Calculating and Operationalising the Multiple Benefits of Energy Efficiency in Europe

WP6 Macro-economy

Macro-economic impacts of energy efficiency

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Authors

Helge Sigurd Næss-Schmidt, Partner

Martin Bo Westh Hansen, Managing Economist

Sabine Wilke, Economist

Bjarke Modvig Lumby, Economist

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Project partners ABUD Advanced Building & Urban Design; Copenhagen Economics; Universiteit Antwerpen; Manchester 1824 The University of Manchester

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Preface

This report is part of the COMBI project supported by Horizon 2020. The overall aim of COMBI is to analyse and quantify the multiple impacts of energy efficiency improvement (EEI) actions. In this report, we analyse the macroeconomic implications of energy efficiency investments (Work Package 6 of the project). Elements such as health, productivity and energy security are investigated in other parts of the project.

In our work, we distinguish clearly between short-run macroeconomic effects and structural long-run macroeconomic effects. These are very different in nature and should be treated separately in any assessment. Consequently, we devote Chapter 1 to the short-run effects and Chapter 2 to the long-run effects.

Executive summary

In order for the world to reach a CO_2 trajectory consistent with the 2 degree objective, massive mitigation efforts need to be undertaken and the EU will play a large part in this. In pursuing this objective, energy efficiency is expected to play a significant role together with renewable energy deployment and CSS technologies.[1] In 126 model-based CO_2 trajectories consistent with the 2 degree objective, the median pathway assumes that the overall energy productivity in the world must increase from 4 bn USD/Mtoe to 9 in 2040, and 24 in 2100. [2] Such massive adjustments represent a major challenge.

Carbon mitigation measures are generally associated with costs. Technologies to produce renewable energy are (currently often) more expensive than their fossil-fuel based alternatives, and energy efficient industrial process facilities cost more to develop and build than existing less efficient ones. When deciding on a cost-efficient climate policy and the instruments underpinning this, it is important to make use of the least costly measures seen from a total economic perspective.

In this context, it is important to acknowledge that the attractiveness of many climate mitigation measures, such as energy efficiency, should not just be assessed via their impact on reducing CO_2 emissions for a given cost. In fact, most measures have derived consequences on other socioeconomically important parameters. Most obvious is the impact on the cost of energy input into production, which in some cases is high enough to pay for most or all of the additional investment. However, there are also a number of other consequences associated with energy efficiency, which affect the overall socioeconomic business case of these energy efficiency improvement (EEI) actions. In the following, we label these effects as *multiple impacts*. An important question is, therefore, how sizeable are the multiple impacts, and how do they affect the overall socioeconomic business case?

In this study, we have assessed one of the multiple impacts, namely macroeconomic consequences.[3] For this, we define two very different types of macroeconomic effects: 1) A short-run business cycle perspective, and 2) A long-run, structural perspective. The main difference between these two approaches is that the first looks at the value created through stimulation of the economy, and the second looks at the economic effects over a longer period of time. The macroeconomic indicators considered are GDP, labour market effects, public finance and energy prices.

Concretely, we have analysed a very ambitious energy efficiency programme running until 2030 for EU-28, and equalling a total of 1,615 TWh of energy saved annually and a total additional investment of about €1,330 billion, see Table 1. This programme includes EEI actions across many economic sectors, including industry, transport, tertiary sectors and residential buildings. The content of the programme, which we take for granted in this exercise, has been calibrated in the

[1] Including negative emissions, where CCS is applied on biomass

[2] See Copenhagen Economics' analysis of the more than 1,000 CO_2 trajectories towards 2100 based on among others the AR5 database underpinning the work of the IPCC in the following report: Copenhagen Economics (2016) The future of fossil fuels: How to steer fossil fuel use in a transition to a low-carbon energy system. A report for the Energy Transitions Commission (ETC).

[3] The remaining multiple impacts are quantified in the broader COMBI project

combined COMBI project, and is based on a detailed stock model of technologies analysing incremental energy efficiency actions.[4]

The breakeven point of the actions varies extensively. Some actions pay off in the first year. Other actions take longer to see returns. A long period until breaking even does not necessarily mean the action is a bad investment. The breakeven time for the specific action should be compared to the lifetime of the asset replaced or refurbished. For example, the refurbishment of building shells have a longer breakeven time than cold appliances. However, the lifetime of the building shell is significantly longer than the lifetime of the cold appliances. It should be stressed that the investments and energy savings are uncertain and based on technical estimates.[5]

For this study, the investments considered are all assumed to be privately financed.

Table 1: COMBI energy savings and cumulated investments for the EU-28

Sector	Action	Investments (b€)	Energy savings (TWh/year)	Energy savings (b€/year)	Years until breakeven
Residential buildings	Refurbishment of building shell	302	260	24	18
	New dwellings	28	52	4	8
	Lighting	1	10	8	0
	Cold appliances	15	4	2	9
Tertiary sector buildings	Refurbishment of building shell	109	84	4	Never
	New buildings	7	12	1	10
	Lighting	1	28	6	0
	Product cooling	2	6	1	2
Passenger transport	Modal shift	-	40	11	0
	Motorcycle	6	1	0	Never
	Car	331	284	20	27
	Bus	4	3	0	Never
Freight transport	Modal shift	-	90	24	0
	Light duty truck	118	13	1	Never
	Heavy duty truck	140	32	2	Never
Industry	High-temperature process heating	57	221	38	2
	Low- and medium-temperature process heating	64	199	9	8
	Process cooling	9	10	1	23
	Specific process electricity	5	16	96	0
	Motor drive	85	143	7	17
	Building envelope improvements in industrial buildings	45	144	7	8
Total		**1,330**	**1,615**	**266**	**6**

Note: Years until breakeven measures the number of years with the annual energy savings until the initial investment has been payed-off with an annual interest rate/discount rate of 4%. "Never" indicates that the measure will never pay for itself through energy savings.

Source: Copenhagen Economics based on COMBI Work Package 2

[4] See the work done in Work package 2 of the COMBI project.

[5] For example, occupants in energy inefficient buildings use less energy than their technical estimates and vice versa for occupants in energy efficient buildings, which use more energy than their technical estimates (Sunikka-Blank and Galvin, 2012). This could mean the energy savings for the refurbishment of building shells are overestimated.

Short-run (business cycle) effects

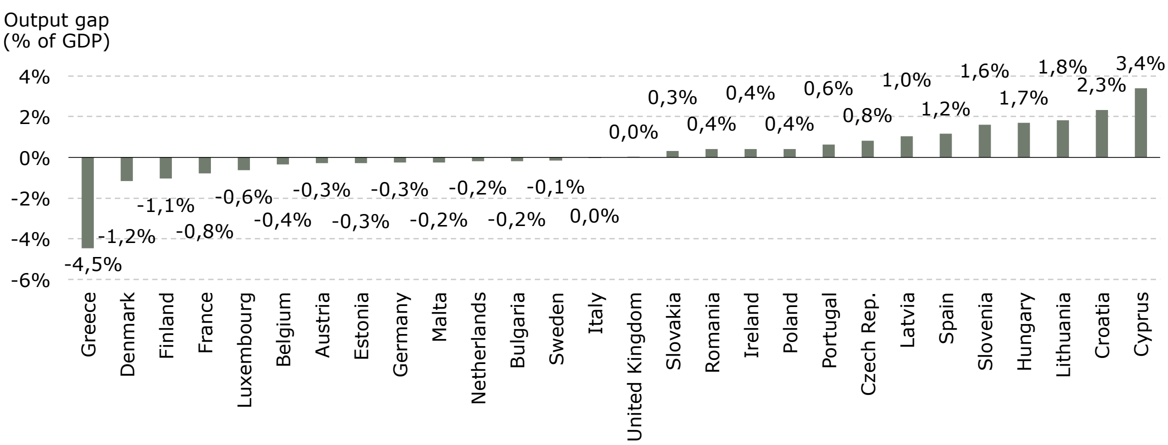
There is a long tradition for engaging in so-called active fiscal policies to smooth out fluctuating business cycles. The basic idea is that volatility in the economy has a cost to society, and avoiding booms and busts in the economy is to be preferred. Consequently, fiscal policy is used to slow down activity when the economy is booming, and stimulate activity in the event of the reverse. An increase in economic activity is therefore helpful when the economy is in a bust, while it is counterproductive when the economy is in a boom (where economic ministries will be trying to reduce activity).

Like any other activity-stimulating investments, energy efficiency investments have an immediate impact on the economy, but do not have a lasting, direct impact on the economy. The investments in energy efficiency improvements will increase activity and short-run GDP compared to not doing an investment. Such investments will increase the short-run demand for labour and capital, and increase employment and GDP. This increased employment and GDP can be treated as a macroeconomic benefit when it takes place in an economic bust, while being counterproductive when it takes place in an economic boom.

We find that, in 2018 the energy efficiency investments considered to be about €89 billion in total, will bring an economic stimulus of about €135 billion, corresponding to 0.9 per cent of EU GDP. This is a massive investment, which would have a noticeable effect on local labour (and product) markets. Following the programme in to the year 2030, we find that such a stimulus would give rise to an increased labour demand of about 2.3 million job-years, and an increase of GDP of 160 billion.

As discussed above, these jobs and additional GDP can only be treated as macroeconomic benefits if the European economies are in an economic downturn. Projections show that in 2018 more than half of the EU countries are no longer in an economic downturn (i.e. they have a positive output gap), and most of the other countries are very close to transitioning into an economic upswing. Only three countries are expected to have a negative output gap of more than 1 per cent of GDP, namely Greece, Denmark and Finland, see Figure 1.

