suspected be due to more stringent building codes in recent years, which may have worked to narrow the difference between dwellings with an Energy Star certificate and uncertified dwellings (Walls et al, 2012).

An overview of early research on the relationship between sustainability and the effect on property value for the Royal Institution of Chartered Surveyors (RICS) sought to synthesise all credible evidence from studies and reports into one definitive resource (Fuerst, 2014). This research identified certain shortcomings in many of the early studies. For example, most of the studies cited in the report focus exclusively on one specific sector of the property market, one specific country or a set of countries and cover only a limited period of time, making it difficult to draw general conclusions (Fuerst, 2014). The report (Fuerst, 2014) also found that many of the early studies rely on a small number of data sources that provide limited information about the environmental performance and general sustainability indicators of assets. However, the report concludes by suggesting that the research clearly shows that there are several compelling benefits from energy efficient buildings, which are received by different stakeholders throughout the life cycle of a property. The report also draws conclusions on the impact of sustainability on the asset value based on a case study performed in three different cities on three continents, being the condominium market in Tokyo, the Helsinki housing market and the US. office market. The results in the report considering the US. office market are discussed in the commercial real estate chapter.

The first case study in Tokyo contained over 50,000 housing transactions in the condominium market, including information on eco-certification of the specific assets. The study found '*small but significant price premia that persist across most market* *segments and time period*' (Fuerst, 2014). Also, the study revealed that asking prices for green properties are minimally higher than the actual transaction prices and provide evidence of a positive link between household income and willingness to pay for a green label (Fuerst, 2014). The second study of the RICS (2014) research focused on Energy Performance Certificates (EPC) and housing attributes of flats in Helsinki, Finland. Fuerst (2014) concludes that evidence is not clear-cut, although some evidence of an overall price premium for the most energy-efficient buildings and apartments was found.

A recent study by Tilburg University and TU Eindhoven (2015) shows that an unfavourable energy label (G) has a negative price effect of €14,000. The most favourable label (A) has a positive effect of €7,000, causing the difference between a label A and a label G dwelling to be up to €21,000. In addition to this, the study indicates that dwellings with an energy label are sold 20 days quicker than dwellings lacking an energy label.

In contradiction to the studies above, Yoshida and Sugiura (2011) argue that green buildings are subject to price discounts rather than premiums. In this study, dwellings in Tokyo were examined. The authors state that the value of green buildings depends critically on the definition of green buildings, institutional settings, policy package and user preferences.

To conclude, an overview of the existing literature reveals conflicting evidence regarding the relationship between energy efficiency and buildings values in residential dwellings. While some studies provide evidence of a price premium for energy efficient residential real estate, others do not. Overall, no solid relationship is found between the two, as the results vary depending on type of dwelling and geographical location.

Commercial real estate

In addition to research on the financial implications of energy efficiency measures on residential real estate, there is also preliminary evidence on the impact of sustainability and energy efficiency on commercial real estate. Research focusing on the price effects of environmental certification on commercial real estate indicates that eco-certified buildings have both a rental and a sale price premium in comparison to other buildings in the same submarkets (Fuerst & McAllister, 2011a).

Fuerst & McAllister (2009a) investigated the effect of voluntary eco-certification on the rental and sale prices of US commercial office properties. Their results suggest that a rental premium of approximately 6% is realised for Leadership in Energy and Environmental Design (LEED) and Energy Star certified buildings. Regarding the sales price premiums they found a price premium of 35% for observations involving LEED-certified buildings (sample of 127 LEED-certified buildings) and 31% for buildings involving Energy Star rated buildings (sample of transaction prices for 662 Energy Star rated buildings). According to Fuerst & McAllister (2009a), there is evidence of a rental and sales price premium for energy efficiency certified commercial buildings, although there are differences in the magnitude of this premium.

Further results from another study by Fuerst & McAllister (2011a), focusing on the US office market, suggest that there is a rental premium of approximately 5% for LEED certification and 4% for Energy Star certification. For sales prices, they found a price premium of 25% for LEED-certified buildings and 26% for Energy Star certified buildings.

