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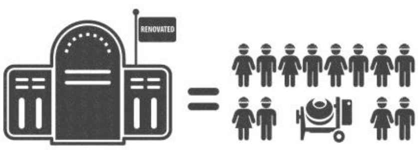
Copenhagen Economics

Multiple benefits of investing in energy efficient renovation of buildings

Impact on Public Finances

Commissioned by Renovate Europe
5 October 2012



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Main findings

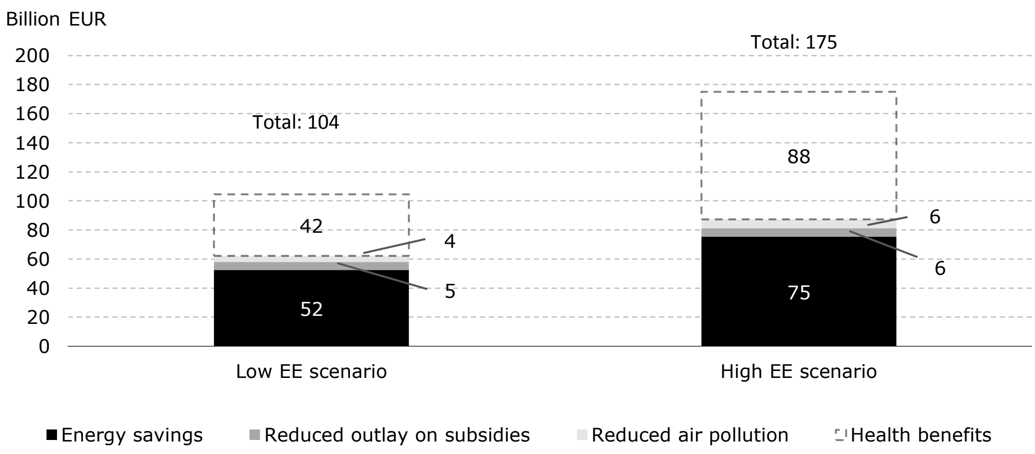
Energy savings through the renovation of the existing building stock is one of the most attractive and low cost options to reduce the emissions of CO_2 and potentially improve energy security by reducing imports of fossil fuels. Indeed, there is wide evidence that undertaking energy efficient renovations at current energy prices often pay for themselves i.e. have negative investment costs.[1] Now is a particularly good time for pursuing such renovations. In addition to the permanent benefits these renovations may bring, it will also produce a much needed stimulus to the European economy at a time of economic underperformance, spare capacity and record low real interest rates in a number of countries.

In addition to the energy savings that renovation of the existing buildings stock will bring, there are a range of co-benefits, which can also be harvested. By reducing energy consumption and focusing on indoor climate issues when renovating, co-benefits can be achieved such as reduced outlay on government subsidies, and improved health due to less air pollution and a better indoor climate, both of which also lead to fewer hospitalisations and improved worker productivity.

Harvesting renovation opportunities could bring huge benefits to the EU economy over the coming decades. Based on available estimates of the potential for energy savings from renovation of buildings, this study suggest a monetised permanent *annual* benefit to society of €104-175 billion in 2020 depending on the level of investments made from 2012 to 2020, cf. Figure 1:[2] €52-75 billion from lower energy bills, and at least €9-12 billion from the co-benefits of reduced outlay on subsidies and reduced air pollution from energy production. If the health benefits from improved indoor climate are included, the benefits are increased by an additional €42-88 billion per year. These health benefits are evident, but very uncertain to estimate, and should be interpreted accordingly. If investments are continued after 2020, these annual benefits can be doubled by 2030.

[1] Net financial savings after deducting investment and running costs are positive
[2] In the low EE scenario, investment costs are expected to be app €41 billion per year, and in the high EE scenario investment costs are expected to be app. €78 billion each year.

Figure 1 Annual gross benefits to society from energy efficient renovation of buildings, 2020



Note: These results include the rebound effect, and can therefore not be compared with the sub-results derived in Chapter 1. We have applied a rebound effect of 20 per cent.

The total does not equal the sum of each element due to rounding.

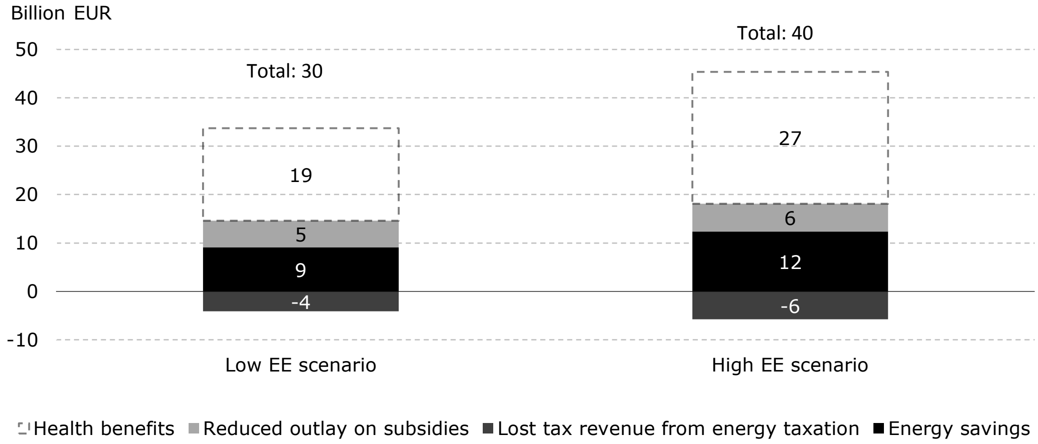
Source: Copenhagen Economics

While most of the benefits from increased investments accrue to society as a whole, governments may also reap additional net revenue gains. A lower level of total energy consumption will reduce public spending on energy bills in e.g. public buildings and institutions, it will contain public spending through less hospitalisation, it will imply a reduced need for subsidies to energy consumption, and facilitate the achievement of EU's 2020 renewable energy targets and reductions of greenhouse gases at a lower cost.

In total, *annual* permanent net revenue gains to public finances could reach €30 – 40 billion in 2020 if health-related benefits from energy efficient renovations are included such as less hospitalisation, cf. Figure 2.[3] This gain is made up from reduced outlay on government subsidies, reduced energy bills, and less hospitalisation need. In this estimate, we have taken into account the loss of government tax revenue from energy taxation. If investments in energy efficient renovation of buildings are continued after 2020, these annual gains are likely to be doubled in 2030.

[3] The health benefits are evident, but very uncertain to estimate, and should be interpreted accordingly

Figure 2 Annual improvements of public finances, 2020



Note: These estimated gains to public finances are already included in in Figure 1, and should not be considered additional to these.

The total does not equal the sum of each element due to rounding.

Source: Copenhagen Economics

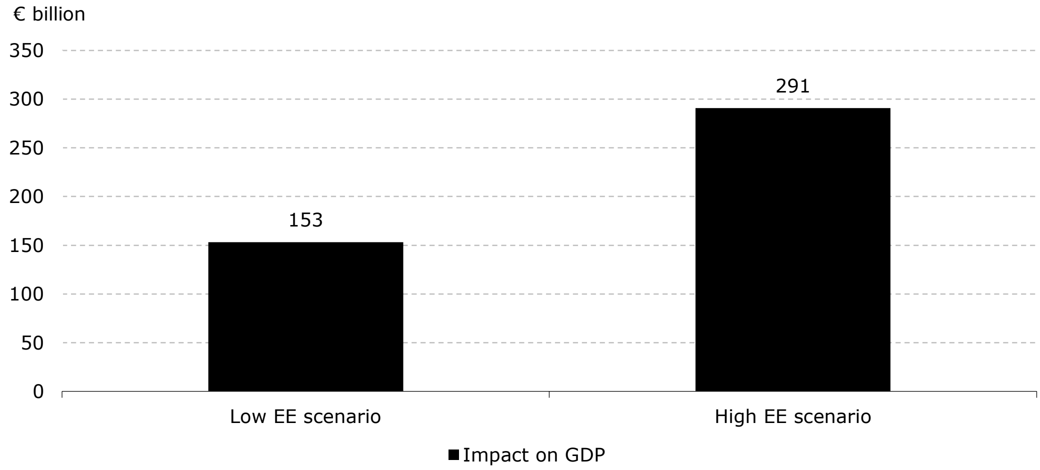
Now is a particularly good time for pursuing these gains. Attaining the benefits *will* require investments and man power, but the current economic climate is ideal for starting such projects. Real interest rates are at record low levels in the majority of EU Member States while, unfortunately, unemployment has risen in nearly all countries since 2008 and are likely to remain above "structural" levels for another 3-5 years. So investment costs are low and there are ample available labour resources.

Our results suggest that by harvesting the investment opportunities provided by energy efficiency renovations in the existing building stock, the EU Member States can stimulate economic activity at an appropriate time, which can give rise to jobs for 760,000 – 1,480,000 people,[4] and bring benefits to GDP of €153 - 291 billion depending on the level of investments, cf. Figure 3. This corresponds to between 1.2 per cent and 2.3 per cent of EU GDP.[5] These benefits stem from increased economic activity in both the primary affected sectors and through the indirect impact on secondary sectors. These benefits are not permanent, but instead a "one-off" benefit from stimulating activity in a period of economic underperformance.

[4] These jobs will to a very large extent be "new jobs" in the time of economic underperformance. In fact, these jobs are likely to remain in the energy efficient renovation of buildings industry. However, as the economy returns to it structural level, there will be no positive effect on total employment in the economy.

[5] GDP measured in 2012 at current prices

Figure 3 Impact on GDP from increasing economic activity, 2012-2017

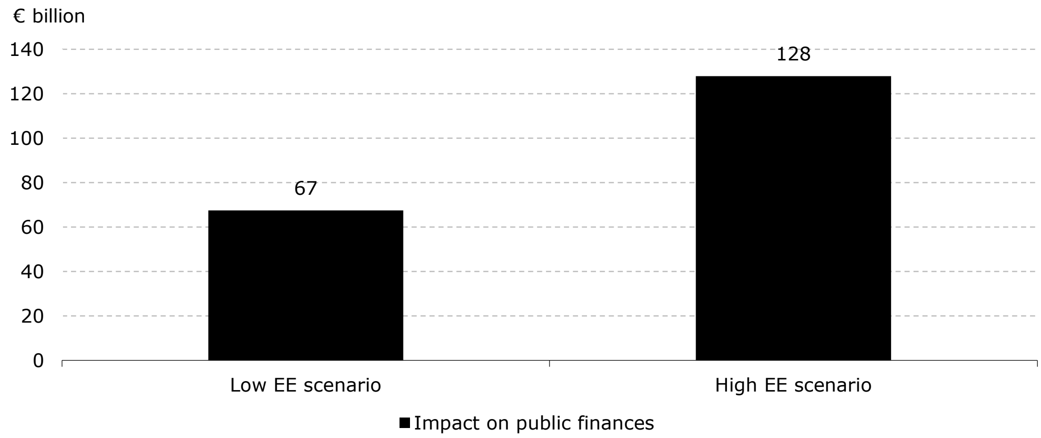


Source: Copenhagen Economics

Speeding up the recovery in the coming 3-5 years with continued projections of substantial overall unemployment will also have a direct impact on public budgets. In the period from 2012-2017 we estimate that public revenue can be increased by €67 billion or €128 billion depending on the scale of investments, cf. Figure 4. This corresponds to between 0.5 per cent and 1.0 per cent of EU GDP.[6] These benefits are associated with more activity and more employment, and come from increased revenue from income taxation, corporate taxation, and VAT, and from reduced outlay on unemployment benefits. These benefits are not permanent, but instead a "one-off" benefit from stimulating activity in a period of economic underperformance.

[6] GDP measured in 2012 at current prices

Figure 4 Impact on public revenue, increased economic activity



Note: The rebound effect is not relevant in relation to effects from increased economic activity

Source: Copenhagen Economics

Indeed, energy savings projects represent a very attractive combination of boosting the economy and improving public finances at the same time. Addressing the main structural barriers holding back these investments is either neutral or tends to improve public finances. We identify at least four key barriers holding these investments back:

Barrier 1: Rent regulation in both publicly and privately owned residential houses, and to a certain extent commercial buildings, often prevents landlords from passing on the costs for improvement in the quality of the buildings, including a lower energy bill to tenants. This greatly reduces the landlords' incentive to invest in energy efficient renovation of buildings. This is a problem as such investments would reduce the total housing bill for the tenant.
Action: Modernise rent regulation to allow landlords and tenants to split the gains from energy efficient renovation of buildings. This is largely without direct costs to public finances.[7]

Barrier 2: Budget management of publicly owned buildings tend to focus on shorter term cash flows as opposed to longer term running costs. This punishes projects with higher upfront costs as counterpart to lower future operating costs i.e. a lower energy bill. In addition, the discount rates applied to assess public investments have not followed the general current trend towards lower market rates.
Action: Reform budget management of publicly owned buildings to allow for a longer term focus in investments and renovation of buildings. This will reduce longer term operating costs in the publicly owned building stock.

Barrier 3: The relatively widespread favourable tax treatment of heating and electricity use in buildings reduces gains from otherwise viable energy savings projects.

[7] As overall housing cost would be reduced, the public costs to e.g. social housing would also be reduced.

Action: Remove/reduce such tax advantages to render energy efficient renovation of buildings more attractive, and provide direct net revenue gains to public budgets.

Barrier 4: Handling of risk in renovation projects has traditionally been a weak point. Investors may face high up-front costs, which imply that they run more substantial risks than for a similar project with lower up-front costs. In this respect it is an important question how you set up, monitor and evaluate performance contracts that ensure that the owner/user of the building de facto gets the promised benefits required to pay back the substantial and non-reversible investment cost over time. Concepts such as Energy Service Companies (ESCO) and Energy Performance Contracts (EPC) which are explicitly designed to align risks and responsibility for the outcome of such projects have not been fully developed to deliver on deep renovation projects. In fact, there are examples of countries not allowing the use of EPCs in the public sector.
Action: Well-designed risk-sharing programmes can help government as well as private building owners to realise cost savings with very limited budget costs.

Chapter 1

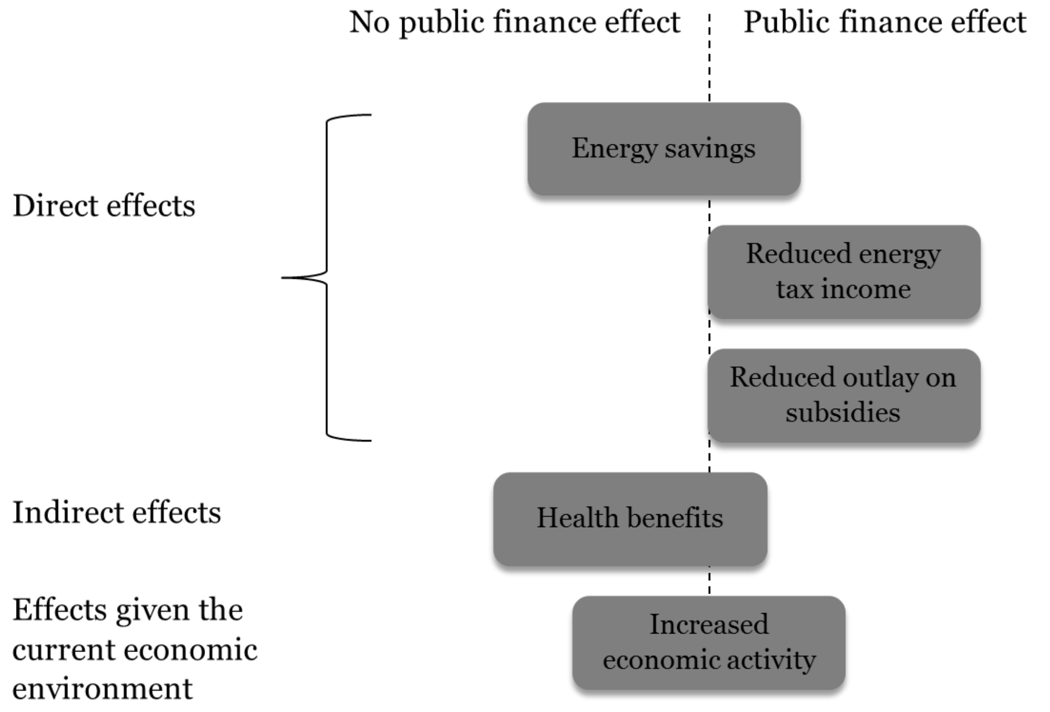
Benefits from investing in energy efficient renovation of buildings

There is an overwhelming amount of evidence that energy savings associated with energy efficient renovation of buildings outweigh the up-front investment costs needed to undertake the projects. As we will describe in Chapter 2, several barriers limit the undertaking of these projects. In this chapter, we describe the benefits that society may reap if the energy efficiency investment potential is released. These benefits go beyond pure energy savings to also include e.g. improved health through reduced air pollution and improved indoor climate, reduced outlay on government subsidies, and macroeconomic benefits from increased economic activity through higher revenue from taxes and reduced unemployment benefits. We have attempted to appraise these co-benefits in order to quantify the aggregate benefits from investing in energy efficient renovation of buildings in the EU. In addition to looking at the overall benefits to society, we have also assessed what impacts there might be on public finances. In this chapter we describe our results, while calculations and documentation of the results is given in the Appendix. It should be noted that several of our estimates are subject to uncertainty, and that constructing these numbers is not an exact science. In the appendix, we state uncertainty spans/intervals on several of the estimates while we in this Chapter show average values for presentation purposes.

1.1 Characterising the benefits

Enhancing the energy efficiency of the existing building stock induces benefits through several channels. While some of these benefits occur directly through e.g. reduced energy consumption, other benefits occur more indirectly through e.g. improved health over several years. In addition, some of these benefits have direct positive effects on public budgets while others are benefits to society at large without having specific public finance effects. Our mapping of the different effects is presented in Figure 5, and discussed in the following section.

Figure 5 Effects of energy efficient renovation of buildings



Source: Copenhagen Economics

Energy savings through reduced energy consumption is a direct benefit stemming from increased energy efficiency. In privately owned buildings the benefits will typically accrue to the owner or the user of the building,[8] while in publicly owned buildings the benefits will accrue to the public or the users of publicly rented apartments. Given the proper distribution of benefits between public entities, this will improve public budgets. The benefit from energy savings implicitly also includes the avoided capital cost of building additional power plants, as these capital costs are included in the price of electricity. The same applies to investments in new grid capacity, which is included in the grid tariffs paid by consumers.[9]

As energy efficient renovation of buildings will reduce energy consumption, it will have a negative effect on public budgets through reduced tax revenue from energy consumption taxes.

The European Member States are currently subsidising both fossil fuel consumption and deployment of renewable energy technologies. By reducing energy consumption through

[8] We will discuss the principal agent problem related to owners/tenants in the section related to reduced energy consumption below.

[9] Over time, consumers will pay for both the variable costs and the capital costs of energy production plants. By considering the retail price of electricity when we calculate the benefits from reduced energy bills, we therefore include the capital cost of new energy production infrastructure.

energy efficient renovation of buildings, both types of subsidy can be reduced. This will have a positive effect on public finances.

A more indirect benefit occurs through *health benefits*. Most energy efficiency measures will improve the indoor temperature, and by choosing renovation measures that also improve the indoor climate, health benefits can be obtained through fewer diseases, 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 fewer hospital expenses and fewer sick days.

Health benefits also occur as power and heat production from power plants, district heating plants and local heating is reduced. Power and heat generated in these facilities give rise to air pollution such as NO_x, SO_2, small particle matters (PM2.5) and CO_2, and by reducing energy consumption this air pollution can be reduced.

Given the current economic downturn, energy efficiency investments can *increase economic activity*, and improve public budgets by reducing unemployment benefits and increasing tax revenue from the increased economic activity. Positive effects from this include, increased tax revenue (including VAT, labour income tax, corporate income tax etc.) from increased activity and employment, reduced unemployment expenses. This effect is relevant during periods of economic crises, when there is spare capacity in the economy.

In addition to these benefits, which we attempt to quantify there are additional benefits which are more difficult to assess and are beyond the scope of this study. Three such benefits are the improved life quality of living in a more comfortable living environment e.g. through a high average living room temperature (benefits which goes beyond the health benefits, which we have tried to quantify), the value of reducing EU's energy supply dependence on third-countries, and the reduced dependence on volatile fossil fuel prices.

1.2 Scenarios

We have considered two scenarios for investments in energy efficient renovation of buildings. These scenarios have been defined in an extensive study for DG Energy and Transport in 2009.[10] This work established the potential penetration in the market of best available technologies under different conditions, such as the level of political ambition for breaking down barriers to energy efficiency investments. Based on this extensive work we focus on two scenarios: 1) Low Energy Efficiency scenario, and 2) High Energy Efficiency scenario. These scenarios take into account a baseline increase in energy efficient renovation of buildings based on a business-as-usual scenario. The potential defined in the two scenarios should therefore be considered in addition to business-as-usual.