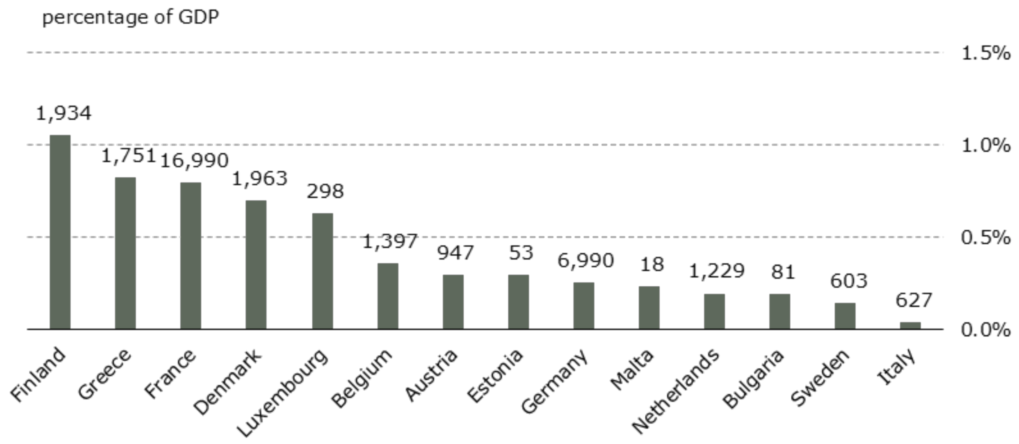
Figure 1: Output gap forecasts for 2018



Source: DG ECFIN (2017)

When looking at 2018, we therefore find that the real macroeconomic benefits from the analysed energy efficiency investments amount to approximately €35 billion, primarily distributed to Greece, Finland, France, Denmark and Luxembourg, see Figure 2.

Figure 2: GDP effect in 2018



Note: The labels show the absolute level of the effect in millions of euros. The size of the columns shows the GDP effects measured in per cent of GDP.

Source: Copenhagen Economics based on IO-model and DG ECFIN (2017)

The countries that benefit most from an increase in GDP will also benefit most from increased employment and public revenue. The total real impact on employment in 2018 amounts to more than 550,000 person years in the EU, while public revenue will increase by almost €20 billion if the increased investments are solely financed through private sources.[6]

When looking further into the future, it is impossible to predict which countries will be where in the business cycle, and to what extent an energy efficiency investment will therefore give rise to an economic benefit. Some countries will experience a positive output gap and others a negative output gap. Due to the uncertain nature of this, we have not estimated the expected effect, but rather found a maximum effect on GDP of between 0.5-1.5%.

Long-run (structural) effects

When looking at the longer run, business cycle effects become irrelevant. Long-term policies should be guided by their long-term effect, and not by the activity-stimulating effect they have in a particular year where there may or may not be a need for the additional stimulus. In the longer run, what matters is that the resources available in the economy are used in the most optimal way, delivering on the multiple, parallel objectives society has e.g. climate change concerns, poverty and distributional concerns etc.

When looking to the longer run e.g. 2030, an ambitious energy efficiency program is likely to affect the economic structure on several different parameters. We have explored the implications by analysing three different parameters:

- Fuel prices and marginal abatement costs

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6 If public money is also spent on these investment programmes, the public revenue effect will be lower

- Structural change in the economy and competitiveness vis-à-vis non-EU countries
- Total value created in the EU economy (ultimately – are the investments more costly than the savings?)

An important result is also that any climate policies including investments in energy efficiency or renewable energy will not have any impact on the employment level in the EU in the long run. This is because any new investments and jobs created in 'green sectors' will eventually, in the long run, be taken from other sectors.

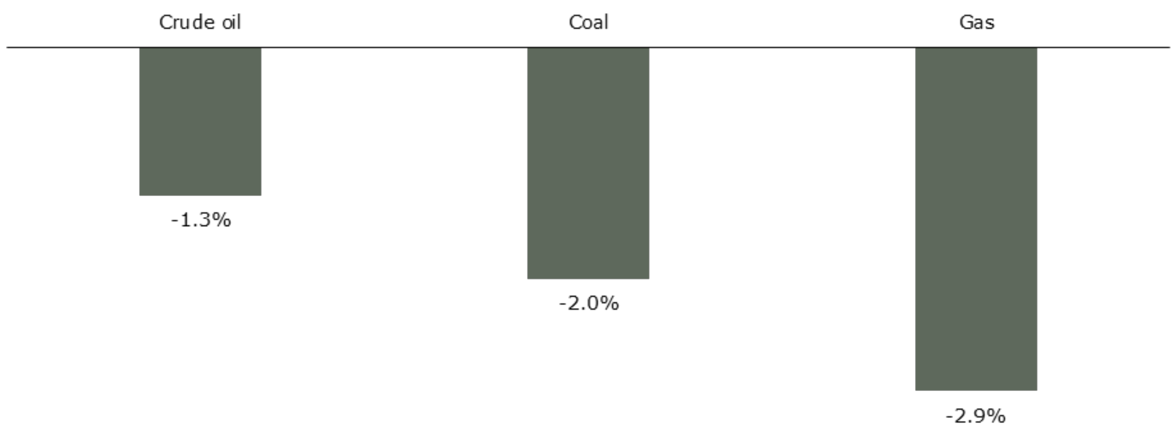
The long-run impact of the COMBI actions has been analysed in a CGE model, Copenhagen Economics global climate and energy model (CECEM). The model contains 16 regions and 16 sectors and explicitly models the value chain for energy sectors. The EEI actions are considered investments in each sector reducing energy consumption and increasing use of capital. The supply of labour in the model is fixed in the long run, reflecting that the structural unemployment are primarily affected by factors such as search costs, which energy efficiency investments will not impact.

Fuel prices

Fuel cost is a significant component of EU production costs in both agriculture and industrial production, in transportation services, and importantly also for power and heating purposes. When the economy becomes more energy efficient, the more efficient sectors will be less exposed to fuel prices. In addition, large energy efficiency improvements in the EU can reduce local prices for energy and therefore improve the relative economic position of sectors relying on energy as input. This holds for energy consuming sectors that have not increased energy efficiency, and may also hold for the sectors that have increased energy efficiency if the costs of doing so are lower than the energy savings achieved.

Our analysis suggests that fossil fuel prices in the EU fall by 1-3% compared to a current policies scenario. The global price on crude oil falls by 1%, while coal and gas prices in the EU are reduced by 2% and 3% respectively, see Figure 3.

Figure 3: Fuel prices are reduced compared to the current policies scenario

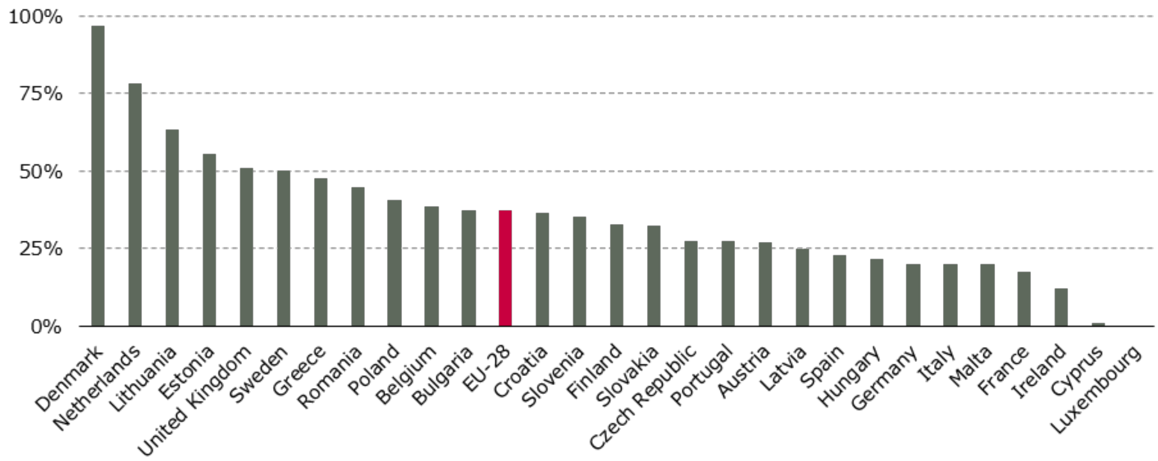


Note: Fuel price changes in the energy efficiency scenario relative to the reference scenario. The oil price is a global price; for natural gas and coal, prices shown are for EU-28.

Source: Copenhagen Economics based on CECEM model.

All EU countries are net importers of fossil fuel across all fossil fuel types, see Figure 4. Hence, a reduction in fossil fuels prices will be benefit all countries. The reduction in fossil fuel prices will have the highest benefit for countries that rely most heavily on fuel imports, such as France and Luxembourg. For countries such as Denmark and the Netherlands, which are only borderline net importers, it may be a drawback depending on the specific change in fuel prices and their net import of specific fossil fuels.

Figure 4: Export/import ratio of fossil fuels, 2015



Note: Measured as the sum of exports of solid fuels, petroleum products and gas divided by the sum of imports of solid fuels, petroleum products and gas. Above 100% means the country is a net exporter of fossil fuels and below 100% means the country is a net importer of fuels.

Source: Eurostat, *nrg_ 100a*.