In 2010, the US office market was studied to analyse the impact of energy efficient design and construction on rents, effective rents and the sales prices (Eichholtz, 2010). The results suggest that buildings with a 'green rating' (Energy Star certification) are likely to generate approximately 3% higher rent per square foot than an otherwise identical commercial building. Eichholtz (2010) concludes that the difference in effective rent between these buildings is approximately 7% and the selling price may increase by as much as 16% for a building with an Energy Star certification. Furthermore, Eichholtz (2010) states that a decrease of 10% in energy consumption leads to an increase in value of approximately 1%, over and above the rent and value premium for a green labelled building (LEED and/or Energy Star label). However, it must be noted that the intangible effects that come with a green label, such as worker productivity or an improved corporate image, seem to play a role in determining the value of sustainable and eco-friendly buildings in the marketplace (Eichholtz, 2010).

Fuerst and McAllister (2011b) studied the UK commercial property market to analyse the effect of energy performance ratings on appraised capital values, rental values and equivalent yields. This research, however, found no evidence of a significant relationship between environmental and/or energy performance and rental or capital value. Although the Energy Performance Certificate (EPC) rating was found to have a minor effect on equivalent yields, the authors concluded that EPC ratings were not yet having the impacts on rents and market values that would be expected if good EPC ratings were either associated with substantial cost savings that are fully reflected in capital values and/or readily available and taken into account by prospective tenants and buyers.

Chegut et al. (2011) investigated the financial performance of Building Research Establishment Environmental Assessment Method (BREEAM) certified office buildings in London over the 2000-2009 period. This study was the first to report the effects of rental contract features and 'green' building competition on certified premiums in the London office market. The authors concluded that the presence of 'green characteristics' has a positive impact of 21% on rental prices (per net square meter) and 26% on sales transaction prices (per net square meter). However, they also found that rental contract features (such as lease term, incentives/rent free period and market signals, such as days on market) have a moderating effect on the rental prices of BREEAM certified buildings, which decrease rental premiums by approximately 5 percentage points. Increase in the supply of BREEAM certified buildings, they argue, will have a positive impact on rents and prices in general within a given micro-location, but will further moderate the BREEAM premium (Chegut et al., 2011). As a result, the researchers conclude that, due to competition in 'green' building markets, the premiums in the rental market decrease by a further 3 percentage points and in the transaction market by 1 percentage point.

A study by Reichardt (2012) has analysed the effects of Energy Star and LEED certification on property rental and occupancy rates in commercial real estate in the ten largest metropolitan markets across the US. This study found a significant rent premium for energy efficient buildings of an average of 2.5% for Energy Star rated buildings and 2.9% for LEED certified buildings (Reichardt, 2012). Furthermore, the study revealed evidence of a significant positive effect of energy efficiency on occupancy rates.

In 2012, the impact of energy labels and accessibility on office rents in the Dutch office market were researched (Kok & Jennen, 2012). The study draws conclusions on the financial implications of energy efficiency and accessibility of buildings, based on their energy performance certificate. According to the study, buildings that are designated as inefficient (EU energy performance certificate D or worse) are associated with a 6.5% discount on rental levels compared to energy efficient buildings.

Although several studies provide results that show a positive relationship between property values, there are a number of caveats. Most studies on energy efficiency in commercial real estate focus solely on office markets. Empirical studies of the industrial and retail market may show different outcomes that reflect the variations in market structure (Fuerst & McAllister, 2009b). There is also limited understanding of the relative contribution of the potential sources to price differentials, such as fiscal benefits and subsidies, improved business performance, image benefits and reduced operating costs. As Fuerst & McAllister (2009b) point out, lease type may be a major determinant of the allocation of the costs and benefits of eco-certification costs and benefits and, in turn, may influence the price determination process.