The *low EE scenario* assumes a relatively high level of policy initiative, in order to break down barriers to otherwise cost effective investment potential. However, the entire investment potential is so called "cost-effective" meaning that under normal assumptions

[10] Fraunhofer ISI et al (2009)

on for example energy prices and consumer's discount rates, the energy savings following over time will be able to pay for the upfront investment cost.[11] As an example, the scenario assumes that the heating systems, and windows, which can be cost effectively replaced by more efficient models (not necessarily *the* most efficient model) will be upgraded.

The *high EE scenario* on the other hand assumes full penetration of best available technologies. This should be seen as an upper limit for energy efficiency investments given the *current* level of technology. As an example, the scenario assumes that all windows will be upgraded to the most efficient models available on the market. While this implies that technologies will be deployed beyond what is cost effective from an energy savings point of view, it will bring additional benefits through e.g. improved health, which will improve the overall profitability of the investment. While this example specifies an upper level on the potential given current technologies, the potential for energy efficient renovation of buildings is expected to increase going forward, as technologies improve and cost of technologies are reduced.

1.3 Identifying the energy saving potential

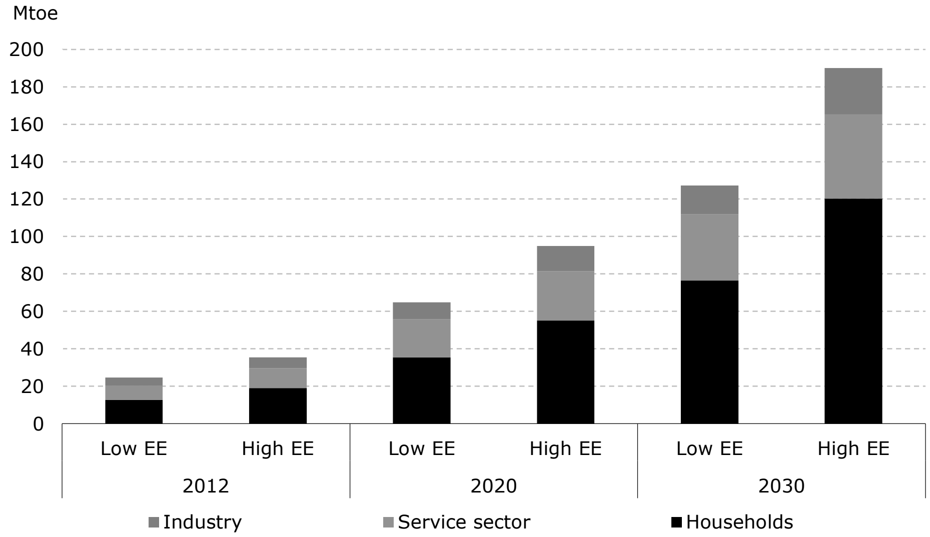
Energy efficient renovation of buildings in the EU holds a large potential for energy savings. The potential for achieving energy savings in 2012 is 25 Mtoe in the low EE scenario (35 Mtoe in the high EE), cf. Figure 6.[12] In 2020 this potential is accumulated to 65 Mtoe in the low EE scenario (95 Mtoe in the high EE) which corresponds to app. 5.4 per cent of EU final energy demand (8.2 per cent in the high EE).[13] In 2030 the accumulated energy savings are increased to 127 Mtoe in the low EE scenario (190 Mtoe high EE), which corresponds to app. 10.6 per cent of EU final energy demand (15.8 per cent in the high EE). The largest potential for renovating buildings lies in the household sector, followed by the service sector and industry. The energy saving potential is only from energy efficient renovation of existing buildings, such as upgrading heating systems, improving insulation, replacing windows, improving lighting systems, ventilation systems and air conditioners. Energy efficiency improvements from household appliances such a washing machines, energy efficiency gains from constructing new buildings or gains from more efficient industrial process such as improving the kiln for making cement clinkers from limestone are *not* accounted for in these calculations.

[11] Cost effectiveness is defined using consumer's real discount rates ranging from 4 – 8 per cent. 8 per cent is applied to industry to depict shorter pay back horizons than households. Public investments are given a 4 per cent real discount rate.

[12] This potential is identified in an extensive study for DG Energy and Transport by Fraunhofer et al (2009). The calculations take into account the specific building stock in all EU Member States including its age, the different climatic zones including the amount of heating degree days, the energetic standard of the buildings (U-values), and the energy demand in the different countries. This allow the authors to calculate energy consumption per square meter for different buildings types in specific countries. Country specific information on material cost, labour costs, and very detailed cost structure for different types of refurbishment is also taken into account, including learning curves for different technologies and the implied cost reductions over time.

[13] Based on DG Energy (2010)

Figure 6 Accumulated energy saving potential over time

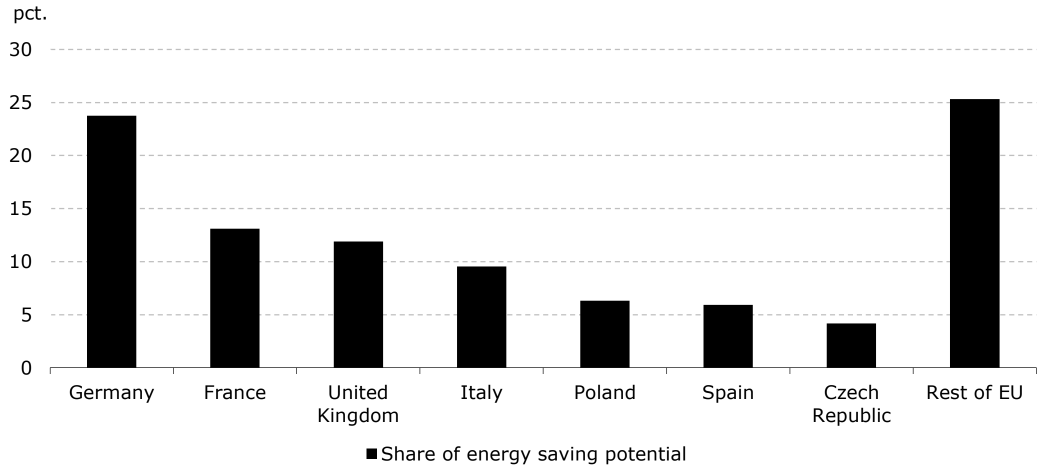


Source: Copenhagen Economics based on http://www.eepotential.eu/esd.php

The energy saving potential is not equally spread out across Member States, but will depend on the size and the condition of the existing building stock. Countries with a smaller existing building stock will naturally have a smaller absolute potential for renovations. Countries with an ageing building stock will also have a higher potential for renovations. One study finds that more than 68 per cent of apartments and 60 per cent of single family homes in France were built before 1975.[14] This makes energy efficient renovation of buildings more relevant in France than in countries, where the building stock is younger.[15] We find that the largest potential is present in Germany (24 per cent of EU total), France (13 per cent), UK (12 per cent), and Italy (10 per cent), cf. Figure 7. These four countries constitute 58 per cent of EU's total energy savings potential.

[14] McKinsey Global Institute (2011), page 89
[15] Ibid

Figure 7 Share of energy saving potential by country, 2030



Note: Energy saving potential is measured by Mtoe.
The figure shows the distribution in 2030. A similar picture holds for the potential in 2020.
The full distribution of potentials on countries can be found in the appendix.

Source: http://www.eepotential.eu/esd.php

The gross investment costs associated with meeting this energy saving potential is estimated to be app. €41 billion annually from 2012-2020 in the low EE scenario, and €78 billion in the high EE scenario. In order to reach the potential in 2030 a similar annual amount is needed.[16]

1.4 Quantifiable benefits from investing in energy efficient renovation of buildings and the impact on public finances

In this section we quantify the benefits from energy efficient renovation of buildings described in Figure 5. In addition to the benefits we have been able to quantify, there are likely to be additional benefits, which are more difficult to quantify and are beyond the scope of this paper. Three such benefits are the improved life quality of living in a more comfortable living environment e.g. through a high average living room temperature (benefits which goes beyond the health benefits, which we have tried to quantify), the value of reducing EU's energy supply dependence on third-countries, and the reduced dependence on volatile fossil fuel prices. All our calculations and assumptions are elaborated in the Appendix, while we in the main text suffice to describe our results.

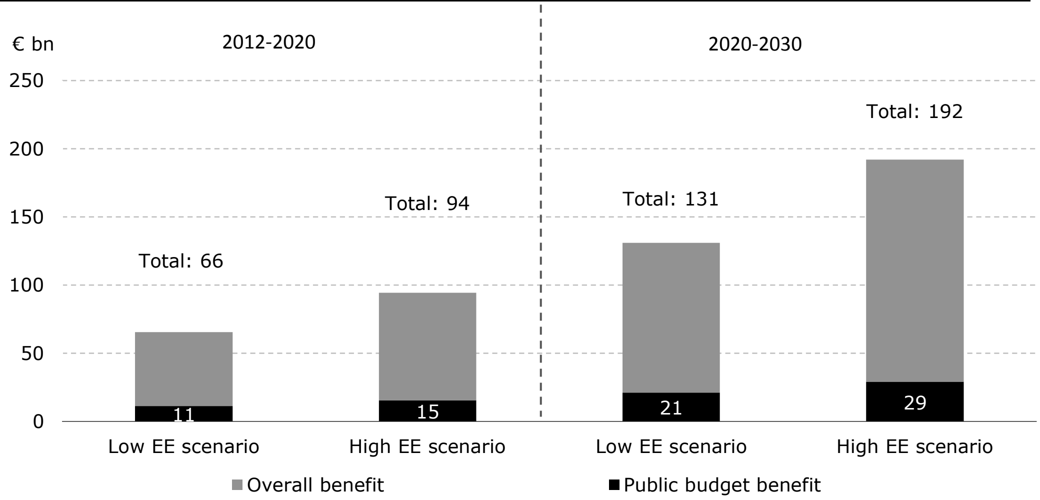
[16] The European Commission (2012), Annex 1 finds that €60 billion per year is needed from 2012-2020 in order to reach the energy efficiency potential in both existing buildings and in new buildings. We focus only on renovating the existing building stock.
For more information on investment cost of renovating buildings, see BPIE (2011) who estimate present value investment costs of various different energy saving scenarios.

Within each element we assess the overall benefits to society, and whether or not it will have an impact on public finances. In the next section (Section 1.5), we aggregate both the overall benefits and the total expected impact on public finances.

Energy savings

The most direct and also the most significant benefit from energy efficient renovation of buildings is the savings resulting from lower energy consumption. If the EU is able to achieve the accumulated potential for energy efficiency in 2020 it can save energy costs of €66 billion or €94 billion each year respectively for the low and high EE scenario. These energy savings can be increased to a total of €131 billion or €192 billion annually (low and high scenario) if the EU also fulfils the potential in 2020-2030, cf. Figure 8. As the public sector owns 7 per cent of EU's residential buildings and 29 per cent of non-residential buildings, a significant share of these total energy savings accrue to the public sector. This corresponds to €11-15 billion annually in 2020, and a total of €21-29 billion in 2030.

Figure 8 Energy savings from renovation of buildings



Note: The energy savings are annual savings which can be achieved in 2020 and 2030 respectively given an investment path that meets the potential for energy efficiency renovation of buildings in 2020 and 2030 respectively.

Note that the public budget benefits are a share of total benefits to society.

The total does not necessarily equal the sum of the elements due to rounding.

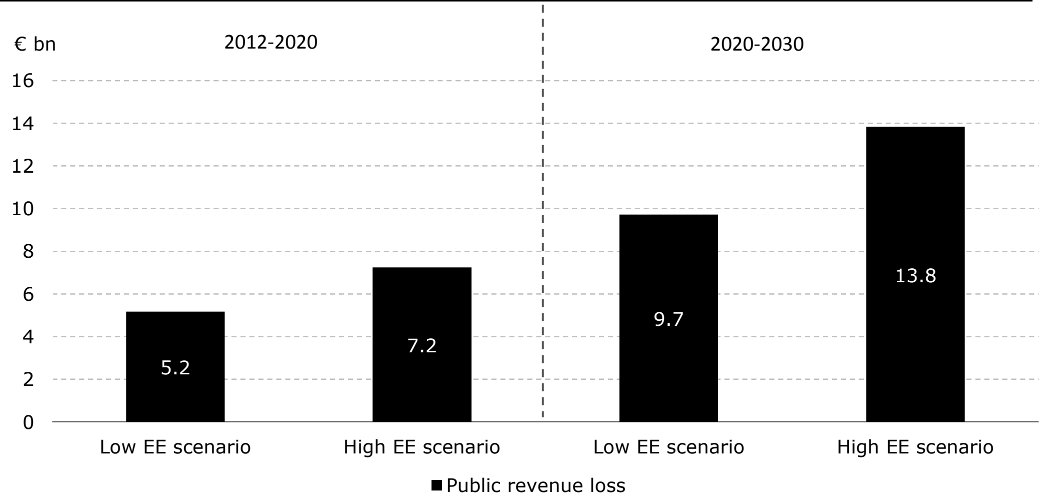
Source: http://www.eepotential.eu/esd.php for energy saving potential.

Price of energy projections: DG Energy (2010)

Reduced tax revenue from energy taxation

One source of tax revenue for European governments is energy taxes. As energy consumption is reduced from energy efficiency initiatives, government tax revenue will decrease. We find that the expected reduction in energy consumption in the different scenarios will give rise to a loss of tax revenue of €5.2 billion or €7.2 billion annually in 2020 (depending on the scenario), cf. Figure 9. If the potential going towards 2030 is also met, energy taxes will be reduced annually with a total of €9.7 or €13.8 billion in 2030 (depending on the scenario). This loss of tax revenue is not a loss to society as a whole, since it is a transfer from governments to consumers. However, it still counts against the benefits to public budgets which we find elsewhere in this report.

Figure 9 Reduced tax revenue from energy taxes



Note: The calculation is based on an average electricity tax in EU, and the excise duties on natural gas and coal for heating use in business and non-business for Germany. While the Member States' electricity taxation and excise duties on heat varies greatly, our calculations can be used as an approximate average for EU as a whole.

Source: Copenhagen Economics based on DG Energy (2010), DG TAXUD (2012)

Reduced outlay on government subsidies

In several EU Member States, government subsidies are being allocated both to consumption of energy through e.g. fuel tax reductions/exemptions, and to deployment of renewable energy technologies that cannot yet compete without government subsidies. While some Member States subsidise production of energy, the majority of these subsidies are related to the winding down of coal fired power plants.[17] Such subsidies are not related to the level of energy consumption, and are therefore not expected to be reduced by reduced energy consumption from increased energy efficient renovation of buildings.

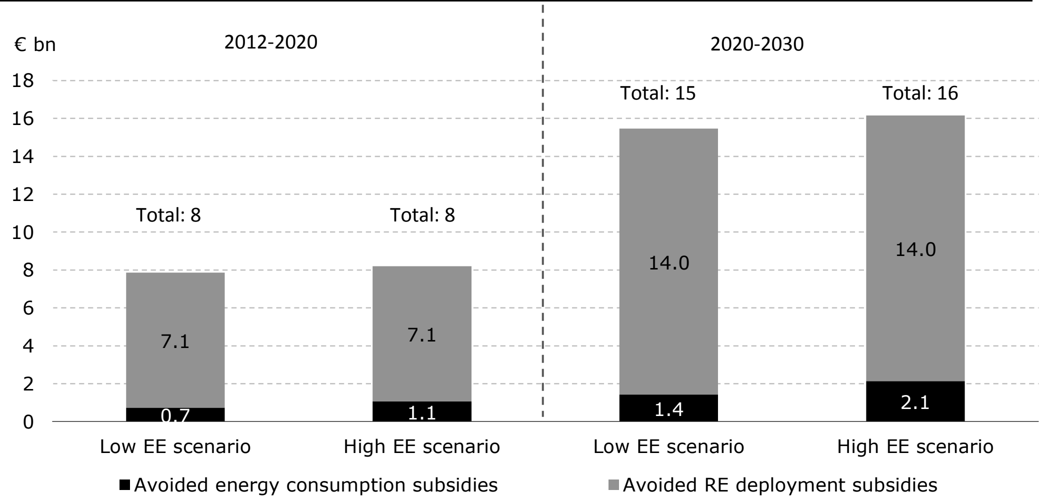
We find that the outlay on energy consumption subsidies in nine large EU countries correspond to about €11.7 billion annually.[18] By reducing energy consumption through energy efficient renovation of buildings according to the potentials identified in our two scenarios, we find that these governments can reduce outlays on subsidies by €0.7 – 1.1 billion annually in 2020 (low and high scenario), cf. Figure 10.

Additionally, by reducing energy consumption, the target of 20 per cent renewable energy by 2020 can be achieved at reduced costs for governments. In particular, EU governments can reduce outlays on subsidies to renewable energy deployment annually by €7.1 billion

[17] See OECD (2011c)
[18] Estimate is based on data from OECD (2011c).

in 2020, cf. Figure 10. These funds could alternatively be used to boost investments in innovation of low carbon technologies, including energy efficiency, in order to meet more stringent climate targets in the future.[19] Our estimates are based on the EU government's envisaged deployment of renewable energy, described in the countries' National Renewable Energy Action Plan (NREAP). It should be noted that the cost of energy from renewable technology is uncertain, and is subject to rapid change over time. We have calculated the gain to public finances from both a low-cost, and a high-cost scenario. Figure 10 shows an average value, and the low and high-cost estimates respectively can be found in the appendix. These benefits will improve public budgets each year.

Figure 10 Reduced outlay on subsidies



Note: Since the EU NREAPs only go to 2020, we have assumed a parallel deployment of the same technologies going towards 2030.

For energy consumption subsidies we have only included the OECD's EU countries.

The total does not necessarily equal the sum of the elements due to rounding.

Source: Copenhagen Economics, based on Member States NREAP, OECD (2011c), DG Energy (2010), and http://en.openei.org/apps/TCDB/

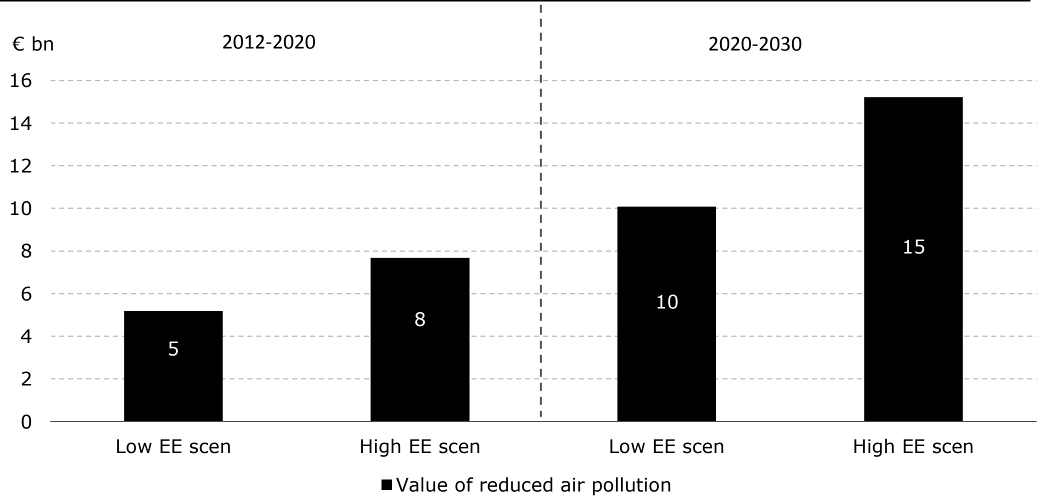
Health benefits – reduced air pollution

By reducing energy consumption, the amount of air pollution will be reduced. As energy production from power plants, district heating plants, and local heating production is reduced, so is the air pollution associated therewith. The air pollution primarily takes place through the emissions of CO_2, NO_x, SO_2, and small particle matters ($PM_{2.5}$).

We find that by reducing air pollution, an annual health benefit worth €5-8 billion will accrue to the European population from 2020, cf. Figure 11. By continuing with energy efficiency investments after 2020, this annual benefit can be doubled in 2030. For comparison, the EU Commission finds that by going from a 20 per cent GHG reduction target to a 30 per cent target, the value of reduced air pollution ranges from €3.5 – 17 billion.[20]

[19] See e.g. Copenhagen Economics (2011), and Copenhagen Economics (forthcoming)
[20] See European Commission (2010), page 95

Figure 11 Value of reduced air pollution



Source: Copenhagen Economics based on GAINS model, DG Transport (2008), DG Energy (2010), Eurostat, and IEA (2012)

The European Commission has calculated the avoided costs from other investment measures in order to reach EU policy objectives of reduced air pollution. This figure can be seen as the alternative value of reducing air pollution. In the scenario for going from a target of 20 per cent GHG emission reductions to 30 per cent, this has the value of €5.3 billion per year. [21] This scenario assumes a reduction in gross energy consumption of 6.5 per cent, and is therefore comparable to a cross between the low and high EE scenario.