Structural change in the economy and competitiveness vis-à-vis non-EU countries

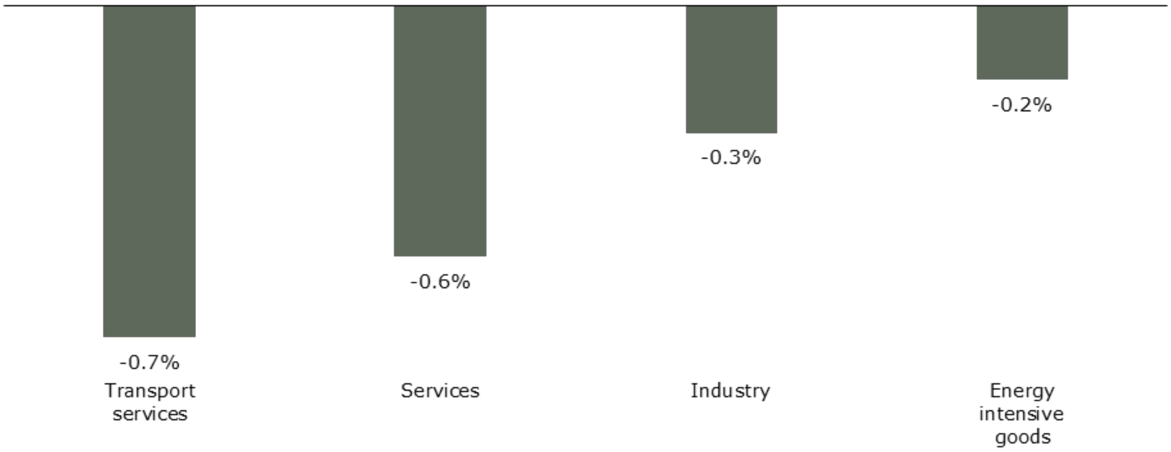
Seen from an economic perspective, an energy efficiency improvement represents an investment in an asset that can reduce costs going forward (energy savings).[7] For some investments, the value of the energy savings will be higher or equal to the costs, and for others the costs will be higher. From a climate economic perspective, such additional cost should not be much higher than alternative mitigation technologies (unless additional multiple benefits).

If the EU pursues a large-scale energy efficiency policy, this will lead to significant structural changes in the economy. The sectors where the energy efficiency improvements are relatively more cost-effective will increase their competitiveness and vice versa. Based on the assessed EEI actions from COMBI WP2, we find that most sectors will decrease their output. The sectors losing out the most are transport services (freight transport) and services (tertiary sectors) where output is expected to decrease by 0.7% and 0.6% respectively, see Figure 5. This is because the efficiency measures defined in the programme are relatively costly in these sectors compared to others. Our results here suggest that energy-intensive industry will contract a little. This is strongly

[7] Adding to this are the corresponding reductions in greenhouse gas emissions and other multiple impacts.

dependent on the underlying economics of the energy efficiency programmes, and underlying assumption that many of the measures are almost cost-efficient by themselves.[8]

Figure 5: Changes in output by sector



Note: Industry include several sectors, including e.g. chemicals and metals production.

Source: Copenhagen Economics based on CECEM model

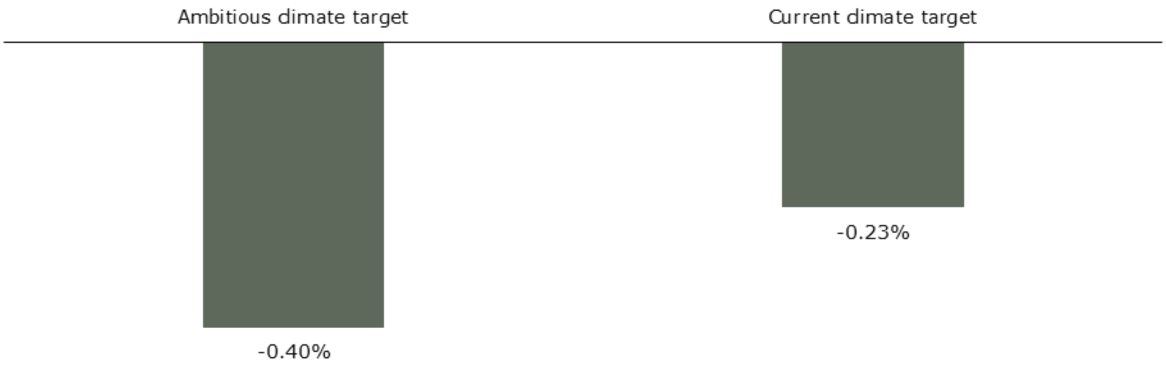
Total value created in the EU economy

From a macroeconomic point of view, it is desirable that the economy as a whole makes the best possible use of its scarce resources. In the extreme, this can be done by purely optimising economic output, but it can also be done under different conditions, such as e.g. delivering on an ambitious climate policy.

Our CGE-based analysis suggest that the energy efficiency initiatives will have a negative impact on the EU's GDP in the long run. If the EU implements an ambitious climate target, where the COMBI initiatives are implemented in addition to current policies and thereby increasing the carbon abatement targets, the EU's long-run GDP will be reduced by 0.4%. If the COMBI initiatives are implemented instead of current policies and thereby keeping the carbon abatement target the same, GDP will still fall, but only by 0.2%. A reduction in GDP suggests that the COMBI initiatives implemented *as a whole package* is likely to be more expensive than other carbon mitigation efforts. This does not mean that the initiatives are bad, but that the package is quite ambitious, and that some initiatives in the package are more expensive than other abatement methods such as renewable energy expansion. In addition, there are other multiple impacts such as e.g. health, energy security, increased labour productivity and agricultural productivity (from air pollution/health) or resource savings which are not studied in this modelling but may outweigh the decrease in GDP. These other benefits are considered in the other COMBI Work Packages and a synthesis of effects done in the COMBI online tool.

8 The economics of the energy efficiency programme has been taken as given in this study. See Work Package 1 of the COMBI project for information about this.

Figure 6: GDP is lowered in the long run due to the costs of climate policy



Note: "Ambitious climate target" includes the assessed energy efficiency improvements in addition to the current emission target, thereby reducing carbon emissions even further. "Current climate target" introduces the energy efficiency improvements but as a substitute for other climate measures to reach current targets.

Source: Copenhagen Economics based on CECEM model

Relation to the Commission's impact assessment of the energy efficiency directive (EED) review

In parallel to our work, the European Commission undertook an impact assessment behind its revised energy efficiency directive.[9] The results of its analysis varies from our findings on a few accounts in particular regarding employment effects. The study used a CGE model (GEM-E3) as well as a macro-econometric model (E3ME), to analyse the long-run impact. Both models show positive impact on GDP and employment in 2030 (except for one scenario). The E3ME model shows an increase in employment of 0.17%, whereas the GEM-E3 model varies from positive 0.20% to -0.18% whether the investments are loan-based or self-financed. GDP is increasing by 0.39% in the E3ME model and varies from +0.26% to -0.22% for the GEM-E3 model, see Table 2.

Table 2: COMBI energy benefits and costs

	GDP	Employment
Copenhagen Economics – Global Climate and Energy model (CE-CEM) *(Ambitious climate target)*	-0.40%	-
Copenhagen Economics – Global Climate and Energy model (CE-CEM) *(Current climate target)*	-0.23%	-
GEM-E3 (self-financing)	-0.22%	-0.18%
GEM-E3 (loan-based)	+0.26%	+0.20%
E3ME	+0.39%	+0.17%

Note: The numbers presented here are based on the EUCO30 scenario of the EU-Commission's EED Impact Assessment, which is used as a comparison to COMBI.

Source: European Commission (2016), EED Impact Assessment

The differences can be ascribed to several drivers, such as differences in scenarios (including baseline scenario) and differences in modelling assumptions. The CE-CEM model uses the traditional way of modelling long-run effects where the economy is initially in an equilibrium with

9 EC (2016), Proposal for a Directive of the European Parliament and of the Council amending Directive 2012/27/EU on Energy Efficiency

no output gap or idle resources. The GEM-E3 and the E3ME models uses an assumption of idle resources for its long-run impacts, which can create positive GDP effects. The assumptions are in principle similar to the maximum effects for 2030 presented in Chapter 1.

In addition, CE-CEM considers labour supply as fixed in the long run, and that wage levels reflect the productivity. In the GEM-E3 model, involuntary unemployment is assumed, and positive employment effects can be obtained from this assumption.[10] In addition the energy efficiency measures are likely implemented differently. We implement the energy efficiency measures as investments, providing a reduction in energy consumption, but also accounting for the actual investment costs. It is unclear how the GEM-E3 and E3ME consider the cost side of the energy efficiency measures. Regarding the use side, CECEM, considers the energy cost savings as an increase in disposable income and allow consumers to spend the savings on other goods. It is our understanding that this was implemented similarly in the GEM-E3 and E3ME model.

[10] More specifically, GEM-E3 is based on the theory of efficiency wages. It assumes that employers set wages above market clearing in order to increase labour productivity. A higher wage would e.g. motivate a worker to increase their productivity or make it more costly to quit the job.

1. Short-run macroeconomic effects

In this chapter, we describe how energy efficiency measures affect GDP, demand and employment, as well as how large those impacts can be expected to be.

The starting point for the analysis of macroeconomic effects are 21 pre-defined actions from an energy efficiency policy running until 2030 and totalling to EUR 1,330 billion, see Table 5. The 21 actions can be grouped into the 5 sectors (1) residential buildings, (2) tertiary sector buildings, (3) passenger transport, (4) freight transport, and (5) industry.