As mentioned in the residential chapter, the third case study included in the RICS study (Fuerst, 2014) used a panel dataset, which contained information on operating expenses, rents and building characteristics in six large office markets in the US. According to the report by Fuerst (2014), this was the largest study in this topic area to date and allowed the researchers to better understand the interaction between green labels, operating expenses and office rents (Fuerst, 2014). For example, the dataset allowed them to isolate pure cost saving benefits from additional certification. Fuerst (2014) concludes that the effect of the energy efficiency components on rental levels increases with the rating scores, which means that it depends on the degree of 'greenness' as reported by the rating (Fuerst, 2014). Even though the RICS report is extensive and provides new and more in-depth insights to the property markets of developed countries and their 'green value', more needs to be done to apply this type of research in other markets.

In 2015, Bendewald, Miller and Muldavin, on behalf of the Rocky Mountain Institute (RMI), compiled a guide for investors in the United States to illustrate how to capture all value beyond energy cost savings resulting from the execution of a deep retrofit project. According to this guide, investors have an opportunity to earn higher returns from their properties by implementing certain types of energy efficiency investments known as 'deep energy retrofits'. Deep energy retrofits employ an 'integrated array of energy efficiency measures, often as part of a multi-year or portfolio-level plan, to reduce energy consumption by 30% or more compared to pre-retrofit energy use, while achieving superior sustainability performance' (Bendewald, Miller and Muldavin, 2015). The deep retrofit value for an investor is defined as the present value of all the benefits beyond the energy cost savings minus the costs accruing to a property, as a result of executing a deep retrofit. The report states that the deep retrofits reduce operating costs and can improve the satisfaction and health of occupants. Furthermore, the improved energy performance plays an important role for tenant companies in increasing sustainability leadership, reputation and risk management.

The authors identified four value elements of the potential types of value that a deep energy retrofit can create. The first value element contains the retrofit development costs, which is the initial capital investment against which future cost savings and other benefits are measured. They state that in many cases the incremental cost of a deep energy retrofit can be reduced through design and construction. The second element regards non-energy cost savings. Deep retrofits can reduce operating costs associated with maintenance costs, insurance and occupant churn rate. The RMI report (Bendewald, Miller and Muldavin, 2015) states that, in 2008, a Leonardo Academy study in the US found that properties that are LEED certified for existing buildings (LEED-EB) had a median maintenance and repair cost (not including janitorial costs) of $1.17 per square foot in comparison to the regional average of $1.52 per square foot. After accounting for slightly higher janitorial costs, the overall maintenance costs per square foot were $0.25 lower, constituting a 9% maintenance cost saving on an annual basis. The Aberdeen Group conducted a study in 2010 and found that adopting a data and performance management strategy could cut 14% or more from maintenance costs (Aberdeen Group, 2010, cited in Bendewald, Miller and Muldavin, 2015). Another study, conducted for the US General Services Administration, concluded that 12 'green' GSA buildings had maintenance costs that were on average 13% less than the general stock.

The third element relates to tenant-based revenues that are assumed to be generated when building owners are able to monetise enhanced demand resulting from a deep retrofit by increasing rents, initial vacant space absorption and tenant retention. The report by Bendewald, Miller and Muldavin (2015) mentions that statistics-based research, on average, has found office rental price premiums for LEED or Energy Star certification of 3% to 6% and occupancy premiums of approximately 10%. Sales prices were found to have premiums of circa 10% to 13%. According to the report, expert-based research findings, performed by real estate market experts, include faster absorption of tenants, reduced tenant turnover, competitive lease terms, reduced operating and maintenance costs and higher tenant satisfaction. The fourth value element regards sales revenue premiums that arise from higher net operating income (due to increased tenant revenues and expense savings), increased investor demand (which can lower capitalisation rates and discount rates) and reduced risk.

All four value elements are part of the retrofit risk analysis that is used to identify and assess retrofit project development and operating risks, evaluate risk mitigation strategies and apply and present the results of the analysis for value creation. The benefits of retrofit include the ability to capitalise on future government incentives, improved ability to meet future regulatory requirements and improved ability to meet changing investor demand.