Health benefits – improved health from improved indoor quality

There is substantial evidence that energy efficient renovation in buildings will have additional health effects. Renovations such as improved insulation, more efficient heating and cooling systems, better indoor lighting, and better ventilation affects both health and productivity through several channels. The health effects stem primarily from alleviating inadequate warmth and increasing access to daylight and ventilation. Studies have shown that respiratory and circulatory hospitalisations have been reduced by insulating houses, as these diseases are particularly responsive to the effects of temperature.[22] Cold houses are also likely to be damp, which can lead to the growth of mould, which can cause respiratory symptoms. In addition better indoor lighting and ventilation improves the indoor climate in office buildings which is likely to increase productivity, and may even improve students' learning ability and their future productivity.[23]

To our knowledge, these benefits have been quantified to a very low extent and only for very specific projects under specific circumstances. Due to high uncertainty related to an

[21] See European Commission (2010), page 59
[22] Barnard et al (2011), page 11.
[23] See e.g. Threlfall (2011), Liddell et al. (2011), Barnard et al. (2011), UK Department of Health (2010), REHVA (2006), and Slotsholm (2012)

extrapolation of such numbers to the whole of the EU, we include them in the aggregate benefits with dashed lines, in order to illustrate the uncertainty they are subject to. Nevertheless, we stress that there is substantial evidence that such health effects are of considerable magnitude and may outweigh the value of energy savings. In fact, our ball park estimates suggest that these health benefits may be worth €33 - 73 billion annually in 2020, in the low EE scenario through improved life quality, less public health spending and fewer missed days of work.[24] In the high EE scenario this amounts to €64 - 140 billion annually. Continuing investments after 2020 may double this amount. This suggests that such effects should be considered when the profitability from a societal point of view of energy efficient renovation of buildings are evaluated. In order to make a more precise estimate of the actual health benefits to EU as a whole, more research in this area is encouraged.

Increased economic activity

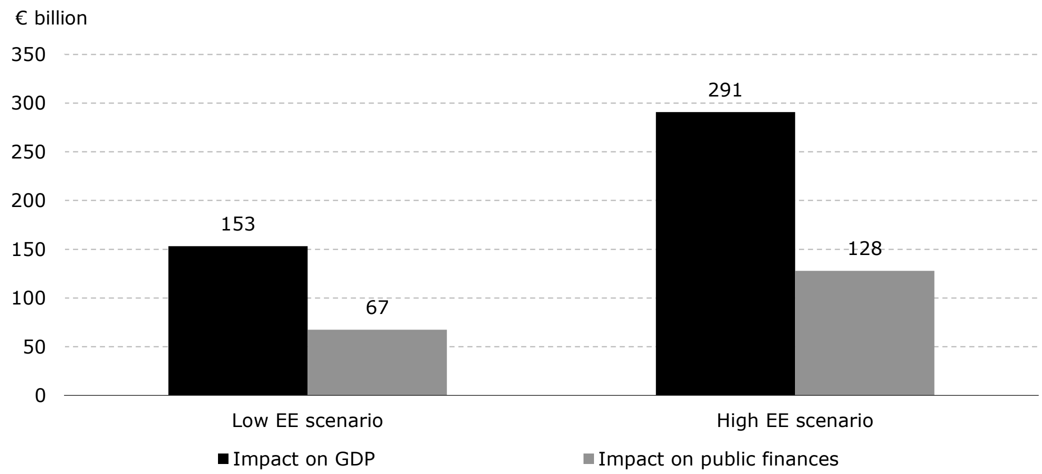
In the current economic environment with relatively high unemployment and spare capacity in the economy, there are good arguments for releasing the energy efficiency renovation potential. Such increased investments will stimulate economic activity, and move people from unemployment to employment. As growth rates catch up and eliminate the substantial amount of spare capacity that the EU economy is currently facing – i.e. the output gap is being closed – the benefit to the total economy from such increased investments is limited, as they will tend to crowd out activity elsewhere in the economy.

We expect that the output gap will not be closed before 2017. In 2011, OECD concluded that EU was expected to close its output gap in 2015.[25] Subsequently, the economic projections have been worse than expected. Based on this we expect that the output most likely will not be closed until 2016-2018, hence we chose 2017 as the basis of our calculations. Based on this, we calculate the direct and indirect macroeconomic effects from increasing economic activity in this period with increased investments in energy efficient renovation of buildings. These effects encompass benefits to GDP and public finances from increased employment through inter alia increased income tax revenue, corporate tax revenue, VAT revenue and reduced unemployment benefits. Our ball park estimates show that app. 760,000 jobs each year can be related to energy efficient renovation of buildings, if annual investments of €40 billion are undertaken towards 2020. We estimate that such an investment path will result in an accumulated impact on GDP in 2012-2017 of €153 billion in the low EE scenario and €291 billion in the high EE scenario, cf. Figure 12. This translates into an improvement in public budgets of €67 billion in the low EE scenario, and €128 billion in the high EE scenario as tax revenues go up and social expenditure to unemployment benefits etc. go down.

[24] See the appendix for the calculations

[25] OECD (2011) Economic Outlook

Figure 12 Benefits from stimulating economic activity



Note: The benefits are measured as an accumulated benefit to EU from achieving the energy efficiency renovation potential from 2012-2017.

These benefits should be interpreted as a one-off benefit in the period 2012-2017.

See the appendix for the calculations

Source: Copenhagen Economics, based on IMF World Economic Outlook database, OECD (2001), and DG ECFIN (2012).

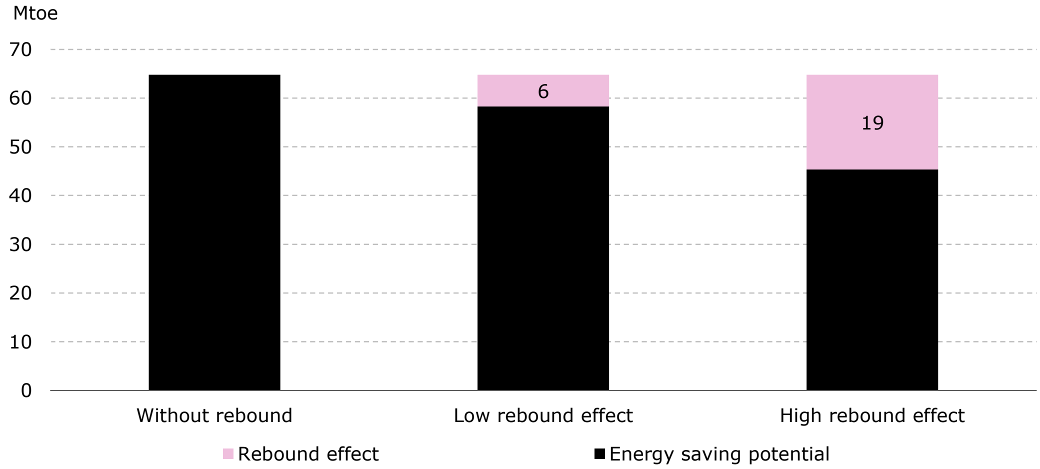
Taking the rebound effect into account

When the cost of energy is reduced (e.g. through increased energy efficiency), consumption of energy is very likely to increase in response. In the economic literature, this is known as the rebound effect. The size of the rebound effect varies from environment to environment, such as for example how many extra kilometres will be driven when the price of petrol is reduced, or how much the average room temperature will be increased when it is cheaper to do so. There is uncertainty related to the actual size of this rebound effect. A survey of the rebound literature has shown however, that the rebound effect related to room temperature is likely to be between 10-30 per cent.[26] In our context, this means that if energy efficiency investments have the potential to reduce energy consumption by 65 Mtoe in 2020 (low EE scenario), a high rebound effect will increase energy consumption by 19 Mtoe, cf. Figure 13. This will therefore also reduce the expected amount of energy savings.

In our calculations above, we show the results excluding the rebound effect, in order to allow for easy comparison with other rebound estimates. When we aggregate the benefits below, we do include the rebound effect and apply a rebound effect of 20 per cent.

[26] Greening et al (2000)

Figure 13 Energy saving potential with rebound



Note: The figures depicts the low energy efficiency in 2020
Rebound effect is measured for room heating improvements (including insulation)

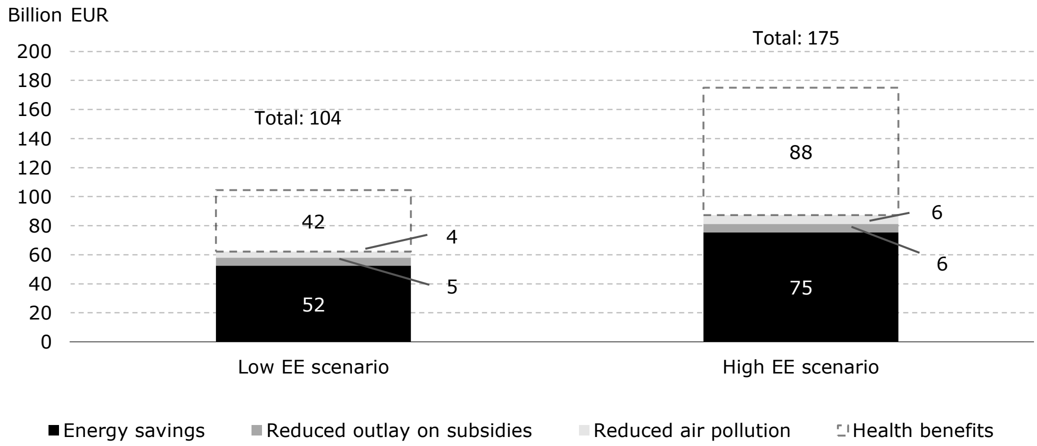
Source: Copenhagen Economics based on Greening et al (2010)

1.5 Aggregating the benefits

In order to consider the profitability of energy efficient renovation in buildings in the EU, not only the pure energy savings should be taken into account. Conversely, co-benefits such as health improvements and reduced outlay for subsidies to energy consumption and renewable energy deployment should also be considered.

We estimate that by achieving the potential for energy efficient renovation in buildings in 2020, EU Member States may achieve *annual* benefits worth of €104 billion in the low EE scenario, and €175 billion in the high EE scenario, cf. Figure 14. €42 and €88 billion of these respectively are benefits from improved health, where our estimates are subject to considerable uncertainty and should be interpreted accordingly. If investments are continued in order to meet the energy efficiency potential in 2030, these annual benefits are likely to be doubled. Please note that in the aggregate benefits, the rebound effect has been taken into account. We apply a rebound effect of 20 per cent. This implies that the aggregate figures used in this section are 20 per cent lower than in the preceding sections, whenever the rebound effect is relevant.

Figure 14 Annual benefits to society, 2020



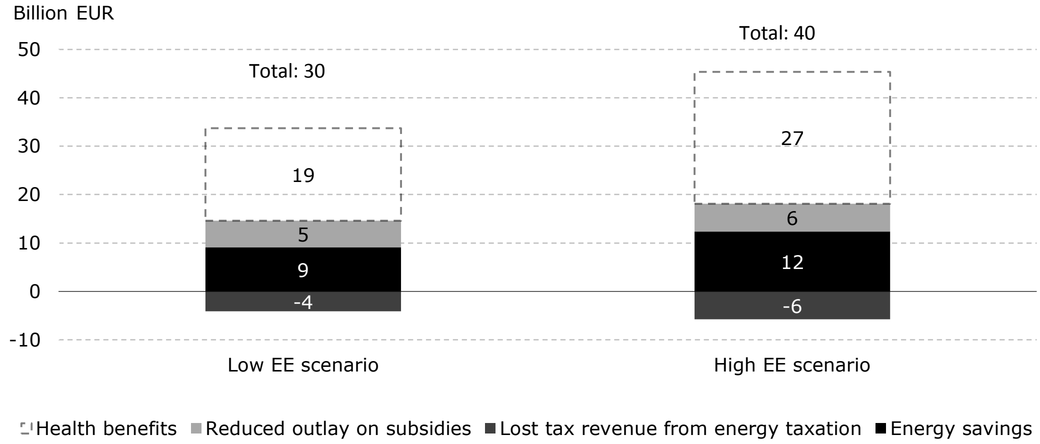
Note: The rebound effect has been taken into account

The total does not necessarily equal the sum of the elements due to rounding

Source: Copenhagen Economics

Our estimates suggest that by releasing the potential for energy efficiency renovation, public finances in Europe can be improved by €30 – 40 billion *annually* from 2020, cf. Figure 15. €19 and €27 billion of these respectively are benefits from improved health, where our estimates are subject to considerable uncertainty and should be interpreted accordingly. Continuing investments towards 2030 will most likely double this amount in 2030. Note that the benefits to public finances are a subset of the overall benefits to society.

Figure 15 Annual improvement of public finances, 2020



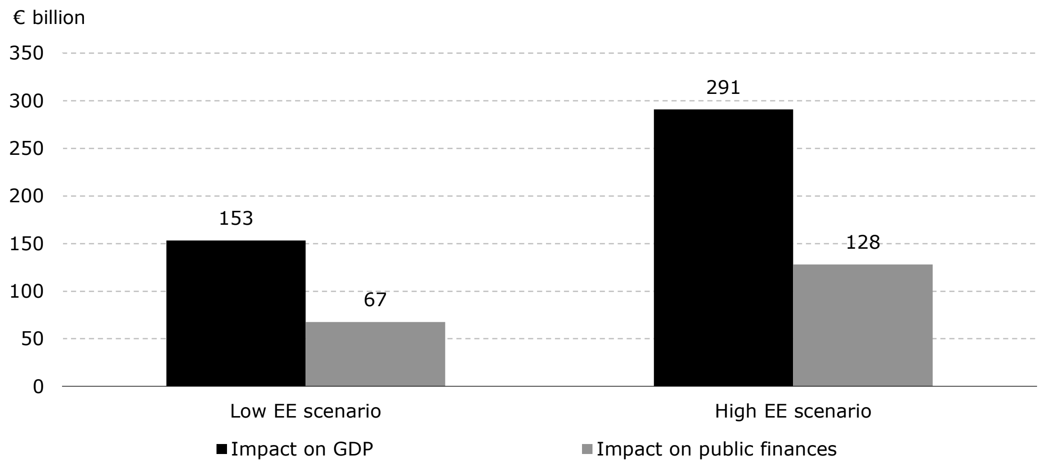
Note: The improvement of public finances is a subset of the overall benefits to society

The rebound effect has been taken into account

Source: Copenhagen Economics

In addition to these *more enduring* benefits, there will be a positive effect from increasing economic activity in a period of economic downturn. This benefit amounts to a one-off gain of €153 billion which will fall to society between 2012-2017 if the low EE scenario is followed, and €291 billion if the high EE scenario is followed, cf. Figure 16. This increased activity also brings means that public budgets will be improved by €67 billion and €128 billion respectively.

Figure 16 Benefits from stimulating economic activity



Note: The benefits are measured as an accumulated benefit to EU from making achieving the energy efficiency renovation potential from 2012-2017.

These benefits should be interpreted as a one-off benefit in the period 2012-2017.

Source: Copenhagen Economics, based on IMF World Economic Outlook database, OECD (2001), and DG ECFIN (2012).

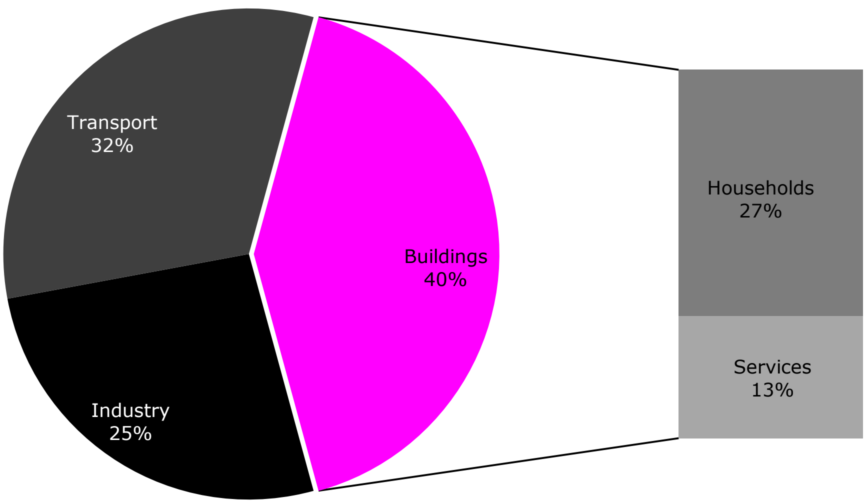
Chapter 2
Barriers and policy responses

2.1 Why are buildings interesting?

Achieving energy efficiency is a key priority for the Commission and Member States. This is illustrated by the EU 2020 objective of increasing energy efficiency by 20 per cent. Renovating buildings is only one method of improving energy efficiency; however it is a very interesting method for at least two reasons 1) The building sector is a large source of energy consumption, and 2) studies show that renovations of existing buildings is one of the low-cost options to reduce emissions of CO_2.[27]

Firstly, energy consumption in buildings constitutes 40 per cent of total final energy consumption in EU, cf. Figure 17. This is a larger share than both the transport and the industry sector. This figure includes both elements that can be affected by energy efficiency renovations such as heating consumption (can be affected through better insulation etc.), and elements that cannot be affected such as energy consumption by appliances such as TVs and washing machines.

Figure 17 Final energy consumption by sector



Note: Energy consumption in agriculture, fishing and "other" makes up 3 per cent of final energy consumption, and is not included in the above figure

Source: DG Energy: EU Energy in Figures 2012

[27] McKinsey & Company (2010) for examples finds that such renovations are one of the most attractive options to bring down greenhouse gas emissions cost effectively.

Secondly, much evidence has shown that renovating the existing building stock is one of the most attractive and low cost options to reduce CO_2 emissions, and potentially improve energy security by reducing imports of fossil fuels. A number of studies have suggested that the net cost of investing in renovating the existing building stock is not only low, but is in fact negative.[28] This means, that through the induced energy savings, investments in energy efficient renovation of buildings will pay for themselves at current energy prices.

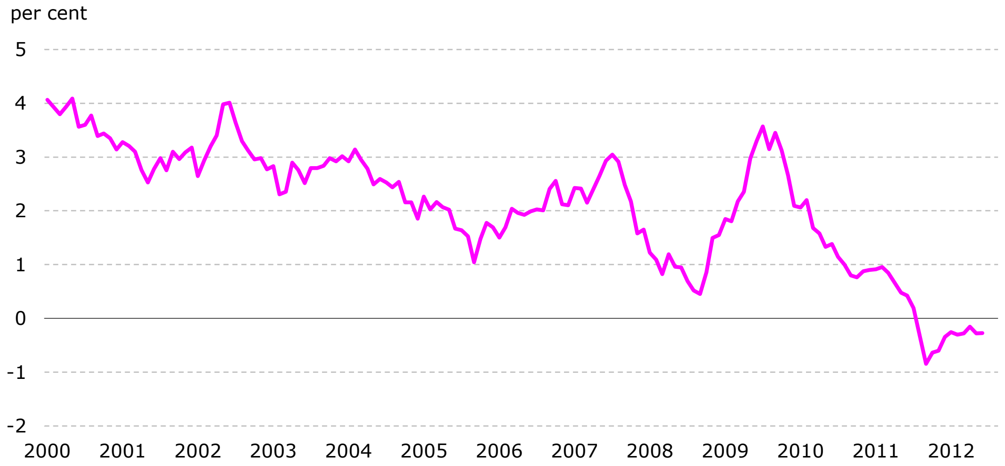
In addition to Marginal Abatement Cost curves (MAC-curves) prominent in several macro studies, several studies find that energy efficiency improvements in buildings are profitable even with very high financing cost. One assessment from 2011 found that the internal rate of return (IRR) on typical energy efficiency investments to be nearly 30 per cent on average for an individual firm (even higher benefits to society).[29] This implies that an investment will be profitable to undertake even when the real interest rate (the financing cost) is 30 per cent or less. The IRR varies across different types of projects, and can be as high as 49 per cent for an average investment in e.g. improving lighting. The largest absolute saving potential is typically found in the heating and cooling category, as its share of energy consumption is relatively larger.