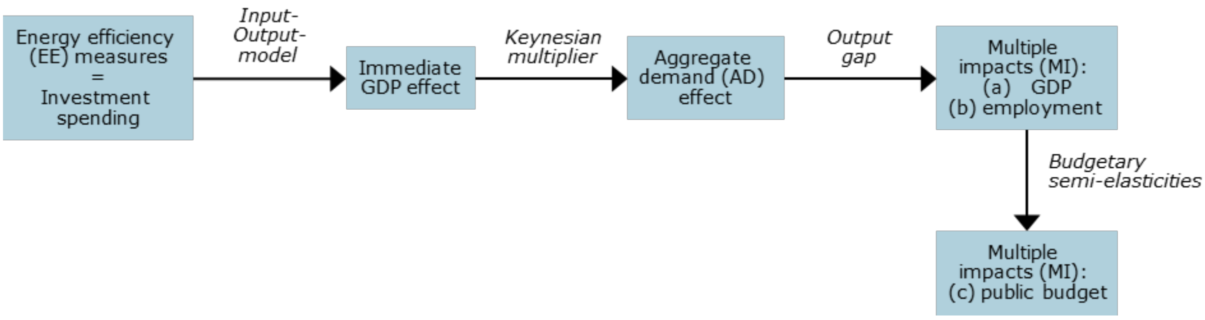
Table 3: COMBI cumulated investments for the EU-28

Sector	Action	Investments (b€)
Residential buildings	Refurbishment of building shell	302
	New dwellings	28
	Lighting	1
	Cold appliances	15
Tertiary sector buildings	Refurbishment of building shell	109
	New buildings	7
	Lighting	1
	Product cooling	2
Passenger transport	Modal shift	-
	Motorcycle	6
	Car	331
	Bus	4
Freight transport	Modal shift	-
	Light-duty truck	118
	Heavy-duty truck	140
Industry	High-temperature process heating	57
	Low- and medium-temperature process heating	64
	Process cooling	9
	Specific process electricity	5
	Motor drive	85
	Building envelope improvements in industrial buildings	45
Total		**1,330**

Note: All investments are assumed to be private investments.
Source: Copenhagen Economics based on COMBI Work Package 2

Those energy efficiency measures cause multiple impacts through a range of mechanisms, which are illustrated in Figure 7. The single steps of this chain of effects as well as the magnitude of the effects are described in detail in the sub-chapters 1.1 to 1.5, as well as in the appendices.

Figure 7: From energy efficiency measures to multiple impacts on GDP and employment



Source: Copenhagen Economics

Energy efficiency investments go hand in hand with investment spending, either public or private. The investment spending will have an immediate GDP effect. The relative magnitude of this effect depends on how many of the required resources originate from the domestic economy, and which share has to be imported; this can be modelled based on an input-output-model covering the economies of all 28 EU member states. A higher GDP means an increased income and spending, resulting again in a higher GDP. This multiplier effect – called the Keynesian multiplier – has to be added to the immediate GDP effect to obtain the aggregate demand effect. The aggregate demand effect is the total potential impact on the economy.

Importantly, this potential can only be realised if the economy has the capacity for additional output, meaning that the output gap is negative. For countries with a positive output gap, the aggregate demand effect falls flat and cannot materialise in the economy. The actual, realised effects are called multiple impacts. In this analysis, multiple impacts have been quantified for GDP and employment, as well as for the public budget. The effect on the latter is relative to the GDP impact, and is derived using budgetary semi-elasticities. Other changes, such as disposable income through energy savings, foregone energy taxes through energy savings and unemployment schemes, have not been considered in the short-run analysis. These effects can affect the results either upwards or downwards depending on the net benefit of each COMBI action.

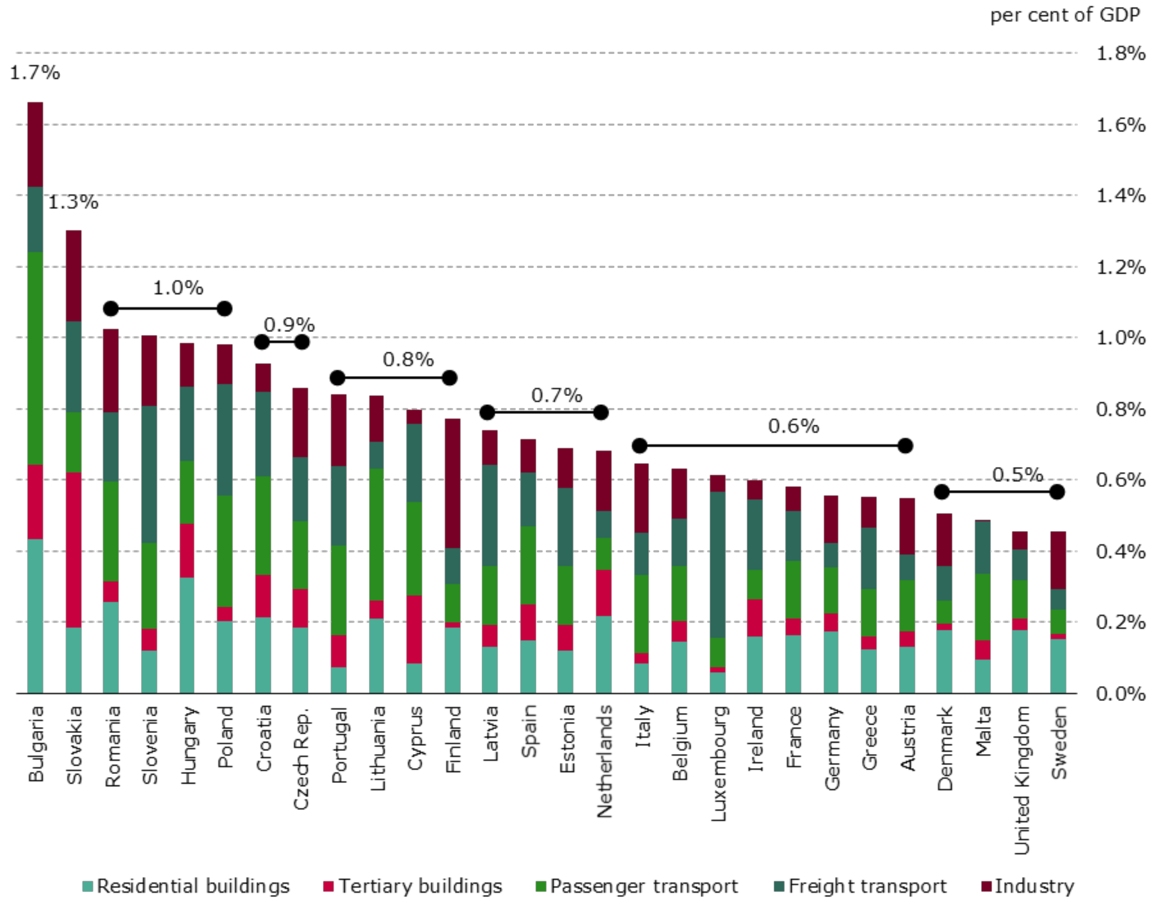
1.1 Aggregate Demand stimulus through investment spending

Implementing EEI actions goes hand in hand with investment spending, which in our analysis is assumed to be private (as opposed to public). The investment spending is the starting point of the analysis of short-run macroeconomic effects.

What drives the extent of the countries' investments is their efficiency improvement potential in each of the areas; in other words, to which extent the countries can make cost-effective energy efficiency investments. For a country with a highly energy efficient passenger transport, but a large potential for improvement in the freight transport, more investments will be undertaken in the latter area. The same line of arguments holds between countries. Belgium and Luxembourg, for example, have similar investment spending, but freight transport constitute a significant larger share of the investment spending in Luxembourg, see Figure 8.

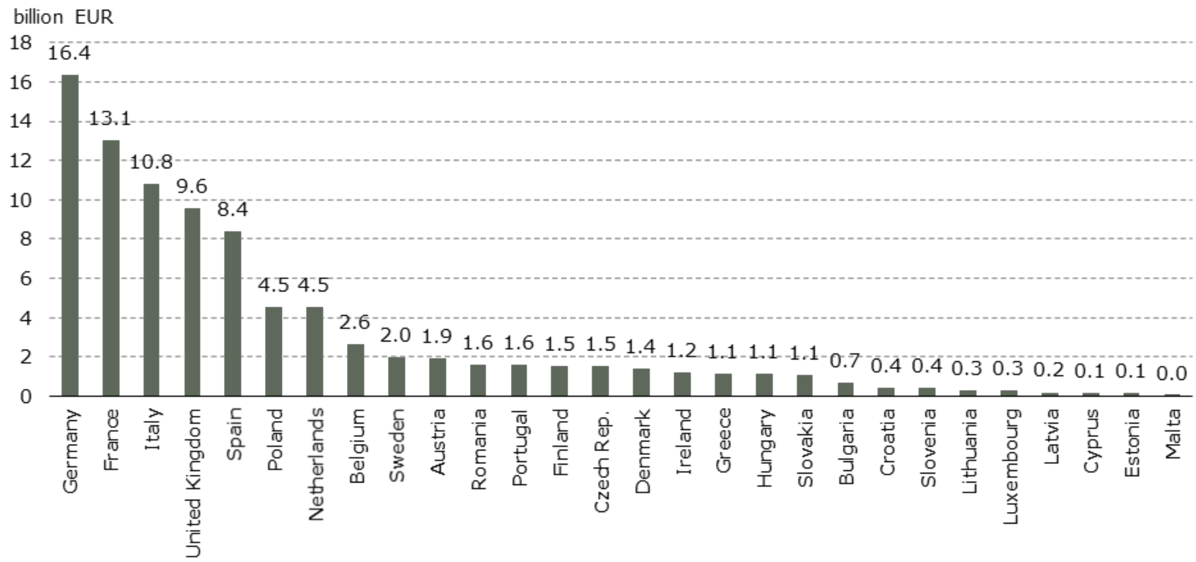
Naturally, for the total amount of investments in absolute terms (measured in billion Euros, see Figure 9), the size of the respective country's economy plays an important role, too.