The RMI report (Bendewald, Miller and Muldavin, 2015) suggests that the hypothesis that energy label certified and highly rated deep retrofits can increase the sales prices of office properties, beyond those that result from energy cost savings alone, has been proven in various recent studies. Sales price premiums for these properties range from 2% to 26%, with a clustering around 10% to 13%. However, the evidence on rents and occupancy rates is less comprehensive, although a positive relationship between sustainability/energy efficiency certification and property values is provided. The report concludes by stating that, where possible, the generalised statistical studies of sales price premiums should always be supplemented with locally specific research. However, given the difficulty of controlling for all the factors that affect sales prices, specific local statistically based studies will be difficult to find and are not particularly useful beyond establishing a baseline relationship between sustainability performance and value.

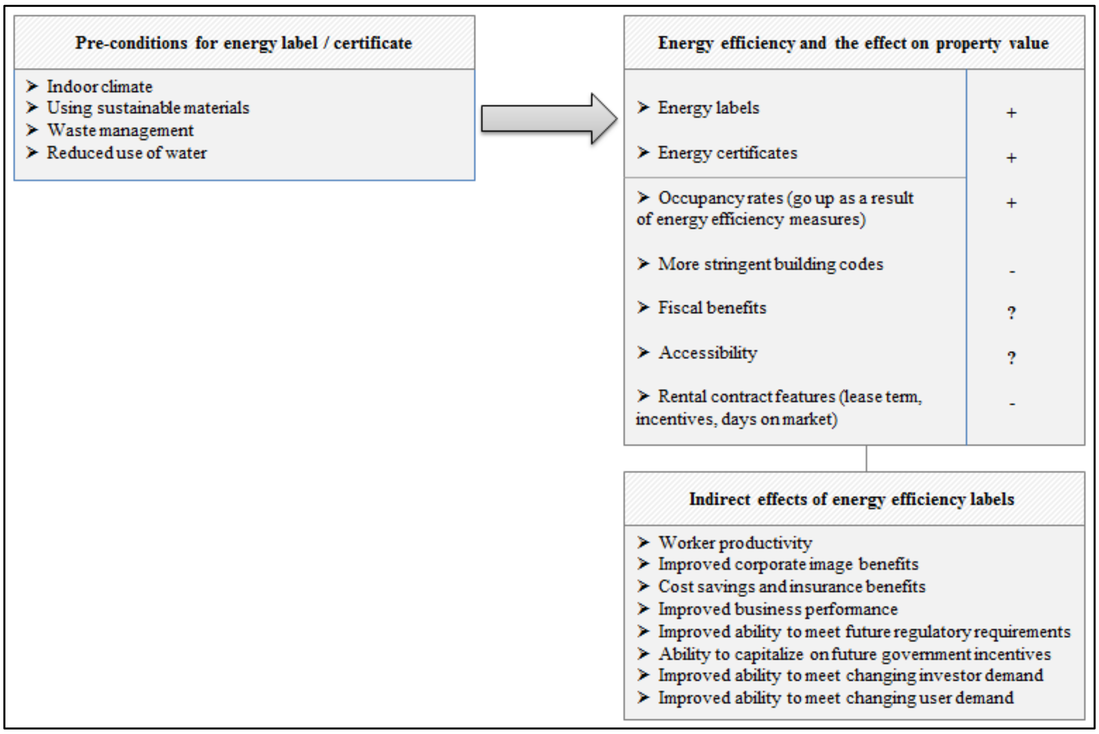
The international real estate markets embrace sustainability and are aware of the fact that it can be a distinctive factor. As discussed in this literature review, the effect of sustainability measures on real estate value is a popular topic and the empirical evidence predominantly shows a positive relationship. This applies mainly for measurable aspects of sustainability in buildings, such as energy efficiency, that translate into greater value in the form of higher rental rates, increased sale prices, increased occupancy rates and lower capitalisation rates. Energy efficiency features can also benefit the end user due to lower operating expenses, improved indoor climate and increased worker productivity.