Some criticism has been raised against the MAC and IRR approach in general and specifically on the McKinsey approach on several accounts, inter alia:[30] 1) that ex ante studies dominate much of the estimates, and that ex post assessments often show a lower than expected potential, 2) that “free riders” are not always properly accounted for, so that the overall potential includes behaviour that would have taken place even without policy, 3) most assessments ignore the rebound effects, which implies that as the price of energy is reduced in response to increased energy efficiency, demand for energy (consumption) increases, and 4) transaction cost, including e.g. scarce management time and resources are typically not included. In sum, this implies that such findings tend to value the potential too optimistically.

However, even with a reduction in the profitability of energy efficiency projects, there is strong reason to believe that such projects are highly profitable. As the real interest rate in most European countries is currently very low – and even negative in several countries –, cf. Figure 18, projects will be profitable even with very low IRRs.

[28] A large number of studies construct MAC-curves that makes this point. The MAC curve has been popularised by e.g. McKinsey & Company (2010).
[29] United Technologies Corporation (2011)
[30] See e.g. NBER (2009)

Figure 18 Real interests rates of government bonds



Note: We use the nominal interest on a 10-year government bond for most European countries. We use the HICP index to adjust for inflation.

The curve shows a weighted average for all EU countries except countries severely affected by the economic crisis leading to extraordinarily high interest rates such as: Italy, Spain, Portugal, and Ireland. The real interest rate has been weighted by the countries' GDP.

Source: Copenhagen Economics, based on data from Eurostat

MAC and IRR studies typically only include the energy savings that may be derived from energy efficient renovations of buildings. However, as we showed in Chapter 1, these renovations will also give rise to a range of co-benefits, which makes each individual project even more profitable from a societal point of view than by just realising energy savings.

The marginal abatement cost curves, and studies on profitability of actual energy efficiency investments suggest that there is a large unfulfilled potential for otherwise profitable investment projects to be undertaken. This is accentuated by the very low real interest rates in most European countries, which by definition makes more investment projects economically profitable. We argue that there are several barriers holding these investments back. The barriers may be grouped into: 1) Regulatory failures, and 2) Market failures. We will describe these barriers in detail in the following sections.

2.2 Barriers from regulatory failure

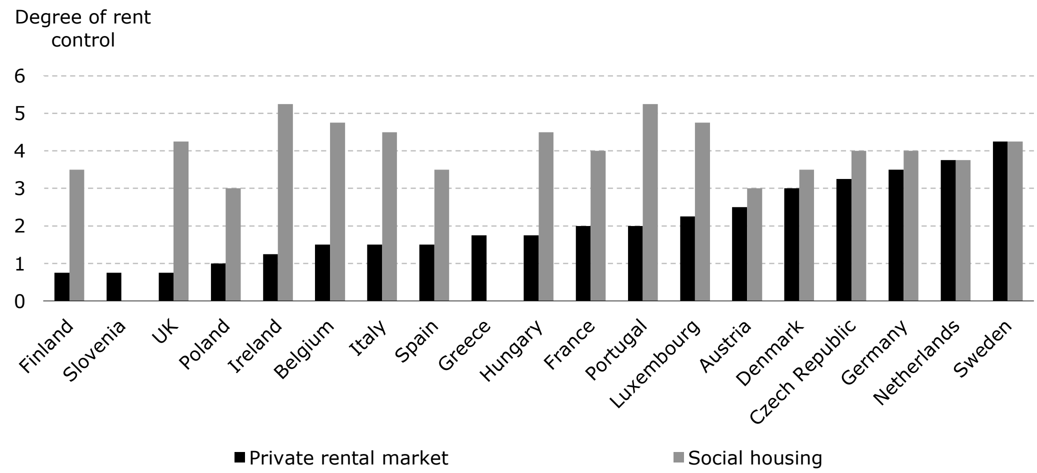
In our view, the existence of regulatory related barriers is the most convincing argument for the existence of unreleased potential for energy efficiency investments in buildings. Several types of regulatory failures are likely to exist:

Rent regulation

Rent regulation is a common feature of almost all EU Member States' housing policies. While concrete regulation differs between countries, the most common feature is rent control, which typically prevents landlords from increasing the rent level above some regulated level. The strictness of the rent control defines e.g. whether or not landlords may pass on cost increases to the tenant, and in which cases what types of costs may be passed on.

The fact that owners/landlords of buildings are the ones to undertake the renovation investment, and users/tenants are the ones to benefit from reduced energy savings, gives rise to a so called split-incentive problem. In the literature this is sometimes known as a principal/agent problem. Basically, the landlords will not have the proper incentive to undertake such investments, unless they have the possibility to pass on (some of) the investment costs to the tenants. The tighter control there is over the rent setting, the less incentive landlords will have to invest. One example in the UK shows that wall cavities where filled at a much higher rate in the owner-occupied sector than in the private rented sector (49 per cent versus 32 per cent in 2008).[31] According to OECD, the EU Member States with the tightest rent control in the private rental market is Sweden, Netherlands, Germany, Czech Republic and Denmark, cf. Figure 19. Rent control for social housing is especially strict in Portugal, Ireland, Luxembourg, Belgium, Italy and Hungary.

Figure 19 Rent control regulation



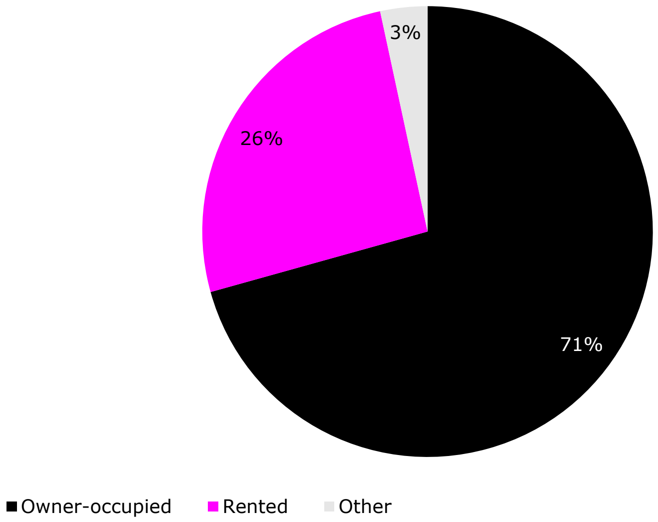
Note: The degree of rent control is a constructed indicator determining how increases in rent are determined, and the permitted cost pass-through onto rents.

Source: OECD (2011a)

The rent regulation problem may have a significant impact, as 26 per cent of the EU building stock is rentals, cf. Figure 20. This includes both residential and non-residential buildings.

[31] UK government Energy Bill, Green Deal Impact Assessment (2010), referring to English Housing Condition Survey (2007) and (2008).

Figure 20 Share of owner-occupied and rental



Note: Data only available for 15 countries

Source: Own calculations based on BPIE (2011)

One of the countries having recognised the misaligned incentives between landlords and tenants as a problem is the UK. In October 2011, UK adopted the Energy Act 2011, which has as a main priority to increase investments in energy efficiency renovations especially in the private rented market. While not concretely addressing rent control legislation, the Energy Act 2011 offers finance for landlords allowing them to undertake such investments with no up-front investment cost, cf. Box 1.

Box 1 The UK Energy Act 2011 – Green deal

In 2011, the UK adopted an Energy Act. One of the three main objectives is how to tackle barriers to investment in energy efficiency. This objective is addressed through three concrete measures: 1) A *Green deal*, 2) Private rented sector reform, and 3) Energy Company Obligation.

Underlying the legislation is an acknowledgment that energy efficiency renovations in buildings holds a large unused potential for reducing CO_2 emissions cost effectively. One of the main barriers being addressed in the legislation is the problem of unaligned incentives between landlords and tenants. While it seems that the UK has not as such adjusted rent control legislation, which is relatively strict on social housing, cf. Figure 19, it has adopted innovative measure to breaking down this barrier. The policy stands on several pillars:

<u>Green deal</u>

The green deal is a new financing framework for energy efficiency renovations in buildings. The financing provided by this legislation is funded by a charge on energy bills. The Green Deal anticipates the retrofit of over a million homes per year, and is expected to deliver aggregate investments in the region of £7 – £11 billion per year over 15 years.[32] A wide range of energy efficiency renovations are eligible for funding under the framework, cf. Table 1.

Table 1 Measure eligible for financing through Green Deal

Heating, ventilation and air conditioning	Condensing boilers Heating controls Under-floor heating Heat recovery systems Mechanical ventilation Flue gas recovery devices
Building fabric	Cavity wall insulation Loft insulation Flat roof insulation Internal wall insulation External wall insulation Draught proofing Floor insulation Heating system insulation (cylinder, pipes) Energy efficiency glazing and doors
Lighting	Lighting fittings Lighting controls
Water heating	Innovative hot water systems Water efficient taps and showers
Microgeneration	Ground and air source heat pumps Solar thermal Solar PV Biomass boilers Micro-CHP

Source: UK Department of Energy and Climate Change (2011), page 7.

Private rented sector

Several provisions related to the private rented sector have been put in place. One provision is that private landlords will be unable to refuse a "reasonable" request from tenants to undertake energy efficiency improvements, if there is a government funding package available (Green deal, or ECO as covered below). In addition, it is from 2018 rendered unlawful to rent out a residential or business premise that does not reach a minimum energy efficiency standard. These requirements are subject to there being no upfront financial cost to landlords.

Energy Company Obligation

A new energy company obligation is envisaged, which will work alongside the Green Deal finance offer and target those households which are likely to need additional support, in particular those concerning vulnerable people on low incomes and those in hard-to-treat housing.

Source: UK Department of Energy and Climate Change, Energy Act 2011

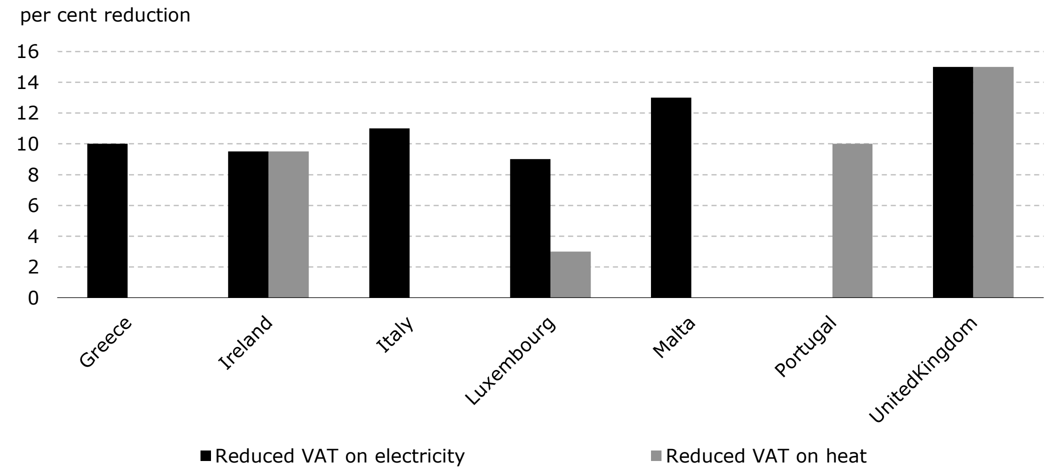
Energy subsidies

In general, increasing the cost of energy will improve the incentives to invest in energy efficient renovations of buildings, as the expected energy cost savings will increase. In several EU countries, however, the opposite takes place, as energy consumption is directly encouraged by targeted fuel subsidies to low-income families, lower excise duties on heating oil than other fossil fuels, and by reduced VAT rates on energy consumption. In most countries, VAT is applied in addition to regular taxes on energy consumption. These VAT rates are however reduced by 9-15 percentage points in Greece, Ireland, Italy, Luxem-

[32] Climate and Strategy Partners, Financing Mechanisms for Europe's Building Renovations.

bourg, Malta and United Kingdom on electricity, cf. Figure 21, while VAT on heating is also reduced in most of the same countries, including Portugal.

Figure 21 Reduced VAT on energy consumption



Note: All countries with reduced VAT rates on energy electricity and heating is included in the figure

Source: Copenhagen Economics based on DG TAXUD (2012)

One study which assessed policies with the objective of mitigating so called fuel poverty in UK, Ireland and USA found that in 2010 the UK and the US together spent €6 billion on income-supplementing fuel payments and social tariffs to reduce effective energy prices.[33]

Such subsidies to energy consumption are typically based on distributional concerns, as the energy bill typically constitutes a relatively large share of especially low-income families' budgets. While acknowledging these income distribution considerations, we note that the subsidies are inefficient and costly for public budgets in addition to harming the environment. Income distribution concerns will much more effectively and efficiently be addressed through targeted income redistribution. Indeed our proposal, as noted later, is to push for deep and economically viable energy savings programmes that will reduce the need for energy subsidies in the first place while *replacing* general energy subsidies to all households with income transfers to the households most severely affected by the unwinding of the subsidies. The net effect will be public savings, energy savings, and safeguarding of income distribution objectives. Indeed if the EU removed existing general reduced VAT-rates on energy consumption (heating and electricity), energy consumption in EU would fall by app. 0.8 per cent,[34] and public budgets would be improved by €3.4 billion corresponding to 0.03 per cent of GDP.[35] These energy saving estimates are medi-

[33] IEA (2011a), p. 7

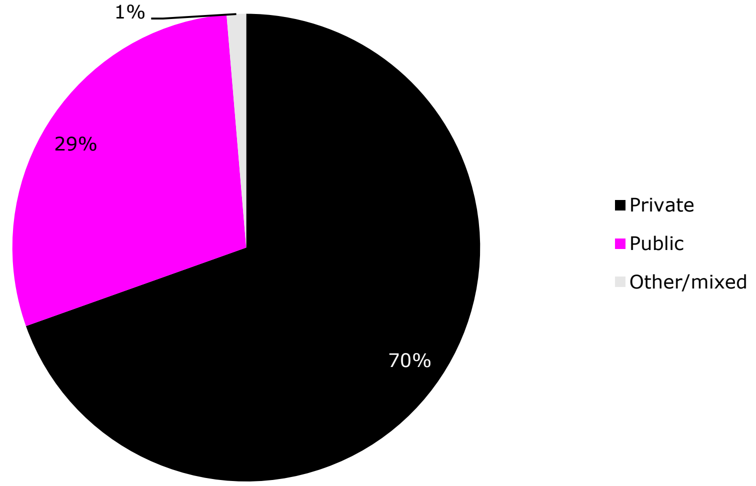
[34] Copenhagen Economics (2008), p. 66. The model simulations in this study are based on reduced VAT rates present in 2008. Some countries have removed these reduced rates since giving rise to a lower expected reduction in energy consumption.

[35] Copenhagen Economics (2008), p. 68. Some countries have removed these reduced rates since giving rise to a lower expected increased in VAT revenue

um term effects, and the longer term effects are likely to be much larger, as the increased implicit energy price affects investment incentives, and leads to e.g. more energy efficient buildings. If this is broadened to include all energy consumption tax breaks in the largest EU countries, public budgets could be improved by €11.7 billion.[36,37]

Regulation of public investment and ownership of buildings
Several studies have suggested that regulation of public ownership of, and investments in, buildings provides insufficient incentives, and even restricts investments in energy efficient renovations of buildings. As the public sector owns 29 per cent of non-residential buildings in the EU, cf. Figure 22, this may be a significant barrier to overall energy efficiency investments.

Figure 22 Share of public ownership of non-residential buildings



Source: Copenhagen Economics based on BPIE (2011)

A typical governance structure in EU Member States is to assign ownership of public buildings such as schools, hospitals, recreational centres etc. to local municipalities. In many countries, the municipalities are not allowed to borrow externally to finance investments, which imply that energy efficiency investments typically must be taken out of the annual budgets. In fact, a survey of public officials in UK, Germany and France showed that while access to finance instruments from banks was not considered a barrier, insufficient budgets and to some extent high upfront cost for energy efficiency improvements were considered as important barriers for energy efficiency improvements.[38] This consequently implies that behaviour tends to focus on shorter term cash flow effects as opposed to the long term benefits accruing over the life time of the assets they own. In

[36] OECD (2011c).
[37] Under the assumption of no rebound effect
[38] Institute for building efficiency (2011a), p. 5

addition, the limited funds available restrict deeper retrofit investments, which typically give rise to the most significant energy savings.[39]

This point does not only apply to energy efficient renovation of buildings, but to maintenance of buildings in general. A study from Denmark showed that the local municipalities were not making sufficient maintenance renovations to maintain a sustainable building stock quality and condition.[40]

Engaging in Energy Performance Contracts (EPCs) with Energy Service Companies (ESCOs) may overcome this structural barrier if the ESCO is willing to finance the vast majority of the up-front investment cost. However, public regulation often inhibits the involvement of ESCOs or the implementation of energy performance contracts.[41]

An additional barrier is that many central administrations do not allow savings from energy efficiency projects to be recycled into the next year's annual budget. There are very valid public governance reasons for doing so, however it provides no incentive for local governments to undertake the investments if they obtain no benefits of doing so. Given the high expected returns from energy efficiency investments, it should be economically feasible to construct a model that allows local governments to reap a share of the energy savings (at least for a period of time) while channelling the remaining share into the overall public finances.

There has been considerable discussion about the appropriateness of the discount rates used by the public sector when evaluating the feasibility of public investments. The discount rates should reflect the cost of financing and the perceived riskiness of the investment. As the price of government lending is currently at a historical low in most EU Member States, this suggests that the implied discount rates should be reduced compared to say 5-10 years ago. An additional argument has been put forward; that energy efficiency investments can be considered as a hedging tool against volatile fuel prices, which is by far the most important risk in an energy project.[42] This implies that such investments should be evaluated by a different metric, and with a lower discount rate, than e.g. infrastructure projects with the same perceived risk.

2.3 Barriers from market failure

There is a vast amount of studies supporting market failures as a brake on profitable energy efficiency investments. This suggests that market failures constitute a real problem. Some caution is needed however. Several of the studies do not always factor in all the total costs of energy savings projects into the cost-benefit calculation, such as e.g. scare management time. Moreover, measures to evaluate ex ante gains from energy saving projects have also in certain cases been shown to be too optimistic. Our bottom line from this

[39] Institute for building efficiency (2011a), p. 5
[40] Rambøll (2010)
[41] IPCC (2007), p. 420, and Institute for building efficiency (2011a), p. 6
[42] IEA (2008), p. 38

review is that viable energy renovation projects in buildings is not getting done primarily due to regulatory barriers with market failures compounding this problem.

We identify at least four different market failure barriers that may compound the problem:

Handling project risks and acquiring financing
Several barriers have been identified with respect to financing and undertaking specific energy efficiency renovation projects. One barrier has to do with acquiring finance for a particular investment. As the investment is expected to be profitable, financing should per se not be a problem. However, traditional lenders such as banks are typically not used to assessing the risk of energy efficiency investments, and may thus be reluctant to provide financing. In addition, energy efficiency projects are often perceived as risky, as actual energy savings can be difficult to forecast.[43] Conversely, expected returns on investment are typically quite high. This risk profile is less suitable for commercial banks and more suitable for e.g. hedge funds. However, as individual projects are often too small to be meaningful for these investors, they may be reluctant to get involved. Examples suggest that if the public sector engage in risk sharing arrangements and/or back private financing arrangements, the public sectors' contribution can be leveraged significantly, cf. Box 2.

Box 2 Leveraging public money

In Germany, the federal government makes budget funds available to the KfW Bankengruppe, a promotional bank of the German Republic and the federal states, under a building rehabilitation programme. This programme provides builders with reduced-interest loans or investment bonuses with which they can build or convert their houses or flats into energy-efficient homes. In 2010, €1.4 billion was made available to KfW. This injection spurred promotional loans from the KfW of €8.9 billion, which in turn initiated investments worth of €21.5 billion. That is, for every €1 billion the government injected to the programme, investments worth €15 billion were initiated.

Estimates suggest that these investments have created or safeguarded 340,000 jobs and given rise to additional contributions and taxes worth of €5.4 billion.

A similar example can be illustrated by the Sustainable Energy Authority of Ireland (SEAI). In the Irish Home Energy Saving (HES) scheme, the SEAI spent app. €63 million over 2-3 years, which spurred private investments for an additional amount of almost €110 million.