Figure 8: COMBI input data on investment spending, as share of GDP



Note: COMBI investment spending in the year 2018. The data labels show the investment spending in per cent of GDP, rounded to one decimal, and are grouped for the countries with the same label.
Source: Copenhagen Economics based on COMBI Work Package 2

Figure 9: COMBI input data on investment spending, in absolute terms



Note: COMBI investment spending in the year 2018.
Source: Copenhagen Economics based on COMBI Work Package 2

The energy efficiency improvement potential varies largely across countries. Total investment spending will be lowest for Sweden with 0.5 per cent of GDP, and highest for Bulgaria with 1.7 per cent of GDP. In absolute terms, investment spending varies from 40 million EUR for the small country of Malta to 16.4 billion EUR for the big economy of Germany, which is more than 400 times as much as in Malta.

The figure shows variation both in the scope and the structure of the investments. No universal structure seems to apply in the sense which areas receive most investments; that depends on the respective country. The only tendency worth mentioning is that efficiency investments in tertiary buildings play the least important role on average.

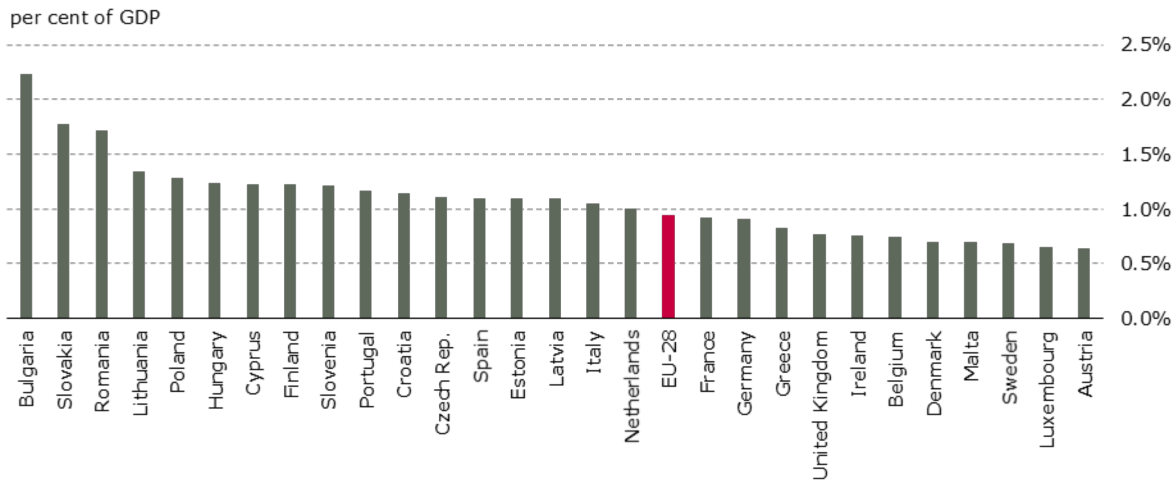
1.2 Aggregated demand effects

The investment spending in each country gives an immediate demand stimulus. The relative magnitude of this stimulus depends on how much domestic production or value added the investments will spur. In the extreme cases that all required goods and services are exclusively produced domestically, the investment value will translate fully into a demand stimulus. In the case that all necessary goods and services have to be imported, there will not be an impact on the domestic economy.

The immediate demand stimulus can be modelled using an input-output-model that covers all 28 EU member states (see appendix A.1 for details). Combining this immediate stimulus with Keynesian multiplier dynamics (see appendix A.2 for details) results in the full aggregate demand (AD) effect, which reflects the economic effect that the defined energy efficiency measures can potentially support in each country.

The aggregate demand effect in 2018 is 1.1 per cent of GDP on average, ranging between 0.6 and 2.2 per cent of GDP. It is highest for Bulgaria, Slovakia and Romania, and lowest for Austria, Luxembourg and Sweden, see Figure 10.

Figure 10: Aggregate demand boost in 2018



Source: Copenhagen Economics based on COMBI Work Package 2, Timmer et al (2015), Hervé et al (2010), Eurostat (2017)

Energy efficiency investments in residential buildings contribute most to the overall aggregate demand boost in the EU. Especially action 1, “residential refurbishment of building shell, space heating, ventilation and space cooling" drives the demand boost. It makes up 26 per cent of the total boost in the EU. The action with the second highest impact is action 11, "passenger transport car". The aggregate demand boost caused by such investments makes up 22 per cent of the total EU boost.

The EU-wide demand effect in 2030 will be of similar magnitude in absolute terms as in 2018.[11] With 0.9 per cent of GDP on average, the demand boost is lower measured relatively to the economy, but GDP in the EU will have grown by 2030. The demand effect in 2030 will be highest for Bulgaria, Portugal and Italy (1.2 – 1.4 %), and lowest for Luxembourg, Greece and Sweden (0.6 %), see Figure 11.

Figure 11: Aggregate demand boost in 2030

Source: Copenhagen Economics based on COMBI Work Package 2, Timmer et al (2015), Hervé et al (2010), Eurostat (2017)

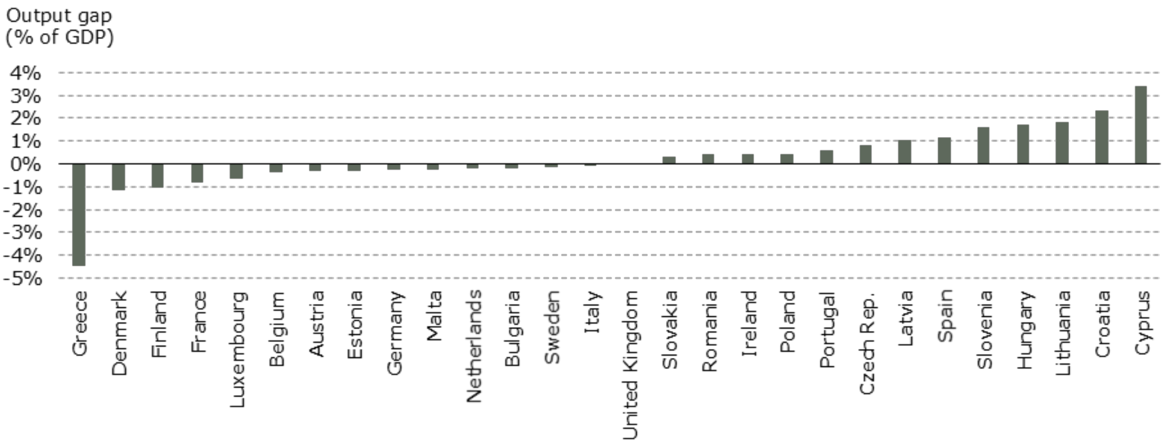
1.3 Output gaps

The aggregate demand effect is a potential effect that only materialises (in the short-run macroeconomic sense) if the economy is in a situation where the output gap is negative and to the extent that it is negative. A negative output gap means that the economy's actual output is below the potential output. A positive output gap means that the economy is overheated; the actual GDP in that situation is greater than the estimated potential, causing cost-push inflationary pressures. Resources like labour are used beyond their efficient capacity. In an economy with a positive output gap, there are no idle resources that could support further economic growth, and the potential positive GDP effect of energy efficiency measures falls flat.

Forecast indicate that only about half of the EU-28 Member States are expected to have a negative output gap in 2018, see Figure 12. Greece is expected to have the largest negative output gap (-4.5 % of GDP), followed by Denmark and Finland with significantly smaller gaps of -1.2 and -1.1 % of GDP.

[11] This calculation is based on the same input/output multipliers but a different sized investment stimulus.

Figure 12: Output gap forecasts for 2018



Source: DG ECFIN (2017) AMECO database

Output gap estimates are uncertain by nature, and become even more so the further in the future the forecasts go. Looking as far as 2030, it is very difficult to make meaningful output gap forecasts. Instead, we will consider the minimum and maximum potential if the output gap was sufficiently large. A positive output gap is the lower relevant extreme, and means that there will be no GDP effect at all. A negative output gap sufficiently large to absorb each country's full aggregate demand boost in 2030 is the upper relevant extreme. In this case, the full impact on GDP will materialise. The results showing this maximum possible effect on GDP, employment and public budget in 2030 are shown in the next section.