Given the dynamic nature of real estate markets and the limitations of the studies discussed, there is a clear scope for further research. Sustainability encompasses more than energy efficiency, for example waste management, use of sustainable construction materials in buildings, reduced use of water, functional flexibility. The indoor climate and type of end user can also be influential on the classification of being 'sustainable' (Kok, 2009). Furthermore, due to the emergence of the sustainability theme over the last decade, several measurement systems have been developed, often customised for one specific region/country/area or a sector of the property market. These measurement systems are supposed to give an objective evaluation of the impact that a specific building has on the environment. However, these systems differ per country and regard different target groups, different phases of the economic lifecycle and/or may involve voluntary certifications (Kok, 2009). While the RICS report (Fuerst, 2014) provides new in-depth insights into measuring 'green value' on an international scale, more needs to be done to apply this type of econometric analysis to the largest and most dynamic real estate markets in order to make results more generalisable, transparent and quantifiable.

The effect of energy efficiency on property value

Figure 0.10 provides an overview of the potential effects of energy efficiency improvements on property values.

Figure 0.10 Summary of the potential effects of energy efficiency on buildings



Source(s): Main report

Table 0.10 and Table 0.11 below summarise the studies reviewed that covered the impacts on residential and commercial buildings respectively; a more detailed discussion of the findings and implications is included in Part III Section 9 of this report.

Table 0.10 Residential buildings evidence review

Study RRE	Geographic location	Rental Premium	Occupancy Premium	Time to sale	Sales Price Premium
Banfi, S. F. (2008). Willingness to pay for energy-savings measures in residential buildings. *Energy Economics*.	Switzerland	n/a	n/a	n/a	Insulated facade: +3% Ventilation system / insulated window: +8% to +13%
Salvi, M., Horehájová, A. and R. Müri (2008) Der Nachhaltigkeit von Immobilien einen finanziellen Wert geben- Minergie macht sich bezahlt, University of Zurich, Center for Corporate Responsibility and Sustainability, November 2008	Switzerland	n/a	n/a	n/a	Single family: 7% Flats: 3,5%
Brounen, D. K. & Kok, N. (2010) *From: Copenhagen Economics (2015). Do homes with better energy efficiency rating have higher house prices?*	NL	Positive significant effect on rental prices.	n/a	n/a	Positive significant effects on sales and rental prices. Relative to EPC D-label: A + 10,2% B +5,5% C +2,1% E -0,5% F -2,3% G -4,8%
Brounen, D. K. & Kok, N. (2011). On the economics of energy labels in the housing market. *Journal of Environmental Economics and Management*.	NL	n/a	n/a	n/a	Labelled as more energy efficient –> greater price premium +3,6%
Fuerst, F. M. (2013). An investigation of the effect of EPC ratings on house prices. *Cambridge: Department of Energy and Climate Change.*	UK	n/a	n/a	n/a	Relative to EPC G-label: E/F +6% D +8% C +10% A/B +14%
Fuerst, et. al. (2015) *From: Copenhagen Economics (2015). Do homes with better energy efficiency rating have higher house prices?*	UK	n/a	n/a	n/a	Relative to EPC D-label: A/B +5% C +1,8% E -0,7% F -0,9% G -6,8%
Walls, M., Palmer, K., & Gerarden, T. (2013). Is Energy Efficiency Capitalized into Home Prices? Washington: Resources for the future.	USA	n/a	n/a	n/a	1995 - 2006 unquantified premium - 2006+ no premium
Kok, N. and M.E. Kahn (2012) The Value of Green Labels in the California Housing Market: *An Economic Analysis of the Impact of Green Labeling on the Sales Price of a Home.*	USA	n/a	n/a	n/a	Dwelling with a Green Label (EnergyStar, LEED or GreenPoint) sell for 9% more than comparable houses
Addae-Dapaah K. and S.J. Chieh (2011) "Green Mark Certification: does the market understand" in *Journal of Sustainable Real Estate*, Vol. 3, No. 1: 162-191	Singapore	n/a	n/a	n/a	9.2-27.8% depending on rating
Deng, Y., Li, Z. and J.M. Quigley (2012) "Economic returns to energy-efficient investments in the housing market: Evidence from Singapore" in Regional Science and Urban Economics 42: 506-515.	Singapore	n/a	n/a	n/a	+4%
Case study 1 - Fuerst, F. (2014). Measuring 'Green Value': An International Perspective. Royal Institution of Chartered Surveyors (RICS).	Tokyo	n/a	n/a	n/a	Price premium for "Green label buildings" (unquantified)
Case study 2 - Fuerst, F. (2014). Measuring 'Green Value': An International Perspective. Royal Institution of Chartered Surveyors (RICS).	Finland	n/a	n/a	n/a	Significant price premium for energy efficient buildings (unquantified)
Definitief energielabel woningen: resultaat in het eerste halfjaar (2015). TIAS Vastgoed LAB (Tilburg University and TU Eindhoven).	NL	n/a	n/a	Engergy label -20 days compared to no energy label	Label G: -14k Label A: +7k
Yoshida, J. S. (2011). Which "Greenness" Is Valued? Evidence from Green Condominiums in Tokyo. The Pennsylvania State University, Tokyo Association of Real Estate Appraisers.	Tokyo	n/a	n/a	n/a	No price premium observed - rather a discount (-5,5%)
Mudgal, S., Lyons, L., Cohen, F., Lyons, R. & Fedrigo-Fazio, D. (2013). Energy performance certificates in buidings and their impact on transaction prices and rents in selected EU countries.	Ireland	Rent effect is small: effect of one-letter improvement is +1,4% higher rent	n/a	n/a	EPC rating: effect of one-letter improvement is 2,8%
Hyland, et. al. (2013) *From: Copenhagen Economics (2015). Do homes with better energy efficiency rating have higher house prices?*	Ireland	Positive significant effect on rental prices.	n/a	n/a	Sales prices relative to EPC D-label: A +9,3% B +5,2% C +1,7% E -0,7% F/G -10%
Mudgal, S., Lyons, L., Cohen, F., Lyons, R. & Fedrigo-Fazio, D. (2013). Energy performance certificates in buidings and their impact on transaction prices and rents in selected EU countries.	Austria	Rent effect of energy efficiency on advertised rent is large: EPC rating - effect of one-letter improvement +4,4% higher rent	n/a	n/a	Strong price effects of energy efficiency on list prices: EPC rating - effect of one-letter improvement is +8% higher price