Source: KfW Bankengruppe (2011a) and SEAI (2011)

In order to bridge this gap, firms such as the Energy Service Companies (ESCOs) are starting to grow. These companies are specialised in providing different services related to energy efficiency investments such as identification of possible savings, recommending measures, designing and installing measures, training of staff etc.[44] Importantly, ESCOs also offer Energy Performance Contracts (EPC) which stipulates that the ESCO will cover

[43] Early studies have shown that utility-sponsored programmes achieve only 50-80 per cent of predicted savings, even though there is evidence that utilities have improved their abilities to predict savings. See e.g. NBER (2009)
[44] UNDP (2010) and IPCC (2007), p. 428.

all or a share of the initial investment cost in return for the achieved energy savings going forward. The ESCOs thus have the potential to overcome the public regulation barriers where municipalities cannot borrow to finance investments, by taking on the entire up-front investment cost. Such EPC contracts are a significant step in the right direction, but are inherently difficult to monitor. Designing an EPC so the risk is distributed properly and the behaviour/outcome of the users is a difficult task. In addition, as ESCOs are still relatively unproven companies with significant credit risk, it may be difficult to obtain sufficient finance without straining their balance sheets. In Korea, e.g. ESCOs have an average debt load of 378 per cent compared with 160 per cent for manufacturing companies.[45]

[45] UNDP (2010), p. 44

Box 3 ESCO partnerships in Europe

The most common ESCO in Europe is an independent company specialising in providing services such as energy analysis and audits, project design and implementation and monitoring and evaluation of savings to name just a few. While 62 per cent of European ESCOs define themselves in this category, 17 per cent are Energy utility or supply companies, and about 16 per cent are public sector agencies or public-private joint ventures. Almost all companies provide financing services, 89 per cent offer guarantee of performance meaning that they are prepared to accept part of the technical and financial risk, and about 58 per cent offer insurance coverage.

The vast majority of ESCO projects take place in either industry (50 per cent) or in the public sector (38 per cent). The choice of applied technology is more diverse and ranges from improved heating systems, heating ventilation and air conditioning to improved lighting and industrial processes and combustion improvement. The length of an ESCO partnership contract is typically 5-15 years.

Germany was one of the first movers, and is currently one of the most mature ESCO markets in the EU. The focus has primarily been on public buildings in the commercial sector with building "pools" of up to 100 separate buildings in order to minimize transaction costs. In 1995 Berlin launched an energy saving strategy, and by an ESCO partnership managed to reduce the annual energy cost bill by almost €3 billion and to reduce CO_2 emissions by 25 per cent.

In Nyköping in Sweden, an ESCO offered a contract covering 123 of the municipality's buildings totalling an area of 257,000 m^2. The improvements included the installation of a Building Management System in all buildings to monitor energy consumption, new heat pumps and solar panels, including sensor controlled lighting and heating/cooling. The project resulted in a reduction of 21 per cent in the municipality's energy bill.

The Royal Gwent Hospital in UK engaged an ESCO to renovate old infrastructure and ensure energy savings. The project introduced more effective energy and heating systems, a lighting retrofit and water conservation measures. The project has resulted in annual savings of at least €620,000.

Source: DG JRC (2005) and www.EU-esco.org

Energy costs are a small share of overall costs

While the total value of energy savings at macro level might be substantial, energy costs account typically for a small part of overall costs for business and to a less extent households.[46] One study has found that the energy costs in commercial building in high cost city centres like London account for just 1-2 per cent of total costs.[47] Partly for the same reason, energy cost management is typically not centralised within a single unit that holds responsibility for the overall energy bill. Instead, energy cost management may be shared across different departments within firms and institutions. This gives little incentive to invest resources into reducing the energy bill, especially as these projects involve transaction costs of gathering information, inconvenience of installing new equipment etc.

[46] For some households, especially low-income households, energy costs may be a substantial share of total costs.
[47] European Commission (2012), citing Guertler, Pett and Kaplan (2005)

Externalities
The costs of adverse effects on health and worker productivity from buildings with outdated energy efficiency management will often be born not by the owner of the building but potentially the society at large. This is certainly the case for reduced health from air pollution linked to energy production both from electricity production and heating. These costs to society are not included in the building-owner's decision to invest in renovations. Consequently, there will be invested too little in energy efficient renovation of buildings from society's point of view.

Households have too short term perspective
A number of studies suggest that some barriers are particularly predominant in the residential sector. One finding is that households tend to value present and short-term events much higher than future events. In the economic literature this is known as having a high implicit discount rate. This implies that households typically like to see early pay back on investments, and may be reluctant to make too high up-front investments.[48]

One reason for this is that households are typically more risk averse than e.g. companies. The actual realised energy savings will be uncertain, and households may be unwilling to invest an amount of money which may make up a large share of the household budgets and/or savings. In addition, households may not be sure that they will continue to live in the same building for a sufficiently long period of time in order to reap enough of the benefits from the investment to make it financially attractive.[49] In addition, they may not expect to be able to fully capitalise the benefits into the property's market value.

Energy efficient renovation of buildings – especially "deep renovations" – typically come with a significant inconvenience cost for households. This includes costs of preparing a project, obtaining permits and financing, finding contractors, supervising their work, possibly moving out during the renovation etc.[50] As these costs are contained in the up-front investment costs, it is given high value in the households' decision.

These inconvenience costs are typically compounded for multi-family homes. An issue such as coordination may turn out to have large transaction costs. In addition, in multi-family homes, the number of households that expect to find new homes within a foreseeable future may be significant. These households may try to block otherwise profitable renovations, as the up-front inconvenience costs outweigh the expected longer term benefits from reduced energy costs. We expect such coordination problems to be greatest in the Baltics and Italy, but also in several of the EU-12 countries as the share of multi-family homes is especially high in these countries, cf. Figure 23.

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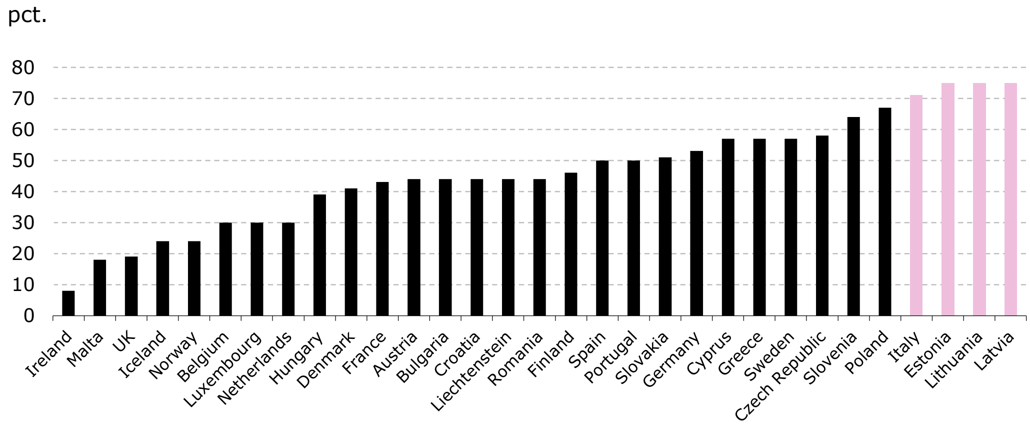
[48] Economic research has also suggested that households may have so called hyperbolic discount functions, meaning that they will place a higher value on the near future than on the more distant future. See e.g. Frederick, Loewenstein and O'Donoghue (2002).
[49] In the UK e.g., households move every seven years on average. See UK government Energy Bill, Green Deal Impact Assessment (2010)
[50] European Commission (2012)

Figure 23 Share of multi-family homes



Source: Copenhagen Economics based on Fraunhofer ISI et al. (2009), page 101.

2.4 Policy response

Substantial evidence suggests that there exists a large and unfulfilled potential for increasing profitable investments in energy efficient renovation of buildings. In addition, much evidence suggests that there are significant barriers holding these profitable investments back. This calls for government action to spur demand for investments by breaking these barriers. In several EU Member States, governments have tried to address these barriers by establishing financial promotion activities, cf. Box 4.

Box 4 Specific promotion activities for investments in energy efficiency renovations

Several countries have introduced activities to promote investments in energy efficiency renovations in buildings.

The sustainable Energy Authority in Ireland (SEAI) has for the past number of years been supporting households and businesses to shift to more sustainable energy use. SEAI contributes with several issues including advice, mentoring, training and financial support to a broad range of energy users. More than 4,000 registered service providers are associated with SEAI programmes. SEAI runs a programme for the residential sector (Home Energy Saving - HES) and for small and medium enterprises (SME). The HES scheme provides financial support to households for energy efficiency upgrades. Since 2009, over 100,000 homes have been upgraded with a combination of improved insulation, high efficiency boilers and heating controls through these schemes. The scheme has been evaluated to deliver a net benefit of €5 to society for every €1 spent on the programme. The SME programme is evaluated to be even more profitable, delivering a net benefit to society of €15-€33 for every €1 spent on the programme.

In Germany, the state bank KfW Bankengruppe is essential in channelling public and private funding into energy efficiency investments. Germany currently refurbishes around 200,000 buildings a year and has to date retrofitted 9 million units to high energy efficiency standard. Existing German homes use around three times more energy for heating than new buildings. Energy efficiency investments in deep retrofits are estimated to have halved the energy use in the buildings treated by the KfW since 2002. Germany has been particularly succesfull in leveraging its public investments by bringing in additional private investments from e.g. institutional investors. From 2001-2006 the German Alliance for Work and Environment spent $5.2 billion public subsidies and stimulate total investments of $20.9 billion in building retrofits. From 2006-2009, KfW financing activities across various programmes deployed €27 billion in loans and grants leading to total investments of €54 billion.

In Estonia, a Credit and Guarantee Fund – KredEx – was established in 2001 with the purpose of improving the financing opportunities to a variety of measures, including housing renovations and energy-saving measures in general. Apart from a general objective to improve the competitive strength of Estonian companies, a major pillar was to improve the housing conditions of Estonian inhabitants, including developing an "energy-saving way of thinking". Some of the projects undertaken with KredEx are also part of the broader Baltic Energy Efficiency Network.

Source: SEAI (2011), Climate & Strategy Partners, Financing Mechanisms for Europe's Buildings Renovation, and Kallaste (2009), KredEx, Energy Efficiency Competence Centre, Estonia.

In the current context of available capacity in the economy and stress on public budgets due to the economic crisis, such energy savings projects are a particularly attractive option to increase economic activity, as a number of structural barriers are holding back otherwise profitable investments. By addressing the most significant structural barriers, these investments may help to boost the economy, while not reducing governments' net revenue. Conversely such initiatives may even create net revenue. This is a direct consequence of the nature of the four key structural barriers that hold back energy savings in buildings *and* the policies required to deal with them. We identify at least four:

Barrier 1: Rent regulation in both publicly and privately owned residential houses, and to a certain extent commercial buildings, often prevents landlords from passing on the

costs for improvement in the quality of the buildings, including a lower energy bill to tenants. This greatly reduces the landlords' incentive to invest in energy efficient renovation of buildings. This is a problem as such investments would reduce the total housing bill for the tenant.
Action: Modernise rent regulation to allow landlords and tenants to split the gains from energy efficient renovation of buildings. This is largely without direct costs to public finances.[51]

Barrier 2: Budget management of publicly owned buildings tend to focus on shorter term cash flows as opposed to longer term running costs. This punishes projects with higher upfront costs as counterpart to lower future operating costs i.e. a lower energy bill. In addition, the discount rates applied to assess public investments have not followed the general current trend towards lower market rates.
Action: Reform budget management of publicly owned buildings to allow for a longer term focus in investments and renovation of buildings. This will reduce longer term operating costs in the publicly owned building stock.

Barrier 3: The relatively widespread favourable tax treatment of heating and electricity use in buildings reduces gains from otherwise viable energy savings projects.
Action: Remove/reduce such tax advantages to render energy efficient renovation of buildings more attractive, <u>and</u> provide direct net revenue gains to public budgets.

Barrier 4: Handling of risk in renovation projects has traditionally been a weak point. Investors may face high up-front costs, which implies that they run more substantial risks than for a similar project with lower up-front costs. In this respect it is an important question how you set up, monitor and evaluate performance contracts that ensure that the owner/user of the building de facto gets the promised benefits required to pay back the substantial and non-reversible investment cost over time. Concepts such as Energy Service Companies (ESCO) and Energy Performance Contracts (EPC) which are explicitly designed to align risks and responsibility for the outcome of such projects have not been developed to deliver on deep renovation projects. In fact, there are examples of countries not allowing the use of EPCs in the public sector
Action: Well-designed risk-sharing programmes can help government as well as private building owners to realise cost savings with very limited budget costs.

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[51] As overall housing cost would be reduced, the public costs to e.g. social housing would also be reduced.

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Appendix A

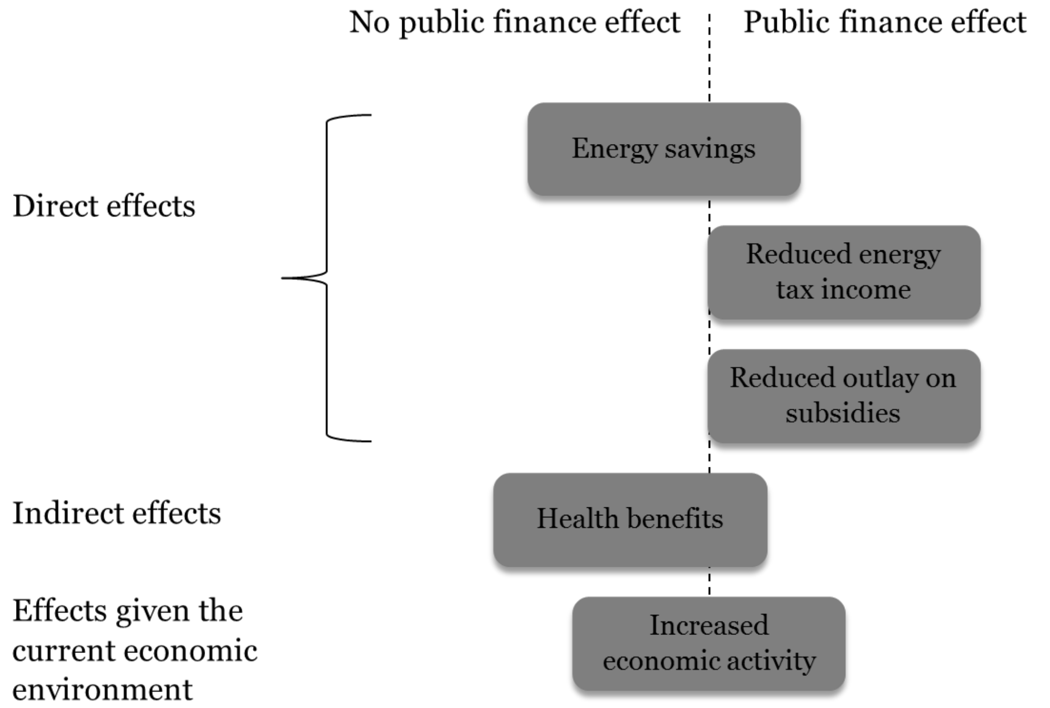
Calculating the benefits from energy efficiency investments

In this appendix we present the assumptions and calculations behind our assessment of the benefits related to investments in improving energy efficiency in existing buildings. Our point of focus is on energy efficiency improvements through renovating existing buildings. Concretely, this could for example be through floor and wall insulation, replacing windows and window frames and replacing heating systems. We do not focus on the efficiency potential that exist through replacing old appliances such as washing machines and refrigerators with more efficient ones. We do, however, consider ventilation systems and air conditioning, as such installations are typically a more integral part of buildings.

A.1 General description of our modelling approach

Enhancing the energy efficiency of the existing building stock induces benefits through several channels. While some of these benefits occur directly through e.g. reduced energy consumption, other benefits occur more indirectly through e.g. improved health over several years. In addition, some of these benefits have direct positive effects on public budgets while others are benefits to society at large without having specific public finance effects. Our mapping of the different benefits is presented in Figure A.1, and discussed in the following section.

Figure A.1 Effects of energy efficient renovation of buildings



Source: Copenhagen Economics

Energy savings through reduced energy consumption is a direct benefit stemming from increased energy efficiency. In privately owned buildings the benefits will typically accrue to the owner or the user of the building,[52] while in publicly owned buildings the benefits will accrue to the public or the users of publicly rented apartments. Given the proper distribution of benefits between public entities, this will improve public budgets. The benefit from energy savings implicitly also includes the avoided capital cost of building additional power plants, as these capital costs are included in the price of electricity.

As energy efficient renovation of buildings will reduce energy consumption, it will have a negative effect on public budgets through reduced tax revenue from energy consumption taxes.

The European Member States are currently subsidising both fossil fuel consumption and deployment of renewable energy technologies. By reducing energy consumption through energy efficient renovation of buildings, both types of subsidy can be reduced. This will have a positive effect on public finances.

A more indirect benefit occurs through *health benefits*. Most energy efficiency measures will improve the indoor temperature, and by choosing renovation measures that also im-

[52] We will discuss the principal agent problem related to owners/tenants in the section related to reduced energy consumption below.

prove the indoor climate, health benefits can be obtained through fewer diseases, 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 fewer hospital expenses and fewer sick days.

Health benefits also occur as power and heat production from power plants, combined heat and power plants (CHP) and local heating is reduced. Power and heat generated in these facilities give rise to air pollution such as NO_X, SO_2, small particle matters (PM2.5) and CO_2, and by reducing energy consumption this air pollution can be reduced.

Given the current economic downturn, energy efficiency investments can *increase economic activity*, and improve public budgets by reducing unemployment benefits and increasing tax revenue from the increased economic activity. Positive effects from this include, increased tax revenue (including VAT, labour income tax, corporate income tax etc.) from increased activity and employment, reduced unemployment expenses. This effect will be most pronounced during periods of economic crises, when there is spare capacity in the economy.

A.2 Scenarios

In the following calculations, we consider two different scenarios for the level of energy efficiency investments. These scenarios have been developed by Fraunhofer et al (2009) who has created a comprehensive database for energy efficiency investment potentials in all EU countries. The available potential for energy efficiency depends on the level of policy commitment to e.g. break down barriers to energy efficiency investments.

In our calculations we follow Fraunhofer et al ’s (2009) definition of two scenarios. The first scenario assumes a high level policy intervention which makes it possible to undertake all energy efficiency investments which is considered cost-effective by Fraunhofer et al (“HPI” in Fraunhofer et al). The second scenario is the upper level for possible energy efficiency investments (“Technical” in Fraunhofer et al) and is defined as full penetration of current best practice technologies, such as replacing all washing machines with the most energy efficient model, upgrading all heating systems to the most efficient model etc. In our calculations we refer to these as “Low Energy Efficiency (EE) scenario”, and “High Energy Efficiency (EE) scenario”.

The low EE scenario, includes investments in energy-efficiency measures which are cost-effective for the end-user.[53] This means, that investments will only be undertaken if they are cost effective in the sense that the energy savings resulting from the investment will be higher than the cost of the investment. The low EE scenario also assumes a high level of policy ambition in terms of removing barriers to energy efficiency investments. The more barriers that are removed, the higher the potential will be.

[53] Fraunhofer ISI et al (2009) defines which measures are “cost-effective” based on several assumptions among others energy prices, and consumer discount rates.

The *high EE scenario* basically includes all investments in energy efficiency measures that are technically feasible. This means both investments that are cost-effective, and those that are not cost-effective. The scenario only includes technologies that are technically viable, and not extremely expensive. Even though these investments may not be cost-effective from a purely energy savings perspective, they bring additional benefits through improved health, reduced subsidies to RE technologies etc., and may achieve cost effectiveness when these parameters are included. This is the reason that we consider this scenario as well.

Price of energy
In the model calculations, we make use of projections of the price of energy in 2020 and 2030. For this, we use figures from DG Energy (2010), projecting energy prices in 2020 and 2030.[54] These energy prices, depicted in Table A.1, are also used to construct the energy efficiency potential in the Fraunhofer et al (2009) study.

Table A.1 Projected energy prices, 2020 and 2030

	2020 (EUR/MWh)	2030 (EUR/MWh)
Electricity - post tax (average)	141	141
Electricity - pre tax	121	120
Heating oil price	76	81
Natural gas price	41	44
Hard coal price	12	13

Note: Electricity post tax is an average of industry, services and households
Source: DG Energy (2010)

The DG Energy projections assume that the price of CO_2 in the ETS sector is €16.5 / ton CO_2 in 2020 (2008 prices). This projection assumes, among others, that Member States achieve their national targets under the Renewables directive 2009/28/EC and the GHG effort sharing decision 2009/406/EC in 2020.

There is some uncertainty related to the fuel input in heating in the Fraunhofer et al (2009) study. This mix determines the average price of heating and thus the value of energy savings from renovation projects. The proper calculation of the price of heating is determined by the heating sources used by the buildings in which Fraunhofer et al has identified the energy efficiency potential. It seems as though Fraunhofer uses heating oil as the primary heating source, even though this has not been confirmed. This may be the result of identifying the largest potential in buildings that are primarily heated by heating oil, which is typically the case in the residential sector in countries with limited district heating. In the following, we will maintain the input mix of heating used by Fraunhofer et al (2009).