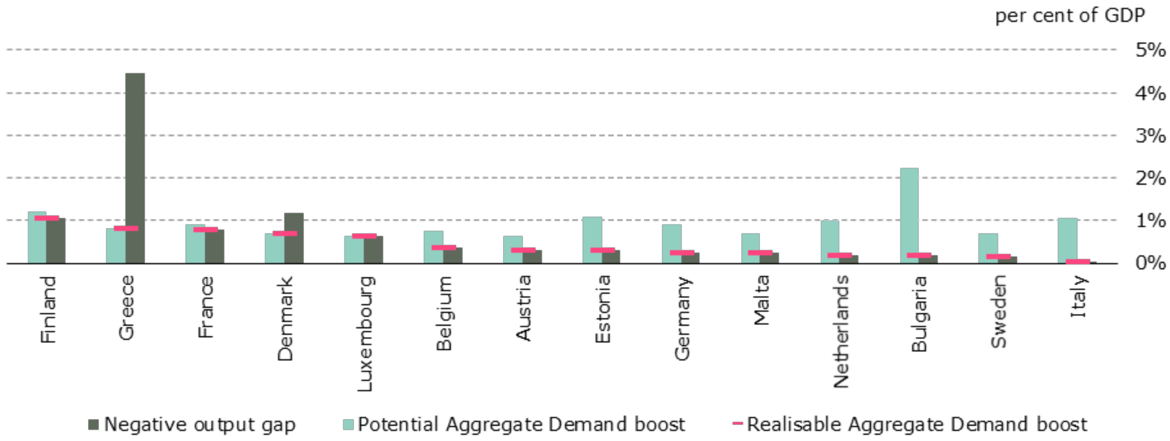
1.4 Multiple impacts on GDP and employment

The sign and magnitude of the output gap defines to which extent the aggregate demand stimulus can be realised and benefit the economy through a positive impact on GDP and employment. The realisable effects are called multiple impacts, or multiple benefits.

The countries with a positive output gap will not be able to realise any short-term benefits in terms of an increase of GDP and employment. Countries with a negative output gap will be able to realise those benefits to the extent that they "fill in" the negative gap. The magnitude of the negative gap is the upper ceiling for the realisable benefit. Once the negative output gap has been "filled", additional aggregate demand is not a benefit, as it will contribute to over-heating of the economy and to crowding out of private investments. The multiple benefit equals either to the potential aggregated demand effect, or to the magnitude of the negative output gap, whatever is smaller.

Only Greece and Denmark have a negative output gap large enough to absorb the full aggregate demand stimulus, see Figure 13. Their multiple benefit equals the aggregated demand boost. In all other countries with a negative output gap, the benefits are capped by the magnitude of the gap, meaning that only a certain share of the stimulus can be realised. In Bulgaria, the country with the largest potential aggregate demand boost of more than 2 per cent of GDP, only a small share of less than a tenth (approx. 0.2 %-points) can be realised.

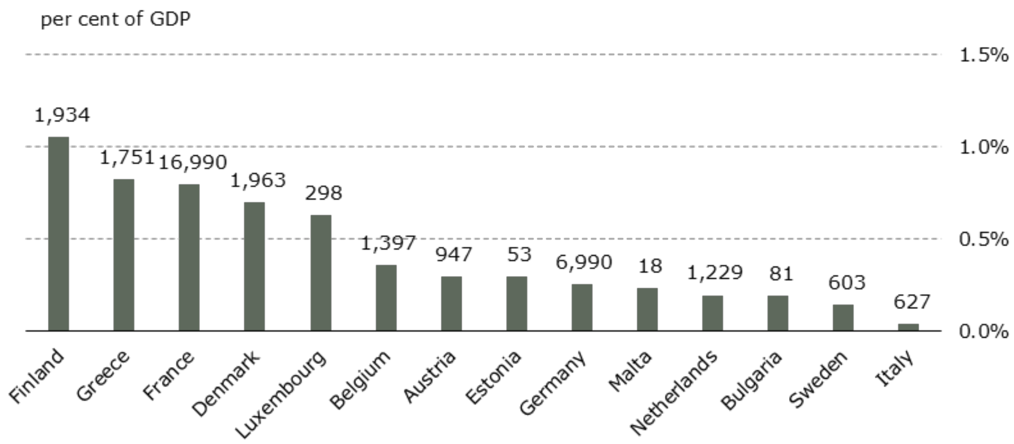
Figure 13: Output gaps restrict the benefit in most countries 2018



Note: The multiple benefit to GDP is whichever is lower of the AD boost and the (negative of the) output gap. The figure shows only countries with a negative output gap forecast for 2018.
Source: Copenhagen Economics

The multiple impact on GDP in 2018 ranges from 0.04 per cent (Italy) and 1.05 per cent (Finland) of GDP (0 for other countries). In absolute terms, the multiple benefits for the economy are largest for France (almost 17 billion EUR) and smallest for Malta (18 billion EUR), see Figure 14.

Figure 14: GDP effect in 2018



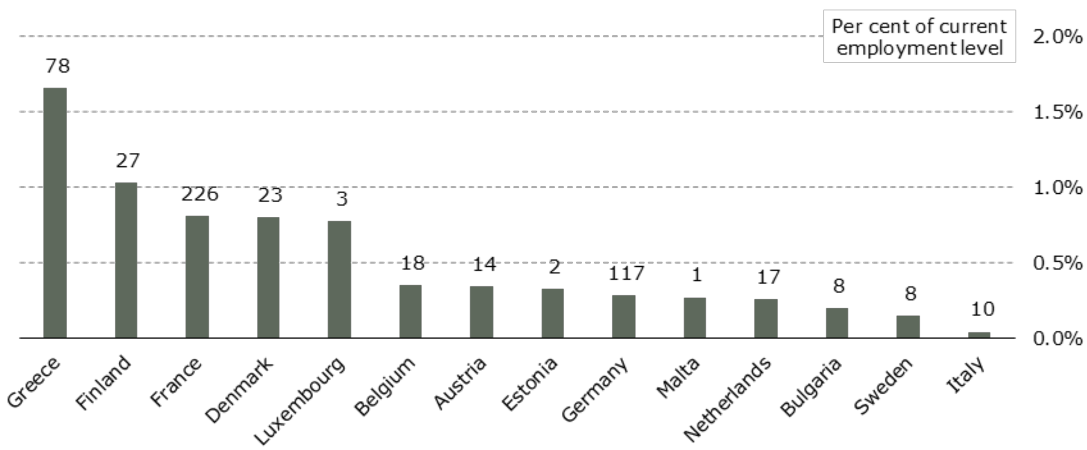
Note: The labels show the absolute level of the effect in millions of euros. The size of the columns shows the GDP effect measured in per cent of GDP.
Source: Copenhagen Economics based on IO-model and DG ECFIN (2017)

The largest drivers of the GDP effect in 2018 are the energy efficiency actions 1 (residential refurbishment of building shell, space heating, ventilation and space cooling), action 5 (non-residential refurbishment of building shell, space heating, ventilation and space cooling) and action 11 (passenger transport car). Together, those three actions account for more than half of the total GDP effect in the EU. On a sector-level, the picture is more equal. All five sectors (residential buildings, tertiary buildings, passenger transport, freight transport and industry) play a significant role for the GDP effect, each of them contributing between 11 per cent (tertiary buildings) and 29 per cent (residential buildings).

The multiple impact on employment in 2018 ranges from 0.04 per cent (Italy) to 1.66 per cent (Greece) of the current employment level, see Figure 15. As for GDP, the absolute impact on employment is largest in France, where the benefits from energy efficiency measures lead to estimated 226,000 job-years.

The magnitude of the benefits for 2018 in absolute terms for France might seem high against the backdrop of an aggregate demand boost just below EU average (Figure 10). The reason for those comparably large absolute GDP and employment benefits is twofold. Firstly, France is one of the largest economies of the EU with a high total GDP, which means that also smaller relative effects – like an aggregate demand boost of 0.9% of GDP in case of France – will entail large absolute effects. This first argument also holds for other large economies such as Germany, the UK, Italy and Spain, which all feature large aggregate demand boosts in absolute terms. The reason that the effect materialises only for France to this large extent is that here, the negative output gap is sufficiently big to absorb most of the boost, namely 90% (Figure 13). For Germany and Italy in turn, only a small part of the boost can be realised, and for the UK and Spain, the output gap is positive and does not allow for any positive multiple benefit.

Figure 15: Employment effect in 2018



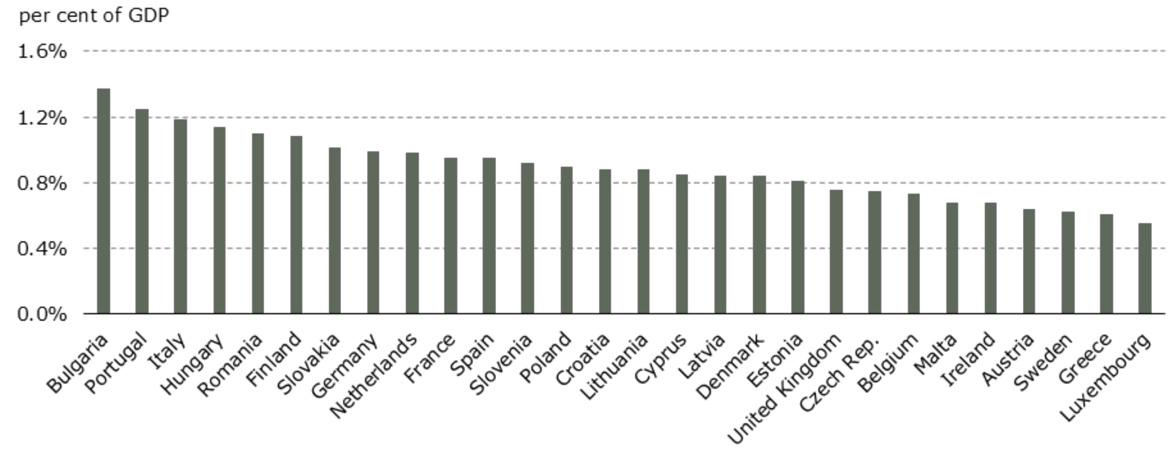
Note: Labels show the level of the effect, in 1,000 job-years in 2018.
Source: Copenhagen Economics based on IO-model and DG ECFIN (2017)

The results at the action and sector level show that most EU-wide jobs will be created in the residential buildings sector (more than 320,000 potential person-years EU-wide) as well as in the industry sector (more than 240,000 potential person-years EU-wide). The other three sectors (tertiary buildings, passenger transport and freight transport) contribute less, but still significantly to the employment effect. The potential job creation in those sectors is between 120,000 and 190,000 person-years EU-wide. Important to note, the figures are potential job-years in each of the sectors limited by the output gap of each country. The total job-years to be created will be less than the sum of those, as the totals per country will also be limited by the output gap.