Mudgal, S., Lyons, L., Cohen, F., Lyons, R. & Fedrigo-Fazio, D. (2013). Energy performance certificates in buidings and their impact on transaction prices and rents in selected EU countries.	Belgium	Flanders: +3,2% Wallonia: +5,4% Brussels: +2,9%	n/a	n/a	Flanders: +4,3% Wallonia: +1,5% Brussels: +2,2%
Mudgal, S., Lyons, L., Cohen, F., Lyons, R. & Fedrigo-Fazio, D. (2013). Energy performance certificates in buidings and their impact on transaction prices and rents in selected EU countries.	France	n/a	n/a	n/a	Marseille: +4,3% Lille: +3,2%
Sbi (2013) *From: Copenhagen Economics (2015). Do homes with better energy efficiency rating have higher house prices?*	Denmark	n/a	n/a	n/a	Positive significant effects on sales and rental prices. Relative to EPC D-label: A/B + 6,4% C +6% E -6,2% F -12,3% G -19,4%
Soriano, F. (2008) Energy efficiency rating and house price in the ACT: Modelling the relationship of energy efficiency attributes to house price: the case of detached houses sold in the Australian Capital Territory in 2005 and 2006	Australia	n/a	n/a	n/a	3% per star level

Table 0.11 Commercial buildings evidence review

Study CRE	Geographic location	Rental Premium	Occupancy Premium	Sales Price Premium
Eichholtz, P. K. (2010). Doing Well by Doing Good? Green Office Buildings. *American Economic Review*.	US	Energy Star: 3.3% LEED: 5.2%	n/a	16% LEED/Energy Star
Eichholtz, Kok, Quigley (2008, 2009, 2010)	US	No statiscally significant premium	n/a	No statistically significant premium
Fuerst, F., & McAllister, P. (2011a). Green Noise or Green Value? Measuring the Effects of Environmental Certification on Office Values. *Real Estate Economics*.	US	11.8% LEED/Energy Star	n/a	Energy Star: 10% LEED: 31%
Wiley, J.A., Benefield, J.D. and K.H. Johnson (2010) "Green design and the market for commercial office space" in Journal of Real Estate Financial Economics 41:228-243.	US	LEED: 130 dollar / square foot Energy Star: 30 dollar / square foot	n/a	Energy Star: 7-9% LEED: 15-18%
Pivo, G. and J.D. Fisher (2010) "Income, value, and returns in socially responsible office properties" in The Journal of Real Estate Research, Vol. 32, No. 3:243-270.	US	+ 8,5%	n/a	+ 5,2%
Miller, N., J. Spiver and A. Florance (2008) Does Green pay off?, Final draft: 12 July 2008	US	n/a	n/a	Energy Star: 5,8% LEED: 10%
Fuerst, F., & McAllister, P. (2009a). *New Evidence on the Green Building Rent and Price Premium.* Henley University of Reading.	US	6% LEED/Energy Star	n/a	Energy Star: 31% LEED: 35%*
Bloom, B., Nobe, M.C. and M.D. Nobe (2011) "Valuing Green Home Design: A study of ENERGY STAR Homes" in JOSRE, Vol.3, No. 1, 109-126,	US	£8,66 per square foot	n/a	n/a
Fuerst, F., & McAllister, P. (2011b). The Impact of Energy Performance Certificates on the Rental and Capital Values of Commercial Property Assets. *Energy Policy*.	UK	No premium	n/a	No premium