[54] DG Energy (2010), page 45. We use the reference scenario implying that recent policy initiatives (in 2010) have been taken into account. The projections are based on simulations from the PRIMES model.

A.3 Identifying and characterising the energy efficiency potential

The potential for energy efficiency investments in Europe has been defined in an extensive study for DG Energy and Transport in 2009 by Fraunhofer et al (2009). The central part of the identification of energy saving potentials is the bottom-up MURE simulation tool.[55] This tool includes a rich technological structure for the demand sectors. The project refined the MURE model with further details. The MURE database can be found here: www.mure2.com. Identification of the concrete potential for energy efficient renovations of buildings in Europe is based on a country-specific evaluation. This evaluation takes into account the specific building stock in all EU Member States including its age, the energetic standard of the buildings (U-values), the different climatic zones including the amount of heating degree days, and the energy demand in the different countries. This allow the authors to calculate energy consumption per square meter for different building types in specific countries. Country specific information on material cost, labour costs, and very detailed cost structure for different types of refurbishment is also taken into account, including learning curves for different technologies and the implied cost reductions over time.

The energy saving potential is derived for several different renovation measures, and for both the residential, commercial and industry sector. The energy saving potential is available both for the existing building stock and for new buildings. We focus only on the existing building stock. With respect to the different measures, we have focused on the following, which are related to renovation of existing buildings:[56]

- Heating improvements from heating systems (heating pumps etc.)
- Heating improvements from refurbishment of existing buildings (insulation, window improvements, better ventilation and air conditioning etc.)
- Water heating
- Appliances in the service sector (only air conditioning and ventilation)
- Lighting systems

According to the database on energy saving potentials, the accumulated energy saving potential in 2020 (a baseline has been deducted) in the low EE scenario in the mentioned categories is 65 Mtoe, while investing in all technically feasible energy savings (the high EE scenario) will generate 95 Mtoe in energy savings, cf. Table A.2. This corresponds to 5 and 8 per cent of EU final energy demand respectively.[57] The largest source of energy savings comes from renovations that improve heating systems and insulation in households, followed by heating and insulation in the service sector, and in the industry.

[55] Mesures d'Utilisation Rationelle de l'Énergi
[56] We have not looked at e.g. household appliances such as washing machines etc., efficiency potential in construction new buildings, improving the efficiency of industrial processes, or efficiency in the transport sector.
[57] Based on DG Energy (2010)

Table A.2 Energy saving potentials from different sources, 2020

Renovation source	Energy saving potentials - low EE scenario (Mtoe)	Energy saving potentials – high EE scenario (Mtoe)
Households - heating and insulation	31.0	47.8
Households - water heating	2.6	4.9
Service sector - heating and insulation	13.5	19.5
Service sector appliances (air conditioning & ventilation)	3.8	3.8
Industry – heating and insulation	9.0	13.5
Households - lighting	1.8	2.4
Service sector - lighting	3.1	3.1
Total savings	**65**	**95**

Note: The savings potentials are accumulated from 2012-2020.
These estimates do not include the rebound effect
Heating and insulation also contains reduced heating demand from better ventilation and air conditioning

Source: Copenhagen Economics, based on Data Base on Energy Saving Potentials - http://www.eepotential.eu/

The accumulated potential increases towards 2030, where the energy saving potential is 127 Mtoe and 190 Mtoe in the two scenarios respectively, cf. Table A.3. This corresponds to 11 and 16 per cent of EU final energy demand respectively.[58]

Table A.3 Energy saving potentials from different sources, 2030

Renovation source	Energy saving potentials - Low EE scen (Mtoe)	Energy saving potentials – High EE scen (Mtoe)
Households - heating and insulation	65.0	101.1
Households - water heating	5.3	10.2
Service sector - heating and insulation	21.8	31.4
Service sector appliances (only air conditioning & ventilation)	6.5	6.5
Industry – heating	15.4	24.9
Lighting	13.3	16.0
Total savings	**127**	**190**

Note: The savings potentials are accumulated from 2012-2030.
These estimates do not include the rebound effect
Heating and insulation also contains reduced heating demand from better ventilation and air conditioning

Source: Copenhagen Economics, based on Data Base on Energy Saving Potentials - http://www.eepotential.eu/

These energy saving potentials are not equally spread out across Member States, but will depend on the size and the state of the existing building stock. Countries with a smaller existing building stock will naturally have a smaller absolute potential for renovations.

[58] Based on DG Energy (2010)

We find that the largest potential is present in Germany (24 per cent), France (13 per cent), UK (12 per cent), and Italy (10 per cent) in the low EE scenario, cf. Table A.4. These four countries constitute 59 per cent of EU's total energy savings potential. A similar picture shows in the high EE scenario.

Table A.4 Country specific energy saving potentials 2030

Member States	Total saving potentials - Low EE scen (MToe)	pct. of EU wide	Total saving potentials - High EE scen (MToe)	pct. of EU wide
Austria	3	2	4	2
Belgium	4	3	7	3
Bulgaria	2	1	2	1
Cyprus	0	0	0	0
Czech Republic	5	4	7	4
Denmark	2	1	3	1
Estonia	0	0	0	0
Finland	1	1	2	1
France	17	13	26	14
Germany	30	24	43	22
Greece	2	2	3	2
Hungary	2	2	4	2
Ireland	1	1	1	1
Italy	12	10	18	10
Latvia	0	0	1	0
Lithuania	0	0	1	0
Luxembourg	0	0	0	0
Malta	0	0	0	0
Netherlands	4	3	7	4
Poland	8	6	11	6
Portugal	2	1	2	1
Romania	4	3	6	3
Slovakia	1	1	2	1
Slovenia	1	1	1	0
Spain	8	6	11	6
Sweden	3	2	4	2
United Kingdom	15	12	24	13
Total	**127**		**190**	

Note: The total row does not equal the sum of the country specific numbers due to rounding off.

The energy saving potential is accumulated from 2012-2030. The distribution of energy savings is relatively similar across time periods.

Source: European Commission Data Base on Energy Saving Potentials - http://www.eepotential.eu/

A.4 Gross investment costs

The above stated energy saving potentials can be realised through investments in renovation projects. While extensive work has been undertaken on identifying the energy saving potential, the total size of investments needed to fulfil this potential has been subject to less research. One of the estimates was made by the European Commission (2012), Annex I, where it is found that annualised investments of €60 billion per year is needed from 2012-2020 to reach the potential corresponding to our low EE scenario in both the existing building stock, and in *new buildings*. We use the same method applied by the Commission, but only considers the potential in the existing building stock. We begin by taking the MAC-curves presented in ECF (2010), page 54 and read off the net investment cost (or saving) per investment type per GJ.

By combining the net cost of investment per GJ with the energy saving potential for each measure, we can transpose the net cost of investment into a total cost in EUR. The net cost of investment is by definition equal to the gross cost of investment minus the annualised achievable savings from reduced energy consumption. Since we know both the energy saving potential, and the price of energy used in the ECF (2010) study (both for electricity and heating inputs), we can deduce the gross cost of investment.

We find that for EU27 the annualised gross investment costs needed to achieve the renovation measures in the low EE scenario from 2012-2020 to be €41 billion, and €78 billion in the high EE scenario, cf. Table A.5. A similar annual amount is needed to reach the potential going from 2020-2030.

Table A.5 Gross annualised investment cost of energy saving investments, 2012-2020

Renovation source	Gross investment cost - low EE scenario (bn EUR)	Gross investment cost - high EE scenario(bn EUR)
Households – heating and insulation	20.8	40.5
Households - water heating	2.8	5.5
Service sector – heating and insulation	8.6	16.1
Service sector appliances (air conditioning & ventilation)	0.7	0.7
Industry – heating and insulation	7.0	12.7
Households – lighting	0.2	1.0
Service sector – lighting	1.1	1.1
Total gross investment costs	**41**	**78**

Note: In order to calculate investment cost, we have assumed that all water heating is generated by use of electricity, and all that all heating is generated by use of heating oil.

Source: Copenhagen Economics, based on ECF (2010) and methodology in European Commission (2012)

It should be noted that these estimates are calculated on the basis of MAC-curves. MAC-curves typically only include the costs related to the actual investment including the operation and maintenance costs. Other costs, such as transaction costs related to e.g. the use of scarce management time are not included in the analyses. This means that the net savings we derive overestimate the true benefits of the measures, when taking into account of all relevant costs. Consequently, we may underestimate the actual annualised investment costs.

A.5 Savings through reduced energy consumption

As shown in the previous section, there is a potential for achieving energy savings from investments in energy efficiency in buildings. These savings have a very direct and concrete benefit through reduced cost of energy consumption. By using the assumptions on the price of electricity and heating in 2020, as stated in Section A.2, we find that there are annual savings worth of €66 billion in the low EE scenario, and €94 billion in the high EE scenario in 2020, cf. Table A.6. If investments are continued towards 2030, annual energy savings can be increased by €65 billion and €98 billion in the two scenarios respectively.

Table A.6 Gross value of energy savings

	Value of energy savings - Low EE scenario (bn EUR)	Energy savings - High EE scenario (bn EUR)
Households - heating and insulation	27.3	42.0
Households - Water heating	4.3	8.0
Service sector - heating and insulation	11.9	17.1
Service sector - appliances (air conditioning and ventilation)	6.2	6.2
Industry - heating and insulation	7.9	11.9
Households – lighting	3.0	3.9
Service sector – lighting	5.1	5.1
Total	**66**	**94**

Note: * For industry we only consider the potentials from heating, and not from e.g. industrial process.
These estimates do not include the rebound effect
Heating and insulation also contains reduced heating demand from better ventilation and air conditioning

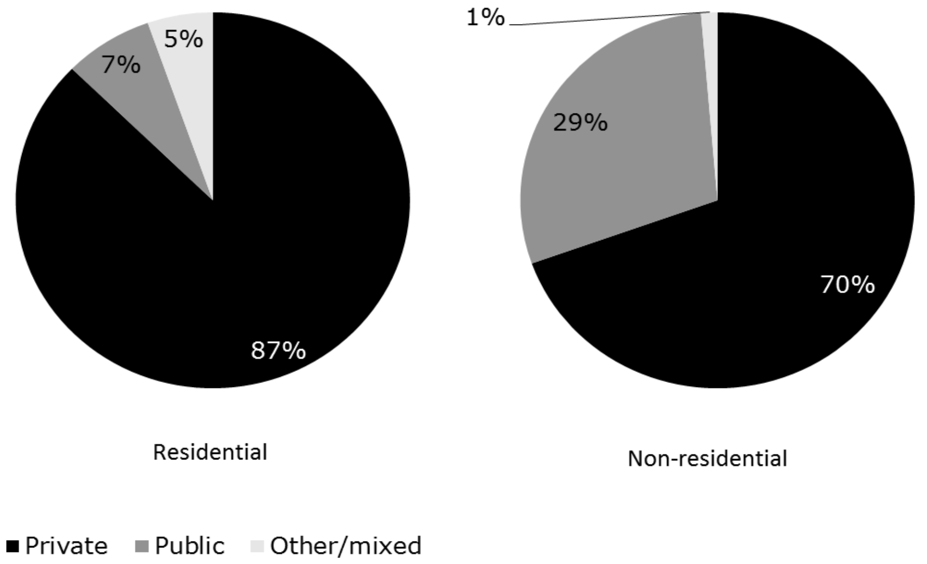
Source: Copenhagen Economics based on data from Data Base on Energy Saving Potentials and estimates for the price of electricity and heating oil as mentioned in the earlier section

These savings in energy consumption will be a specific and direct benefit to the owners and/or users of houses, apartments, office buildings etc. The distribution of these benefits will depend on the structure of the European building stock, including public/private ownership.

The average publicly owned share of residential buildings in EU27 is 7 per cent, while the privately owned share is 87 per cent, cf. Figure A.2. Publicly owned residential buildings are typically social housing. For non-residential buildings the public ownership share is 29 per cent compared with 70 per cent private, cf. Figure A.2. Publicly owned buildings is typically e.g. schools, hospitals, and administration buildings.[59]

[59] According to BPIE (2011), 17 per cent of non-residential buildings in EU are educational, 7 per cent are hospitals, and 51 per cent are wholesale, retail and offices. 26 per cent are hotels, restaurants, sport facilities and others.

Figure A.2 Ownership of building structure



Note: Ownership share is calculated of the number of dwellings (residential) and buildings (non-residential)
Source: BPIE (2011)

From this ownership structure we can deduce how the value of energy savings from Table A.6 is distributed between savings for the public budgets and savings for the overall society respectively. We find that from a public finance point of view, public expenditure can be reduced by €11 billion (€15 billion in the high EE scenario) in 2020, cf. Table A.7. The majority of these savings (€9.0 bn.) in the low EE scenario comes from energy savings in non-residential buildings, while publicly owned residential buildings generate fewer savings (€2.4 bn.) primarily since the public sector owns less residential buildings.

Table A.7 Benefits to society and public finances – energy saving

Overall benefits to society	Value of energy savings - Low EE scenario (bn EUR)	Energy savings - High EE scenario (bn EUR)
Savings from reduced energy consumption in residential buildings	34.5	54.0
Savings from reduced energy consumption in non-residential buildings	31.1	40.3
Total	**66**	**94**

Benefits to public finances (sub section of benefits to society)	Value of energy savings - Low EE scenario (bn EUR)	Energy savings - High EE scenario (bn EUR)
Savings from reduced energy consumption in residential buildings- publicly owned	2.4	3.8
Savings from reduced energy consumption in non-residential buildings- publicly owned	9.0	11.7
Total	**11**	**15**

Note: These estimates does not include the rebound effect

Source: Copenhagen Economics, based on Data Base on Energy Saving Potentials and BPIE (2011).

This calculation assumes that the energy consumption in dwellings/buildings is the same, irrespective of whether the buildings are publicly or privately owned. For residential dwellings this is most likely quite accurate; however for non-residential buildings the assumption may not be 100 per cent precise. A hospital e.g. will most likely not use the same amount of energy as a restaurant or a hotel. However, it is not obvious that the results are biased in one particular direction as a result of this.

In addition, we assume that public budgets will be improved with the value of the energy savings. In reality, energy savings achieved in e.g. a public school may not be channelled back in the general government's budget. However, we still consider this as an overall saving for the public, as the benefit will either accrue to the general government budget or to the local government entity (the school) and materialise in better quality of the provided services. The same reasoning holds in the residential sector, where the rent in public owned apartments can be increased to extract the economic benefit, without making the tenant worse off.

A.6 Reduced tax income from energy taxation

All EU Member States levy taxes or excise duties on energy consumption. Hence, when European energy consumption is reduced, so is government tax revenue from energy taxation. We assess the governments' loss of tax revenue by looking at the taxation on electricity consumption, and the excise duty on natural gas and coal used for heating purposes.

There are vast differences between the European countries' tax on electricity. In our calculations, we use an average tax measure on electricity in the EU which is €20 per MWh, cf. Table A.8.

Table A.8 Pre and post tax price of electricity

EUR/MWh	2020	2030
Pre tax price of electricity	121	120
Post tax price of electricity	141	141

Note: Post tax price of electricity is measured as an average of household, service and industry use.

Source: DG Energy (2010)

For excise duties on heat consumption, we use the excise duties in Germany. Again there are differences within countries. We use the German tax rate as it is a little higher than an average EU country. This implies that we overestimate the loss of tax revenue to a little extent. Including the VAT and the assumed share of input in European heating, we find that the average tax on heating input for business use is €0.96 per GJ, and €1.23 per GJ for non-business use, cf. Table A.9.

Table A.9 Excise duty on heating input

€ / GJ	Business use	VAT	Non business use	VAT
Natural gas	1.14	0.19	1.53	0.19
Coal	0.3	0.19	0.3	0.19
Average	**0.96**		**1.23**	

Source: DG TAXUD (2012)

Based on these tax rates and the reduced energy consumption implied by the two energy efficiency scenarios, we estimate that European governments stand to lose €5.2 billion annually in the low EE scenario and €7.2 billion annually in the high EE scenario in 2020, cf. Table A.10.

Table A.10 Tax revenue lost from reduced energy consumption, 2020

2012-2020	Reduced consumption - Low EE scenario (Mtoe)	Reduced energy tax income (bn €)	Reduced consumption - High EE scenario (Mtoe)	Reduced energy tax income (bn €)
Heating	53.5	2.5	80.8	3.9
Electricity	11.3	2.7	14.2	3.4
Sum	**65**	**5.2**	**95**	**7.2**

Note: These estimates do not include the rebound effect

Source: Copenhagen Economics based on DG TAXUD (2012), and DG Energy (2010).

If investments are continued towards 2030, the annual loss of tax revenue will be increased by €4.6 billion or €6.6 billion in the two scenarios respectively, cf. Table A.11.

Table A.11 Tax revenue lost from reduced energy consumption, 2030

2020-2030	Reduced consumption - Low EE scenario (Mtoe)	Reduced energy tax income (bn €)	Reduced consumption - High EE scenario (Mtoe)	Reduced energy tax income (bn €)
Heating	48.7	2.3	76.6	3.7
Electricity	9.4	2.3	12.0	2.9
Sum	**58**	**4.6**	**89**	**6.6**

Note: These estimates do not include the rebound effect

Source: Copenhagen Economics based on DG TAXUD (2012), and DG Energy (2010).

A.7 Reduced outlay on subsidies – energy consumption

Several EU governments grant some sort of energy consumption subsidy to its citizens and industry. Subsidies to energy intensive industry are typically safeguards against *carbon leakage*; that is the loss of competitiveness by especially energy intensive companies. We do not focus on the subsidies related to energy intensive industries. Instead, we focus on energy consumption subsidies to regular consumers e.g. through tax exemptions to input in power production or excise tax exemptions to natural gas purchases in households. Based on extensive work by the OECD, we find that such energy consumption subsidies in the EU OECD countries constitute €11.7 billion annually, cf. Table A.12. For all of EU we therefore expect this number to be slightly higher.

Table A.12 Energy consumption subsidies in EU OECD

Country	Reduced VAT or taxes on energy consumption	€ billion
Belgium	Fuel Tax Reduction for Certain Professional Uses	1.52
France	Excise tax exemptions and reduced rates	0.47
Germany	Excise tax exemptions and reduced rates	3.54
Hungary	Excise tax exemptions and reduced rates	0.15
Italy	Excise tax exemptions and reduced rates	0.11
Netherlands	Excise tax exemptions and reduced rates	0.26
Spain	Fuel Tax Reductions	1.37
Sweden	Excise tax exemptions and reduced rates	0.51
United Kingdom	Reduced Rate of VAT for Fuel and Power	3.72
Total		**11.7**

Note: Reduced taxes has been considered for all EU OECD countries.

Source: OECD (2011c)

The energy efficiency investments will reduce energy consumption by app. 6 per cent in the low EE scenario, and app. 9 per cent in the high EE scenario. This corresponds to a reduced outlay on subsidies for energy consumption by €0.7 billion in the low EE scenario and €1.1 billion in the high EE scenario, cf. Table A.13.

Table A.13 Reduced outlay on energy consumption subsidies

billion €	Low EE scen	High EE scen
Saved energy consumption subsidies (2012-2020)	0.7	1,1
Saved energy consumption subsidies (2020-2030)	0.7	1.1

Source: Copenhagen Economics, based on OECD (2011c).

In some countries, production of energy based on fossil fuels is also subsidised. These subsidies are however of relatively small, and decreasing magnitude. In Germany e.g. where subsidies to coal production historically has been sizeable, it is being gradually phased out and currently stands at €1.7 billion in 2010 down from about €5 billion in 1999.[60] This subsidy includes support for closing down coal fired power plants. Subsidies of this kind will not be affected by a lower energy consumption spurred e.g. by increased energy efficient renovation of buildings, and is therefore not included in our assessment.

A.8 Reduced outlay on subsidies - renewable energy deployment

The EU Member States have agreed to the ambitious “climate and energy package”, including the three 20-20-20 targets:[61]

- A reduction in EU greenhouse gas emissions of at least 20% below 1990 levels
- 20% of EU energy consumption to come from renewable resources
- A 20% reduction in primary energy use compared with projected levels, to be achieved by improving energy efficiency.

Investing in energy efficient renovation of buildings clearly contributes to the third target, but it also contributes to the first and second target by lowering EU energy consumption and thus greenhouse gas emissions.

All EU Member States have put forward detailed plans on how to achieve the second objective: increasing the share of renewable energy in energy consumption to 20 per cent on average. These plans involve expanding different types of renewable energy in both electricity and heat generation. By reducing the total energy consumption through energy efficiency renovations, the RE-target will be cheaper to meet by definition.