As described earlier, reliable forecasts for the output gap in 2030 cannot be made. One can, however, look at the *maximum possible effect* assuming a negative output gap in each country large enough for the total boost to materialise.

The maximum GDP effect in 2030 ranges from 0.55 per cent for Luxembourg to 1.37 per cent for Bulgaria, see Figure 16. The effect in absolute terms is largest in Italy, France and Germany, where it exceeds 20 billion EUR, and smallest for the smaller economies Malta, Estonia, Cyprus, Latvia and Luxembourg, where the effect is lower than 500 million EUR. The exact estimations for the (maximum) 2030 effects can be seen in Table 4 below.

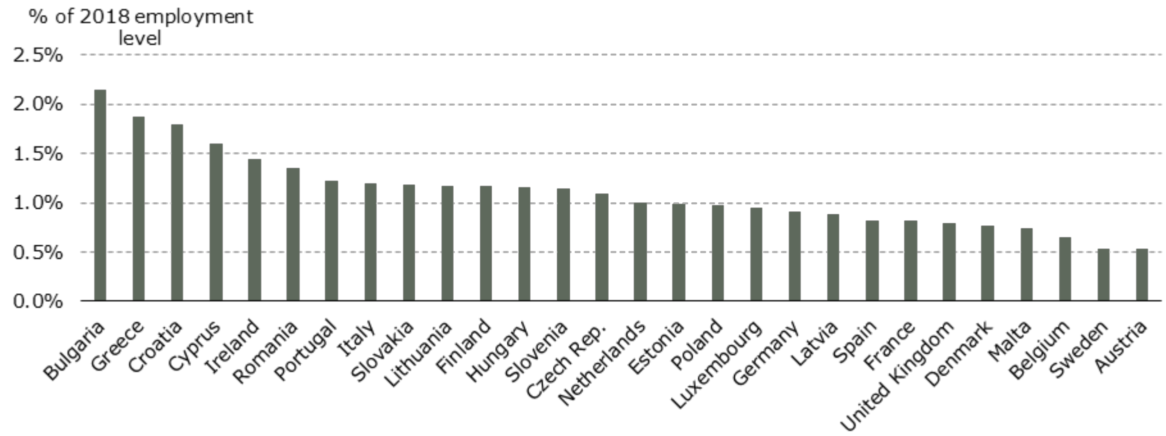
Figure 16: Maximum GDP effect in 2030



Note: Maximum potential effect, assuming an output gap able to absorb the full benefit.
Source: Copenhagen Economics based on IO-model

The maximum employment effect in 2030 assuming a sufficiently large negative output gap is expected to be smallest for Austria and Sweden with 0.53 per cent of the 2018 employment level, and largest for Bulgaria, where the effect surpasses the 2 per cent mark. The absolute effect is largest in Germany, Italy, the UK and France, where more than 200,000 person-years can be created. Detailed estimations on relative and absolute levels can be found in Table 4 below.

Figure 17: Maximum employment effect in 2030



Note: Maximum potential effect, assuming an output gap able to absorb the full benefit.
Source: Copenhagen Economics based on IO-model

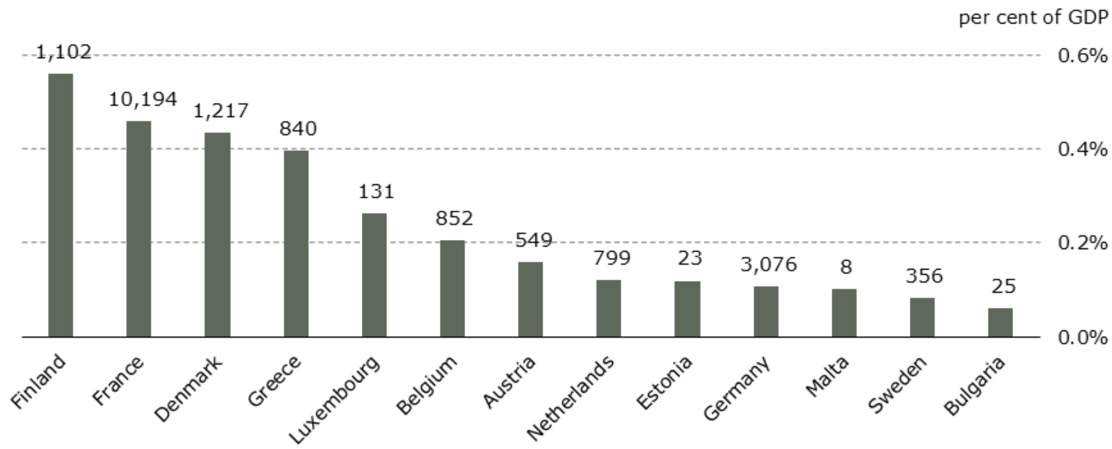
1.5 Multiple impacts on public finances

If an energy efficiency measure increases GDP, there will typically also be a positive public finance effect, unless the measure has been funded primarily through public revenue in the first place. The public revenue effect is proportional to the GDP effect and estimated through budgetary semi-elasticities (see appendix **Fehler! Verweisquelle konnte nicht gefunden werden.** for details). The intuition is that an increased economic activity will generate more tax revenue from both increased labour participation and increased consumption of taxed goods and services.

Other possible impacts on the public budget like those from expenses on social security, healthcare systems or energy tax revenues are not included in this analysis. Depending on these effects, the net effect may be smaller or larger.

The multiple impacts on the public budgets in 2018 range from 0.06 per cent (Bulgaria) to 0.56 per cent (Finland) of GDP, see Figure 18. The absolute effect is by far largest in France, where the energy efficiency measures will add more than 10 billion EUR to the public budget.

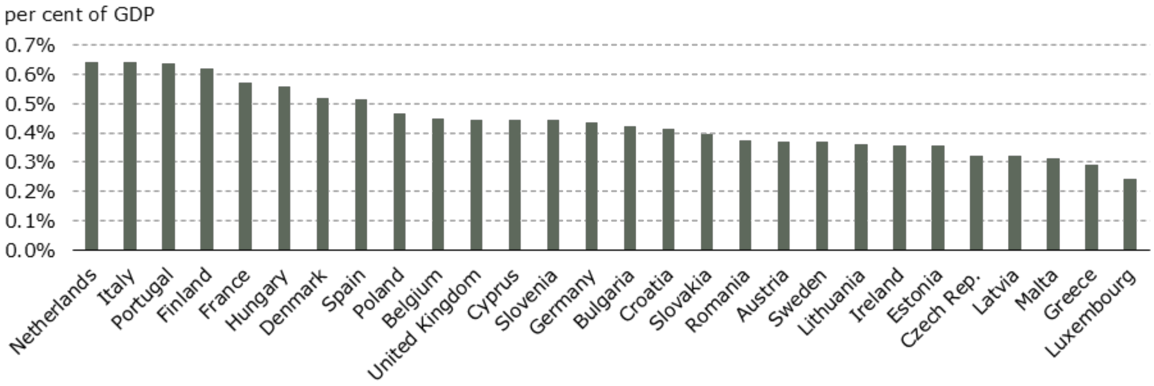
Figure 18: Public budget effect in 2018



Note: The labels show the level of the effect in millions of euros. The remaining 14 countries have positive output gap forecasts, and as such no GDP effect, and hence no public budget effect.
Source: Copenhagen Economics, based on DG ECFIN (2014)

Again, the effect in 2030 depend on the output gap at that time, which cannot be estimated reliably for a time so far in the future. The maximum public budget effects however, assuming a sufficiently negative output gap in all countries to harbour the full potential effect, can be seen below. The effect on public budget is largest in the Netherlands, Italy and Portugal with 0.64 per cent of GDP in all these countries. In Luxembourg and Greece, the maximum public budget effect is smallest, with less than 0.3 per cent of GDP, see Figure 19. The detailed estimates, both relative in per cent of GDP, and absolute in million EUR, can be found in Table 4 below.

Figure 19: Maximum public budget effect in 2030



Note: Maximum potential effect, assuming a negative output gap able to absorb the full benefit.
Source: Copenhagen Economics, based on DG ECFIN (2014)

The following table shows the maximum effects from energy efficiency measures on GDP, employment and public budget in 2030.