Jaffee, D., Stanton, R. and N. Wallace (2011) Energy factors, leasing structure and the market price of office buildings in the US, Working paper, August 2011	US	n/a	n/a	13,40%
Chegut, A. E. (2011). The Value of Green Buildings: New Evidence from the United Kingdom. *Working Paper.*	UK	up to 21% for 'green' labeled buildings**	n/a	26% for 'green' buildings**
Reichardt, A. F. (2012). Sustainable Building Certification and the Rent Premium: A Panel Data Approach. *Journal of Real Estate Research*.	US	Energy Star: 2.5% LEED: 2.9%	Energy Star: 4.5%	n/a
Kok, N., & Jennen, M. (2012). The impact of energy labels and accessibility on office rents. Elsevier: *Energy Policy*.	NL	6.5% discount for 'non-green' labeled buildings'	n/a	n/a
Fuerst, F. (2014). Measuring 'Green Value': An International Perspective. Royal Institution of Chartered Surveyors (RICS).	US	On average 3 to 6% for LEED or Energy Star	10% for LEED or Energy Star	On average 10 to 13% for LEED or Energy Star

*Only the Leed Certified and Platinum level have a significant premium

** Also evidence that evidence that rental contract features (such as lease term, incentives/rent free period and market signals, such as days on market) have a moderating effect on returns to BREEAM certified rental prices, which in turn decreases rental premiums with approximately 5 percentage points. With regard to expanding the supply of BREEAM certified buildings they state that this has a positive impact on rents and prices in general within a given micro-location, but moderates the BREEAM premium further. As a consequence of this further moderation, the researchers conclude that due to competition in 'green' building markets the premiums in the rental market decrease by 3 percentage points and in the transaction market by 1 percentage point.

Appendix C Additional Results

1 Introduction

This appendix includes additional detailed results that were excluded from the main report for reasons of space.

2 Impacts on air pollution

The impacts from reduced localised air pollution are largely realised in benefits to human health. They are described in more detail in Part IV Section 3. The estimated changes in emissions that determine the results for health are presented here.

Table 0.12 CO Emissions in 2030, % difference from reference scenario

	S1	S2	S3
BE	-0.2	-1.2	-4.1
DK	-0.2	-1.1	-3.8
DE	-0.2	-1.1	-4.2
EL	-0.7	-2.4	-7.0
ES	-0.4	-1.6	-5.1
FR	-0.4	-2.4	-8.5
IE	-0.3	-2.2	-7.9
IT	-0.1	-0.6	-2.0
LU	0.0	-0.1	-0.6
NL	-0.3	-1.2	-3.8
AT	-0.4	-2.4	-8.6
PT	-0.5	-2.5	-8.6
FI	-0.1	-1.7	-6.7
SE	-0.1	-1.1	-4.1
UK	-0.2	-1.5	-4.7
CZ	-0.3	-1.9	-6.3
EE	-0.7	-2.8	-9.1
CY	0.4	0.2	-0.5
LV	-0.4	-3.2	-12.5
LT	0.3	-1.4	-6.7
HU	-0.2	-0.8	-2.6
MT	0.7	0.3	-1.0
PL	-0.2	-1.7	-6.4
SI	-1.3	-7.6	-26.4
SK	-0.1	-0.2	-0.9
BG	-0.9	-3.0	-7.8
RO	-3.4	-8.6	-15.5