60 See OECD (2011), Inventory of budgetary support and tax expenditure for fossil fuels – Germany, page 3.
61 DG Climate webpage. http://ec.europa.eu/clima/policies/package/index_en.htm

In this section we will calculate a rough estimate of how much cheaper it will be to meet the same RE-target, as the increase in renewable energy in in electricity and heat production can be lower.

The energy efficiency investment potential towards 2020 can reduce energy consumption by 65 or 96 Mtoe respectively in the two scenarios. This implies that EU27 can avoid expanding RE equal to 20 per cent of the reduction in energy consumption and still meet the objective that 20 per cent of energy consumption must come from renewable energy. This equals 13 or 19 Mtoe respectively, cf. Table A.14.

Table A.14 Reduced energy consumption, 2020

Scenario	Abatement potential / Reduced energy consumption (Mtoe)	20 per cent of reduced energy consumption
Low EE scenario	65	13
High EE scenario	95	19

Source: Copenhagen Economics

According to the Member States' National Renewable Energy Action Plans, the primary drivers of renewable energy expansion from 2010-2020 will be biomass in heat (28.7 Mtoe) and onshore wind (16.8 Mtoe) followed by offshore wind and biomass in electricity (11.5 and 11.0 respectively), cf. Table A.15. We have combined the expected expansion path with estimates for the cost of the respective technologies.[62] These costs range from 31-47 €/MWh for geothermal energy (low and high estimates respectively) to 214-300 €/MWh for wave/tidal (low and high estimates respectively). There is substantial uncertainty about the actual costs of these technologies, especially going forward towards and beyond 2020. Increased technological progress and supply chain management is likely to drive the levelised cost of energy down, while conversely the marginal expansion may be more expensive as e.g. the most profitable offshore wind locations are utilised first leaving the more expensive for the marginal expansion.

[62] These cost estimates are taken Open Energy Info, http://en.openei.org/apps/TCDB/

Table A.15 Expansion of renewable energy in EU27 from 2010-2020

Technology	Expected expansion (MToe)	Cost of expansion - Low estimate (€/MWh)	Cost of expansion - High estimate (€/MWh)
Wave and tidal	0.6	214	300
Solar PV	5.5	140	248
Solar thermal	1.6	132	163
Offshore wind	11.5	70	93
Heat pumps	8.2	30	79
Biomass electricity and heat	39.7	39	62
Onshore wind	16.8	39	47
Hydro	2.3	16	70
Geothermal	0.4	31	47
Sum	**87**		

Note: Sorted by highest cost of expansion

Source: ECN (2011), Open Energy Info, http://en.openei.org/apps/TCDB/ ,and Pöyry (2008)

The implicit subsidies to the different technologies are calculated by subtracting the expected price of electricity or heating input from the technology specific generation cost. We estimate that EU governments can reduced their outlay on subsidies to renewable energy deployment by €2-10 billion depending on the high or low cost estimates for renewable, cf. Table A.16.[63] The estimate is the same for both scenarios as the assumed high price of electricity in 2020 will render most renewable energy technologies profitable without government subsidies.

[63] We implicitly assume that Member States can coordinate on postponing the most expensive technologies.

Table A.16 Value of avoided RE expansion – cost effective scen.

Technology	Avoided expansion (Mtoe)	Implicit subsidy - Low price €/MWh	Implicit subsidy - High price €/MWh	Saved subsidy - High price (million €)	Saved subsidy - Low price (million €)
Wave and tidal	0.6	93	179	1,251	651
Solar PV	5.5	19	128	8,163	1,214
Solar thermal	1.6	11	42	786	209
Offshore wind	5.3	0	0	-	-
Heat pumps		0	42		
Biomass electricity and heat		0	0		
Onshore wind		0	0		
Hydro		0	0		
Geothermal		0	10		
Sum	**13.0**			**10,201**	**2,074**

Note: Price of electricity: 121 €/MWh

Weighted price of heating fuels: 37 €/MWh

The conversion factor between toe and MWh is 11.63 MWh per toe.

Source: Copenhagen Economics

A.9 Health benefits

Renovating buildings in order to increase energy efficiency has positive benefits on the overall state of health in society. The benefits accrue from at least two different channels:

1. Increasing energy efficiency will lead to lower energy consumption and consequently lower energy "production". As production of energy in terms of electricity and heat gives rise to air pollution through both power and CHP plants, and local heating, this pollution will be reduced.
2. Renovations such as insulation, ventilation, better heating systems, and improved lighting may improve the indoor climate giving rise to better overall health and well-being, fewer respiratory diseases such as e.g. asthma, increased worker productivity, reduced occurrence of seasonal affective disorder (SAD), and even better educated students.[64] In addition, energy efficiency will tend to increase the average room temperature, which may prevent energy-poverty related diseases and mortality.[65]

These benefits to health can be appraised. However, the level of uncertainty – especially with respect to overall health benefits (item 2 above) – of such estimates is relatively high, and increasing as we attempt to replicate country-specific results for all EU Member States. It is less uncertain to calculate the benefits from reduced air pollution (item 1 above), as the emission factors of air pollution from different inputs, and their health

[64] See e.g. IEA (2012)
[65] See e.g. IEA (2012)

impact is well defined. In the following we therefore calculate the economic value of reducing air pollution, and include this estimate in the aggregate benefits. For the health benefits from insulation, ventilation, lighting etc., we will describe the findings from the different studies, and give a very rough estimate of what this may mean for EU as a whole. However, we will not include this rough estimate in the aggregate benefits, as we believe the uncertainty of aggregating over all EU Member States is high.

1. Health benefits from reduced air pollution from power and heating plants

In this section we estimate how much air pollution can be reduced by reducing the conversion of energy to electricity and heat. In order to calculate the benefits from reduced air pollution, we need to know the following:

- The input mix in electricity and heat production in EU27
- The air pollution emissions from different inputs
- The health value of reducing air pollution emissions

Firstly we look at the amount of energy which can be reduced due to energy efficiency investments. In 2020, annual energy consumption will be reduced by 65 Mtoe in the low EE scenario. 54 Mtoe will be reduced heating and 11 Mtoe will be reduced electricity consumption, cf. Table A.17. In the high EE scenario, heating will be reduced by 81 Mtoe, and electricity by 14 Mtoe. Continuing investments towards 2030 will further reduce annual energy consumption by a similar amount

Table A.17 Reduced energy consumption, 2020

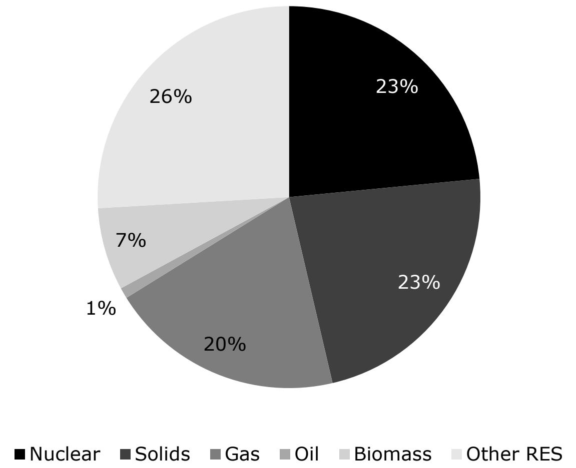
2012-2020	Reduced consumption - Low EE scenario (Mtoe)	Reduced consumption - High EE scenario (Mtoe)
Heating	54	81
Electricity	11	14
Sum	**65**	**95**

Note: These estimates do not include the rebound effect

Source: Copenhagen Economics

The input mix in EU27 electricity production in 2020 is expected to consist of 33 per cent renewable energy, 23 per cent of solids (mainly coal) and nuclear respectively, and 20 per cent gas, cf. Figure A.3. Out of the 33 per cent renewable energy, biomass constitutes app. 7 per cent of total energy consumption. This distinction becomes important, as biomass emits a significant amount of air pollution, especially small particle matters (PM2.5), while other renewable sources such as wind do not.

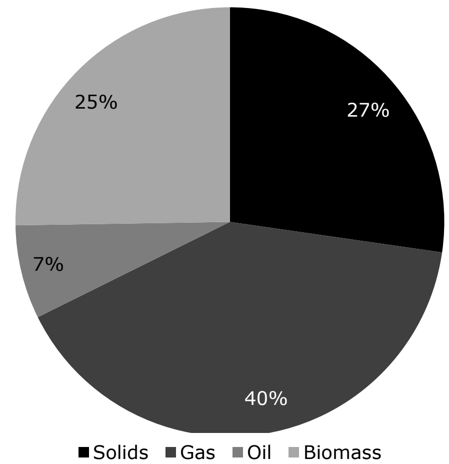
Figure A.3 Expected share of EU electricity production, 2020



Source: DG Energy (2010) page 42

Gas and solids (primarily coal) constitutes app. 40 per cent and 27 per cent respectively of the expected heat production in EU in 2020, cf. Figure A.4.

Figure A.4 Expected share of EU heat production, 2020



Note: The calculation only includes the EU OECD countries

Source: IEA (2012), Energy Statistics OECD countries

To calculate the amount of air pollution from the different input sources, we use so called emission factors. Production of electricity and heat emits several different air pollution sources, including SO_2, NO_x, and small particle matter (PM). The emission of each source is different depending on the input used in production. Natural gas, e.g. has relatively low

SO_2 and PM emissions, while it emits relatively more NO_x than both coal and fuel oil, cf. Table A.18.

Table A.18 Emission factors for an average European power and district heating plant

(kg/GJ)	SO_2	PM2.5	NOx	CO_2
Nuclear	0	0	0	0
Biomass	0.028	0.001	0.060	0.000
Coal	0.083	0.004	0.065	94.197
Gas	0.075	0.000	0.037	56.911
Oil	0.221	0.019	0.513	76.052

Note: Emission factors have been calculated as a weighted average of the existing power plants and district heating plants in Europe, 2012

Source: GAINS model

We assume that the reduction in energy production will reduce the input use proportionally to the expected input-mix in 2020. We also use estimates on the value of reducing the harmful effect of air pollution from DG Transport (2008). We find that by reducing energy consumption, and consequently electricity and heat production, the economic value to EU citizens from reduced air pollution will be in the magnitude of app. €5.2 billion in the low EE scenario, and 7.7 billion in the high EE scenario, cf. Table A.19.

Table A.19 Value of reduced air pollution

2012-2020	Reduced emissions (Ton)	Value of each emission reduction (€/ Ton)	Total value of reductions (billion €)
Low EE scenario			
SO_2	185,713	3,138	0.6
NO_x	202,286	2,676	0.5
PM	7,069	10,805	0.1
Sum			**5.2**
High EE scenario			
SO_2	275,883	3,138	0.9
NO_x	301,559	2,676	0.8
PM	10,517	10,805	0.1
Sum			**7.7**

Note: The value of emission reductions has been calculated as an average between city districts and rural districts

Source: Copenhagen Economics, DG Transport (2008) and GAINS model

2. Health benefits from improved indoor climate

Energy efficient renovation of buildings can improve personal health. The health effects stem primarily from alleviating inadequate warmth through better insulation and more effective heating systems, more daylight and ventilation. Colder houses place more physiological stress on older people, sick people and babies, who have less robust thermoregulatory systems, and are more likely to spend more time inside.[66] Studies have shown that respiratory and circulatory hospitalisations have been reduced by insulating houses, as these diseases have shown to be particularly responsive to the effects of temperature.[67] Cold houses are also likely to be damp, which can lead to the growth of mould, which can cause respiratory symptoms. Improved ventilation and access to daylight may increase worker productivity, and students' learning abilities.

By making Energy efficient renovation to buildings, overall health and worker productivity may therefore be improved.[68] In addition, by improving e.g. indoor air qality and the inflow of light, worker productivity and the learning capabilities of students may increase.[69]

We broadly identify three quantifiable types of health benefits from previous studies. The benefits accruing to individuals come from improvements in personal well-being (e.g. less illness, general improvements in quality of life, and reduced mortality), reduced days of work missed due to illnesses related to poor indoor environmental quality, and lower spending on health care due to these types of illnesses.

We have collected the estimates available from the literature which has attempted to quantify health effects from specific energy efficiency renovations. We have used studies that have stated both the costs of the renovations, and the value of the health improvements. Based on primarily four available studies we calculate cost-benefit ratios by comparing the cost of implementing the programmes with the estimated health benefits the improvements give rise to. The results from these studies are stated in Table A.20.

[66] Barnard et al (2011), page 11.
[67] Barnard et al (2011), page 11.
[68] See e.g. IEA (2012), and REHVA (2006)
[69] See e.g. Slotsholm (2012), which find that Danish GDP may increase by €173 million due to better air quality in primary schools.

Table A.20 Quantifiable health benefits in the literature

		Threlfall (2011) - AWARM programme	Lidell et al (2011) - Kirklees Warm Zone	Barnard et al (2011) - Warm Up New Zealand	UK Department of Health (2010)
Heating	Better life quality	14.79 months extended lifetime (improved health)	758,500 GBP	9 NZD per household	
	Less public health spending				42 pct
	Fewer missed days of work				
Insulation	Better life quality	11.96 months extended lifetime (improved health)	15.2 Quality adjusted life years	465 NZD per household in reduced mortality	
	Less public health spending			75 NZD per household	42 pct
	Fewer missed days of work			59 NZD per household	

Source: Based on the sources in the table

Based on these estimates and the cost of the specific energy efficient projects, we can calculate a cost-benefit ratio of each single health benefit. When the different studies have given different results, we have constructed an interval from the lowest estimate to the highest estimate. The ratios are generally below unity, with the exception of benefits from improved well-being associated with improving insulation which equals 1.64, cf. Table A.21. This result comes from the reduced mortality rate from low indoor temperature.[70]

Table A.21 Cost-benefit ratios

Cost benefit ratios	Health benefits - better life quality	Less public health spending	Fewer missed days of work
Heating	0.36-0.46	0.42	0
Insulation	0.12-1.64	0.42-0.99	0.78

Source: Own calculations based on Threlfall (2011), Liddell et al. (2011), Barnard et al. (2011), and UK Department of Health (2010).

By applying these cost-benefit ratios to the amount of investments needed to realize the energy saving potentials in the EU identified above, we arrive at estimates of the health benefits associated with these investments, cf. Table A.22. Please note that these estimates are highly uncertain at an EU level, since the uncertainty related to the estimate of each study is accentuated by applying it to the EU as a whole. Moreover, e.g. less public health spending is highly dependent on the specific health system in each country.

[70] Note that this result is taken from the project in New Zealand, and the condition of New Zealandic houses may not be directly comparable to European houses. However, the notion of a "European house" it not suitable as the condition varies across countries. This is the primary driver of the conundrum that cold-related deaths is higher in the warmer Southern European countries than in the colder Northern European countries.

Note also that we equalised the "value of a statistical life" which took different values across the UK and NZ study. We have used the UK estimate.

Table A.22 Overall benefits to society of health improvements

Billion €		Low EE scenario	High EE scenario
Heating	Better life quality	3.9 - 5.0	7.6 - 9.7
	Less public health spending	4.6	8.8
	Fewer missed days of work	0	0
Insulation	Better life quality	2.2 - 30.5	4.3 - 58.6
	Less public health spending	7.8 - 18.4	15.0 - 35.5
	Fewer missed days of work	14.5	27.8
Total		**33 - 73**	**64 - 140**

Note: We have aggregated over several studies. These studies differ in the way they calculate the value of health benefits. For example, the New Zealand study uses a statistical value of life of NZD 150,000 (approx. EUR 90,000), while the AWARM study uses a value of GBP 20,000 (approx. €24,000). In order to ensure comparability between the estimates, we apply the lower value to the benefits in the New Zealand study.

Source: Own calculations based on Threlfall (2011), Liddell et al. (2011), Barnard et al. (2011), and UK Department of Health (2010).

The public finance effects are primarily related to the reduced public health spending. Note that the lower estimate on public health spending (€7.8 and €15.0 billion respectively) is derived from the UK health system, and the higher estimate (€17.3 and €33.2 billion respectively) from the New Zealand health system. It is difficult to apply these figures directly to an aggregate European level, as they are very dependent on the level of publicly paid health care. When interpreting these numbers, this should be kept in due attention.

It should also be noted that these studies are based on specific programmes; two in the United Kingdom and one in New Zealand. Hence, there may be country-specific factors related to e.g. local climate which makes generalizations to other countries less reliable. Furthermore, the British studies specifically target low-income areas. Assuming that energy saving renovation take place in higher income households as well, applying results from these studies may lead to overestimation of the health benefits, as it is likely to be the low-income households that suffer from heating related diseases.

Studies have also been conducted regarding the relationship between improved indoor climate and productivity in offices. One literature survey concludes that productivity can be significantly affected by improving indoor environmental quality, cf. Table A.23. The same study concludes that very small increases in productivity of say 0.1 per cent can pay for an increase in energy cost of 20 per cent, or an increase in productivity of 0.66 per cent can pay for an increase in investments of 10 per cent.

Table A.23 Indoor environmental quality

Effect	Temperature	Ventilation	Indoor air quality
	Productivity is reduced by 5-15 per cent when temperature is above the thermal comfort zone	Productivity is increased by 1 per cent for every two-fold increase in outdoor air supply	Performance of text typing improves significantly, when indoor air quality is increased

Source: REHVA (2006)

One study shows that the indoor air quality significantly affects children's ability to learn.[71] The study concludes that by improving the indoor air quality in Danish schools so the amount of fresh air was increased to the level in Swedish schools, this would improve the learning ability of these students, and implicitly the productivity of future workers, which would improve Danish GDP annually by €173 million and public finances by €37 million annually.

A.10 Benefits from stimulating economic activity during a period of recession

Investments in energy efficient renovation of buildings will stimulate economic activity. The beneficial effects of increased investments depend to a very large degree on the current economic circumstances. If investments are to increase during an economic boom, the result would most likely be increased wage pressure in the construction sector, and very little additional activity, as the economic potential in terms of available capacity would be limited. However, during an economic recession, capacity, especially in terms of labour, is more readily available. As energy efficiency investments induce a boost to economic activity during such a period of available capacity, this will bring people from unemployment into employment, to the advantage of overall society and to the public budgets.

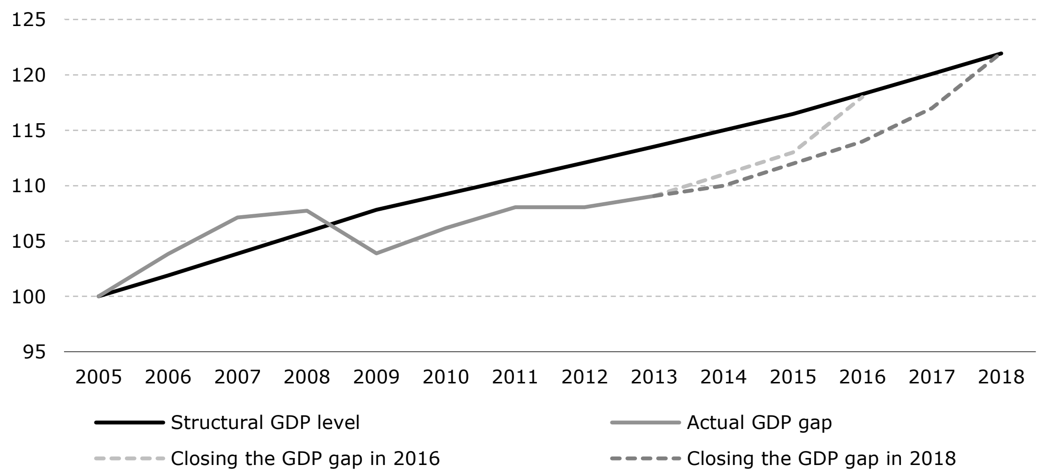
It should be stressed that the benefits calculated in this section are the gross benefits in the sense that they do not include any costs from the actual investments (this is taken into account when measuring the aggregate benefits) or from the cost of incentivising the investments. Hence, we implicitly assume that the investments will be undertaken without any public subsidies, but conversely by breaking down regulatory barriers that prevents the private sector from realising the economic potential of energy efficiency investments. We describe a number of such barriers in Chapter 2.

Potential for increasing economic activity in the current situation
The economic crisis has led to a significant reduction in GDP compared with the so called structural GDP, which is a measure of the GDP in absence of an economic recession or boom. This gap between actual GDP and structural GDP is known as the output gap. When the output gap is negative, there are available resources in the economy (this can for example be relatively high unemployment). As a result of the economic crisis the out-

[71] Slotsholm (2012), Socio-economic consequences of better air quality in primary schools

put gap for Europe is expected to be negative for several years to come. In fact, IMF estimates that the output gap will be negative at least until 2017, cf. Figure A.5.

Figure A.5 Output gap in the European economy



Source: Copenhagen Economics, based on OECD Economic Outlook 91 database

This implies that stimulating economic activity through investments in energy efficient renovation of buildings is a particularly good idea going towards 2017, as this will help the economy towards its structural level.