HR	-0.3	-1.4	-4.9
EU	-0.5	-2.1	-6.3

Table 0.13 SO_2 Emissions in 2030, % difference from reference scenario

	S1	S2	S3
BE	-0.4	-2.2	-6.5
DK	0.0	-0.5	-1.8
DE	-0.3	-1.5	-5.3
EL	-1.6	-4.5	-15.7
ES	-0.4	-1.9	-6.6
FR	0.0	-3.1	-10.8
IE	-0.2	-2.2	-7.2
IT	0.5	-0.5	-2.7
LU	-0.2	-1.1	-4.0
NL	-0.2	-1.1	-4.2
AT	-0.2	-0.9	-3.2
PT	0.3	-0.7	-5.0
FI	-0.3	-2.5	-9.7
SE	0.0	-0.6	-2.4
UK	-0.3	-2.2	-6.4
CZ	-0.4	-2.4	-7.5
EE	-0.7	-2.5	-8.7
CY	12.5	7.9	-5.2
LV	0.0	-2.6	-11.9
LT	0.3	-1.9	-8.0
HU	0.0	-2.1	-7.3
MT	6.5	4.3	-2.6
PL	0.1	-1.2	-4.9
SI	-1.2	-7.1	-32.8
SK	0.1	-0.7	-2.7
BG	-1.9	-5.5	-15.8
RO	-3.1	-8.2	-13.0
HR	0.2	-3.0	-12.8
EU	-0.2	-2.2	-7.5

Table 0.14 NOx Emissions in 2030, % difference from reference

	S1	S2	S3
BE	-0.3	-1.7	-5.1
DK	0.0	-0.4	-1.2
DE	-0.1	-0.7	-2.6
EL	-0.9	-2.5	-8.5
ES	-0.1	-0.6	-2.2
FR	0.0	-1.5	-5.0
IE	-0.1	-0.8	-2.7
IT	0.1	-0.5	-2.1
LU	0.0	-0.3	-0.9
NL	-0.4	-1.8	-5.7
AT	-0.1	-0.9	-3.0
PT	0.1	-0.4	-2.5
FI	-0.1	-1.4	-5.7
SE	-0.1	-0.4	-1.6
UK	-0.2	-1.8	-4.5
CZ	-0.2	-1.3	-4.1
EE	-0.4	-1.6	-5.5
CY	9.6	6.1	-4.1
LV	0.1	-0.6	-3.7
LT	0.2	-0.7	-3.1
HU	-0.2	-1.5	-4.6
MT	5.1	3.3	-2.3
PL	0.1	-0.5	-2.0
SI	-0.4	-2.7	-12.3
SK	0.0	-0.5	-1.9
BG	-0.9	-2.6	-7.4
RO	-1.8	-4.6	-7.7
HR	0.0	-1.0	-4.1
EU	-0.1	-1.1	-3.7

Appendix D Country classification

Table 0.15 Mapping of country abbreviations

Abbreviation	Full Member State name
BE	Belgium
DK	Denmark
DE	Germany
EL	Greece
ES	Spain
FR	France
IE	Ireland
IT	Italy
LU	Luxembourg
NL	Netherlands
AT	Austria
PT	Portugal
FI	Finland
SE	Sweden
UK	United Kingdom
CZ	Czech Republic
EE	Estonia
CY	Cyprus
LV	Latvia
LT	Lithuania
HU	Hungary
MT	Malta
PL	Poland
SI	Slovenia
SK	Slovakia
BG	Bulgaria
RO	Romania
HR	Croatia
EU	EU28

Appendix E References

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