Investment path

In the earlier sections we have derived the expected potential for energy efficient renovation of buildings from 2012-2020, and 2020-2030. In this section we focus on a hypothetical investment path that will reach the identified renovation potential in 2017, when the economy is expected to reach its structural level. We assume that such an investment path will increase in intensity, as barriers to especially the cost-effective investments begin to be broken down.

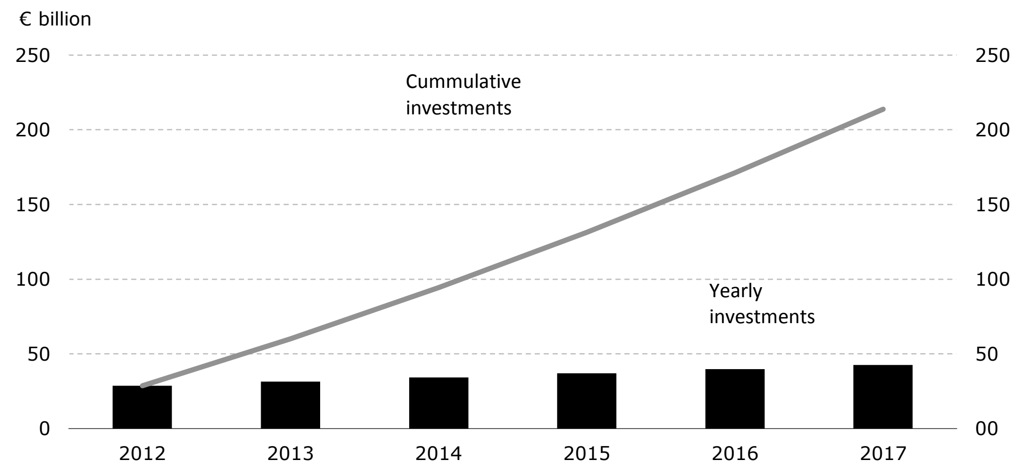
We construct the investment path in order for it to fulfil the renovation potential in 2020 with a slightly increasing investment rate. Our estimates suggest that in order to meet the potential in 2020, a yearly investment of €40 billion is needed in the low scenario, and €76 billion in the high scenario. Our estimate of €40 billion can be compared to the estimate by the European Commission[72] of €60 billion. We consider the same scenario, however the Commission considers also energy savings from new buildings, while we consider only the potential from renovating the existing building stock.

[72] See European Commission (2012)

We construct the investments path towards 2020 by increasing the investment rate with €2.8 billion each year. This allows us to think of the investments as permanent towards 2017, as the investment amount in the following year is slightly higher. This increase is then considered permanent towards 2017, as it will be repeated and enhanced in the next year. This implies that the investment in 2012 will be below €40 billion, while the investment will be above €40 billion in 2020, such as the annualised average investment equals €40 billion in the period 2012-2020.

With the assumed investment path, Europe will have invested for a total of app. €215 billion in 2017 in the low scenario, cf. Figure A.6. By following the investment path, all of EU's identified energy efficiency potential in 2020 will be reached in 2020.

Figure A.6 Assumed investment path (low EE scenario)



Source: Copenhagen Economics based on http://www.eepotential.eu/esd.php

We can now begin to calculate the impacts on GDP from following this investment path. We focus on two positive impacts on GDP: 1) The direct impact from an increase in investments in energy efficient renovation of buildings, and 2) the indirect impact from the indirect effects increased household consumption, extra demand in connected sectors etc.

We begin by deriving the direct impact:

Direct impact on employment

In order to calculate the effect of increased investments in energy efficient renovation of buildings on GDP and the public finances, we need to know how many jobs are "created" per € invested.[73] A study that reviewed 35 different cases found that on average, €1 million invested results in 19 jobs in the sector cf. Table A.24.[74]

[73] One should be careful with the expression: "created jobs" as the "creation" of one job typically crowds out employment in another job. In this example where European economies are in recession, we assume that the unemployed labour capacity will fill up new jobs. This implies that the amount of net jobs created is equal to the amount of gross jobs created.

[74] It is not always clear from the studies whether or not indirect jobs have been included.

Table A.24 Gross employment effect of increased investments

Study	Hypothetical size of investment	Increased number of jobs (average)	Production per job (€)
Janssen and Staniaszek (2012), How many jobs? A survey of the Employment Effects of Investment in Energy Efficiency of Buildings	€ 1 million	19	52,600

Note: Production per jobs is measured as the size of the investment divided by the increased number of jobs needed to complete the investment.

Source: The study mentioned in the table

Direct impact on GDP

In order to calculate the effects on GDP we use the gross value added (GVA) per employed in sectors we believe can be associated with energy efficiency investments in buildings. One natural starting point would be the GVA per employed in the construction sector, which is €55,740, cf. Table A.25. In the sectors we believe are associated with energy efficiency investments, such as manufacture of glass and glass products (to manufacture windows), manufacture of ceramic insulators and insulation, and plumbing, heat and air conditioning installations, the GVA per employee is lower, ranging from 46,110 to 52,220, cf. Table A.25.

Table A.25 Gross value added per employee in relevant sectors

Sector	Gross value added per employee (EUR)
Total manufacturing	55,770
Construction of buildings	55,740
Manufacture of glass and glass products	52,220
Manufacture of ceramic insulators and insulating fittings	46,870
Manufacture of central heating radiators and boilers	48,560
Manufacture of lighting equipment and electric lamps	52,090
Construction of residential and non-residential buildings	46,110
Plumbing, heat and air conditioning installation	46,110
Other construction installation	49,980
Roofing activities	47,600

Source: Eurostat, structural business statistics [sbs_na_con_r2]

Based on these statistics, we construct a low, an average, and a high estimate for GVA per employee from energy efficiency measures in buildings, cf. Table A.26.

Table A.26 Gross value added per employee

	Gross value added per employee (EUR)
Low estimate	46,110
Average estimate	49,476
High estimate	55,740

Note: - Low estimate: the lowest GVA value corresponding to plumbing, heat and air conditioning installations
- Average estimate: an average of all sectors in Table A.25, except Total manufacturing
- High estimate: the GVA in the sector Construction of buildings

Source: Copenhagen Economics, based on Eurostat, structural business statistics [sbs_na_con_r2]

By investing a hypothetical €1 billion in energy efficiency investments, the expected direct impact on GDP ranges from app. €0.88 -1.06 billion, cf. Table A.27.

Table A.27 Direct impact on GDP

Size of investment (€ billion)	Gross jobs created	Impact on GDP - low estimate (bn EUR)	Impact on GDP - average estimate (bn EUR)	Impact on GDP - high estimate (bn EUR)
1	0.019	0.88	0.94	1.06

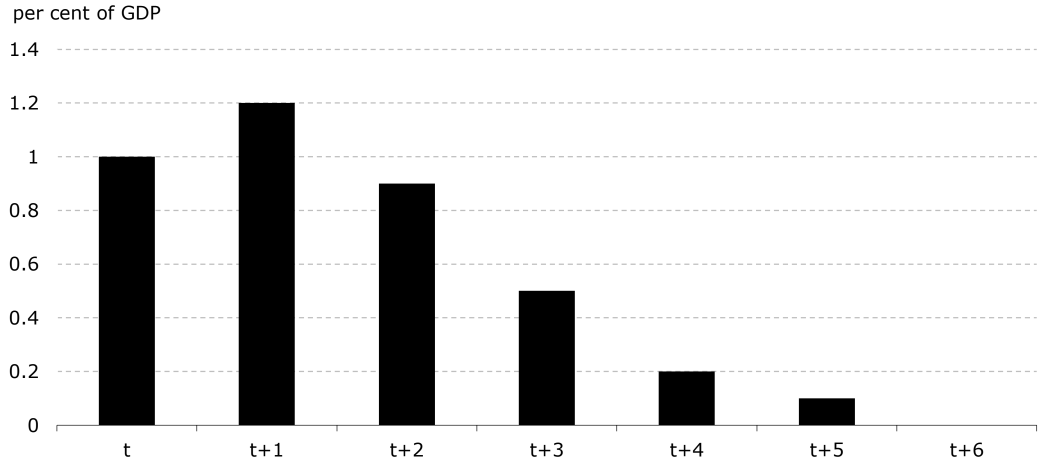
Source: Copenhagen Economics

We now turn to the indirect effects:

Indirect impact on GDP

The direct effect on GDP will have a relatively immediate impact. In the year following the increased investment, the indirect effects from increased household consumption and the impact on other sectors kicks in. As inflationary pressure starts to grow, the positive stimulating impact from the increased investment will gradually crowd out other uses of the same resources. By the 6th year after the initial stimulus the effect will be completely crowded out, cf. Figure A.7.

Figure A.7 Dynamics of a permanent increase in public spending



Note: The effect is showed for the euro area.

Source: OECD (2001)

By combining the assumed investment path of Figure A.6 we can derive the effect on GDP from investing in order to meet the identified potential for energy efficient renovation of buildings in Europe. We do this by assuming that an increase in the energy efficiency renovations is equal to an increase in public spending. Since we have derived the investment path as an increase in the permanent investment level, we can use the multipliers related to a permanent increase in public spending.

We apply the average direct estimate on GDP from Table A.27 as the first year effect, and the multipliers from Figure A.7 to calculate the effects on the following years. We find that the accumulated increase in GDP from investing in energy efficient renovation of buildings during the period of spare capacity to be 1.19 per cent, cf. Table A.28. This equals €153 billion.[75] By the same method, we find that in the high EE scenario the accumulated effect on GDP is 2.26 per cent, equalling €291 billion.

[75] Based on 2012 GDP in current prices

Table A.28 Accumulated impact on GDP, low EE scenario

Pct. increase in GDP as increase in public spending	2012	2013	2014	2015	2016	2017	Total impact on GDP (in percent per year)
Increase in "permanent" investments (€ billion)	28.7	2.8	2.8	2.8	2.8	2.8	
Derived increase in public spending (per cent)	0.23	0.02	0.02	0.02	0.02	0.02	
2012	0.23						0.23
2013	0.28	0.02					0.30
2014	0.21	0.03	0.02				0.25
2015	0.11	0.02	0.03	0.02			0.18
2016	0.05	0.01	0.02	0.03	0.02		0.12
2017	0.02	0.00	0.01	0.02	0.03	0.02	0.10
Total							**1.19**

Note: The single elements do not always equal the total impact due to rounding.

Source: Copenhagen Economics based on OECD (2001).

Effects on public finances

When economic activity is stimulated in a period of economic downturn it creates jobs for people who were formerly unemployed. This improves public finances by reducing expenses to unemployment benefits, and increasing tax revenues e.g. through increased VAT revenue from increased economic activity. In order to assess the size of this effect, we use so called fiscal multipliers which indicate how much public budgets are improved/deteriorated when GDP is increased/decreased. The primary driver of these multipliers is the increase in tax revenue and avoided unemployment benefits, but the multipliers essentially captures any improvements in public budgets from increasing GDP. The average fiscal multiplier for EU27 is 0.44, cf. Table A.29, which means that every time GDP is increased by €1 million, public budgets are improved by €0.44 million.

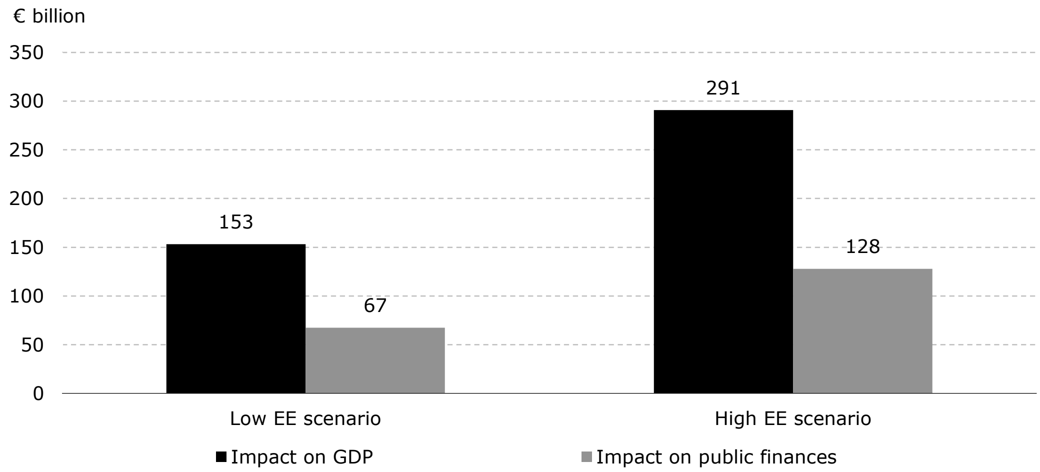
Table A.29 Fiscal multipliers for EU27

Country	(Semi) Elasticities (year 2011)
AT	0.47
BE	0.51
BG	0.33
CY	0.43
CZ	0.36
DE	0.51
DK	0.65
EE	0.30
EL	0.42
ES	0.43
FI	0.58
FR	0.53
HU	0.44
IE	0.44
IT	0.49
LT	0.29
LU	0.44
LV	0.30
MT	0.38
NL	0.62
PL	0.38
PT	0.45
RO	0.32
SE	0.61
SI	0.45
SK	0.33
UK	0.46
Average EU 27	**0.44**

Source: DG ECFIN (2012)

This implies that the accumulated effect on public finances from 2012-2017 is €67 billion and €128 billion respectively in low and high scenario, cf. Figure A.8.

Figure A.8 Benefit from increased economic activity



Source: Copenhagen Economics based on the stated sources in the above calculation steps.

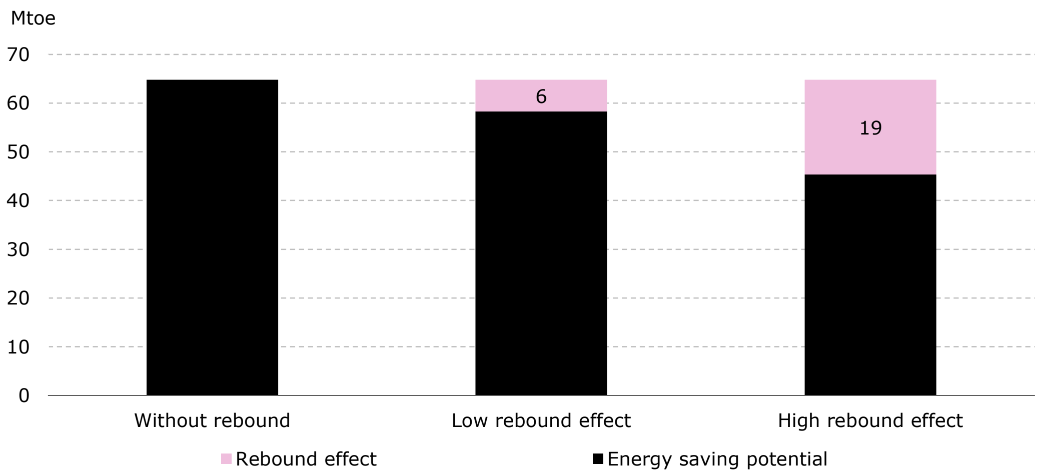
As investments continue to take place after 2017, there will continue to be an increasing pressure on economic activity. However, as this will take place at a time where the economy is expected to be on or above its structural level, we do not consider this is a benefit to the total economy. Instead, such economic activity will most likely crowd out already existing economic activity, and will increase wage and inflationary pressure.

A.11 Aggregating the benefits

The benefits of investing in energy efficient renovation of buildings constitute of several different elements as listed in the above description. While some of the benefits are direct and tangible, such as cost savings from reduced energy consumptions, other benefits are less direct and tangible such as e.g. the value in terms of health of reduced air pollution. In this section we nonetheless aggregate the different benefits with a view to which of the benefits can be attributed to improving public finances. When interpreting the overall benefits, one should therefore be aware of the different levels of uncertainty and timing of the benefits.

As mentioned in the report, several studies find that there is a relatively small, but significant rebound effect of conducting energy efficient renovation of buildings. These renovations essentially make it cheaper to consume energy, which will increase energy consumption. Based on a survey of the economic literature on rebound effects we apply a rebound effect of 10-30 per cent. This corresponds to 6-19 Mtoe less reduced energy consumption in the low EE scenario in 2020 than would have taken place without a rebound effect, cf. Figure A.9.

Figure A.9 Energy saving potential with rebound



Note: The figures depicts the low energy efficiency in 2020
Rebound effect is measured for room heating improvements (including insulation)

Source: Copenhagen Economics based on Greening et al (2010)

By taking a 20 per cent rebound effect into account, we estimate that the overall annual benefits to society is between €85-124 billion in the low EE scenario in 2020, and €135-203 billion in the high EE scenario, cf. Table A.30. These benefits include the health benefits from improved renovation on e.g. respiratory diseases, asthma etc, where the estimates are quite uncertain. If investments are continued towards 2030 these annual benefits will be approximately doubled in 2030.

Table A.30 Overall annual gross benefits to society, 2020

Overall benefits to society (incl rebound)	Value - low EE scenario (bn EUR)	Value - high EE scenario (bn EUR)
Direct annual effects		
Energy savings	52.5	75.5
Reduced outlay on subsidies	2.2 - 8.7	2.5 - 9.0
Indirect annual benefits		
Reduced air pollution	4	6
Health benefits (uncertain)	26.4 - 58.3	50.8 – 112.3
Total (bn EUR)	**85 – 124**	**135 - 203**
Total (pct. of GDP)	**0.7 – 1.0**	**1.0 – 1.6**

Note: Rebound effect has been included

Source: Copenhagen Economics

We also estimate that public budgets will be improved annually by €17-42 billion in 2020 in the low EE scenario, and €28-51 billion in the high EE scenario, cf. Table A.31. This includes the health benefits from improved renovation on e.g. respiratory diseases, asthma etc, where the estimates are quite uncertain. If investments continue towards 2030, these annual benefits will be approximately doubled in 2030.

Table A.31 Annual improvement of public finances, 2020

Improvement of public finances (incl. rebound)	Value - low EE scenario (bn EUR)	Value - high EE scenario (bn EUR)
Direct annual benefits		
Energy savings	9.1	12.4
Lost tax revenue from energy taxation	-4	-6
Reduced outlay on subsidies	2.2 – 8.7	2.5 – 9.0
Indirect annual benefits		
Reduced air pollution	0	0
Health benefits (uncertain)	10.0 – 28.2	19.0 – 35.4
Total	**17.1 – 42.0**	**28.1 – 51.0**
Total (pct. of GDP)	**0.1 – 0.3**	**0.2 – 0.4**

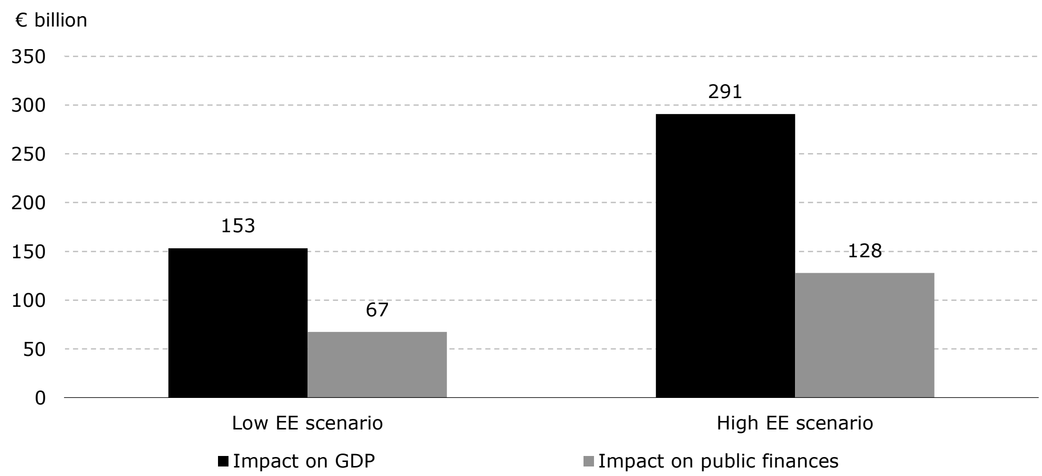
Note: Rebound effect has been included

Annual improvements of public finances are a subset of overall benefits to society.

Source: Copenhagen Economics

In addition to these annual benefits, there will be a one-off benefits to GDP and public budgets from increasing economic activity. This corresponds to €153 billion impact on GDP and €67 billion increased revenue to public budgets in the low EE scenario, cf. Figure A.10. If the high EE scenario is followed, the benefits will be €291 billion impact on GDP and an increase in public revenue of €128 billion.

Figure A.10 Benefit from increased economic activity



Source: Copenhagen Economics based on the stated sources in the above calculation steps.