Table 4: Maximum effects 2030, assuming a sufficient output gap

COUNTRY	MI GDP 2030	MI GDP 2030 AS PROPORTION OF GDP	MI EMPLOYMENT 2030	MI EMPLOYMENT 2030 AS % OF 2018 EMPLOYMENT LEVEL	PUBLIC BUDGET EFFECT 2030	PUBLIC BUDGET EFFECT 2030
	m €	%	person-years	%	m €	% of GDP
AUSTRIA	2,656	0.64%	23,437	0.53%	1,541	0.4%
BELGIUM	3,707	0.73%	32,686	0.64%	2,261	0.4%
BULGARIA	1,108	1.37%	68,576	2.14%	343	0.4%
CROATIA	651	0.88%	33,308	1.79%	306	0.4%
CYPRUS	266	0.85%	6,718	1.60%	138	0.4%
CZECH REP.	2,315	0.75%	57,305	1.10%	996	0.3%
DENMARK	2,337	0.84%	22,151	0.76%	1,449	0.5%
ESTONIA	252	0.81%	6,342	0.99%	111	0.4%
FINLAND	2,854	1.09%	30,962	1.16%	1,627	0.6%
FRANCE	24,125	0.95%	240,246	0.82%	14,475	0.6%
GERMANY	31,553	0.99%	374,702	0.91%	13,883	0.4%
GREECE	2,085	0.60%	87,297	1.87%	1,001	0.3%
HUNGARY	1,677	1.14%	51,353	1.15%	822	0.6%
IRELAND	1,793	0.67%	30,755	1.44%	950	0.4%
ITALY	20,867	1.19%	303,526	1.20%	11,268	0.6%
LATVIA	324	0.84%	8,283	0.89%	123	0.3%
LITHUANIA	604	0.88%	16,147	1.17%	248	0.4%
LUXEMBOURG	384	0.55%	2,816	0.95%	169	0.2%
MALTA	68	0.68%	1,441	0.74%	31	0.3%
NETHERLANDS	7,878	0.99%	87,551	1.00%	5,121	0.6%
POLAND	7,067	0.89%	165,592	0.97%	3,675	0.5%
PORTUGAL	2,620	1.25%	59,922	1.23%	1,336	0.6%
ROMANIA	3,188	1.10%	119,008	1.36%	1,084	0.4%
SLOVAKIA	1,791	1.01%	31,865	1.18%	699	0.4%
SLOVENIA	579	0.92%	11,351	1.14%	278	0.4%
SPAIN	15,361	0.95%	185,647	0.82%	8,295	0.5%
SWEDEN	3,555	0.62%	27,674	0.53%	2,098	0.4%
UNITED KINGDOM	19,175	0.75%	256,652	0.79%	11,313	0.4%

EU-28	160,841	0.92%	2,343,312	0.98%	85,640	0.5%

Source: Copenhagen Economics

2. Structural macroeconomic effects

Implementing the energy efficiency improvements will have long-term structural effects on the EU's economy. The structural effects are primarily driven by the change in productivity in each sector. As some sectors now can produce more with fewer inputs of e.g. fossil fuel into production, they become relatively more competitive than other sectors in the EU and other countries. Other sectors become relatively less productive and will lose competitiveness.

The structural effects have been analysed with the Copenhagen Economics Climate and Energy Model (CECEM). CECEM is a multiregional computable general equilibrium (CGE) model. Unlike many other CGE models, the model has explicit, bottom-up supply functions for different technologies of electricity generation and cars (light-duty vehicles). This makes the model particularly well suited for analysing climate issues.

A CGE model considers the equilibrium effects of a policy shock. This means the model considers many feedback effects in the economy, e.g. impact of changes of disposable income through energy savings and changed energy prices. This allows consumers and companies to spend more on other goods. A more thorough description of the model can be found in the Appendix section A.4

We have created three scenarios to analyse the structural effects of energy efficiency improvements. As a reference scenario, we have used the IEA's 4-degree scenario (current policies). The IEA's 4-degree scenario (IEA 4DS) is in most regards similar to the COMBI baseline reference scenario. The major difference is that some sectors are not included in the COMBI reference scenario and different assumptions on the industry energy consumption in 2030. The COMBI reference scenario assumes a 20% increase of energy consumption in industry from 2015 to 2030, whereas IEA 4DS assumes a -5% change in industry energy consumption from 2013 to 2030.

In our energy efficiency scenarios, we have defined two scenarios:

An ambitious scenario, where the energy efficiency scenario have been analysed as efficiency improvements on top of the existing pledges. This ensures that the European Emission Allowance (EUA) prices will remain the same, leading to lower CO_2 emissions in the EU. This is the main scenario presented throughout this chapter. The scenario is similar to the COMBI energy efficiency scenario.

Additionally, we have explored the efficiency improvements as a part of the already agreed policies and pledges. This will result in lower EUA prices for other carbon emission abatement policies.

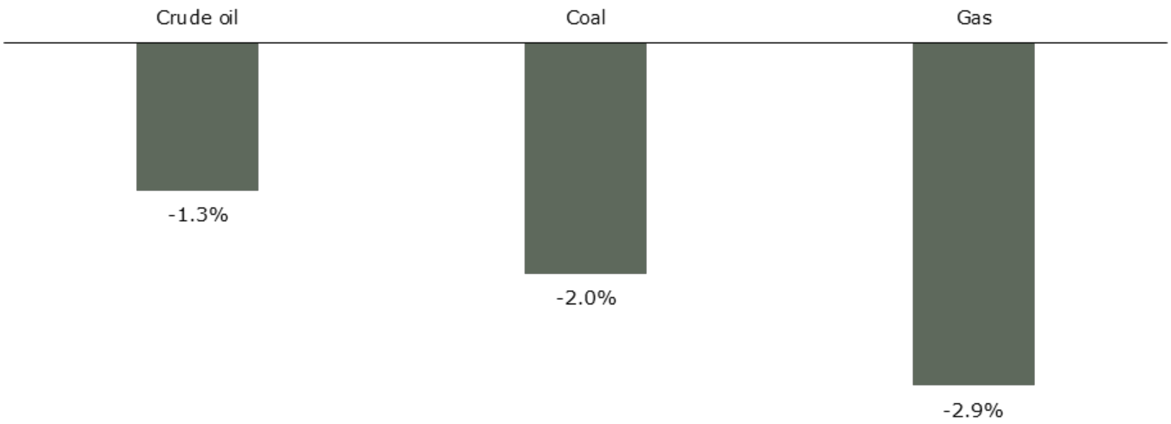
The energy efficiency presented in Table 1 are assigned to the corresponding sectors in the model and implemented as investments considering the energy savings as well as the investment costs. All initiatives are implemented simultaneously.

1.6 Fuel prices

Fuel prices are a significant component of EU production cost in both agriculture and industrial production, in transportation services, and importantly also for power and heating purposes. When the economy becomes more energy efficient, the more efficient sectors will be less exposed to fuel prices. In addition, large energy efficiency improvements in the EU can reduce local prices for energy and therefore improve the relative economic position of sectors relying on energy as input. This holds for energy consuming sectors that have not increased energy efficiency, and may also hold for the sectors that have increased energy efficiency, if the costs of doing so are lower than the energy savings achieved.

Our analysis suggest that fossil fuels prices in the EU fall by 1-3% compared to a current policies scenario. The global price on crude oil falls by 1%, while coal and gas prices in the EU is reduced by 2% and 3% respectively, see Figure 20.

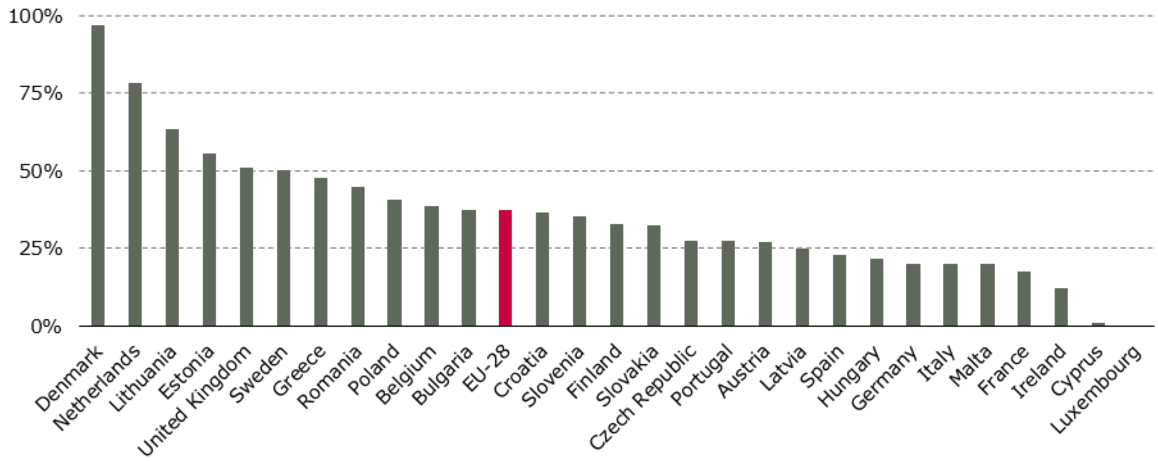
Figure 20: Fuel prices are reduced compared to the current policies scenario



Note: Fuel price changes in energy efficiency scenario, relative to the reference scenario. The oil price is a global price; for natural gas and coal, prices shown are for EU-28.
Source: Copenhagen Economics based on CECEM model.

All EU countries are net importers of fossil fuel when looking across all fossil fuel types, see Figure 21. A reduction in fossil fuels prices will be a benefit for net importers of fossil fuel. The reduction in fossil fuel prices will be most positive for countries that rely most heavily on fuel imports, such as France and Luxembourg. To countries such as Denmark and the Netherlands, which are only borderline net importers, it may be a detriment depending on the specific change in fuel prices by energy carrier and their net import of specific fossil energy carriers.

Figure 21: Export/import ratio of fossil fuels, 2015

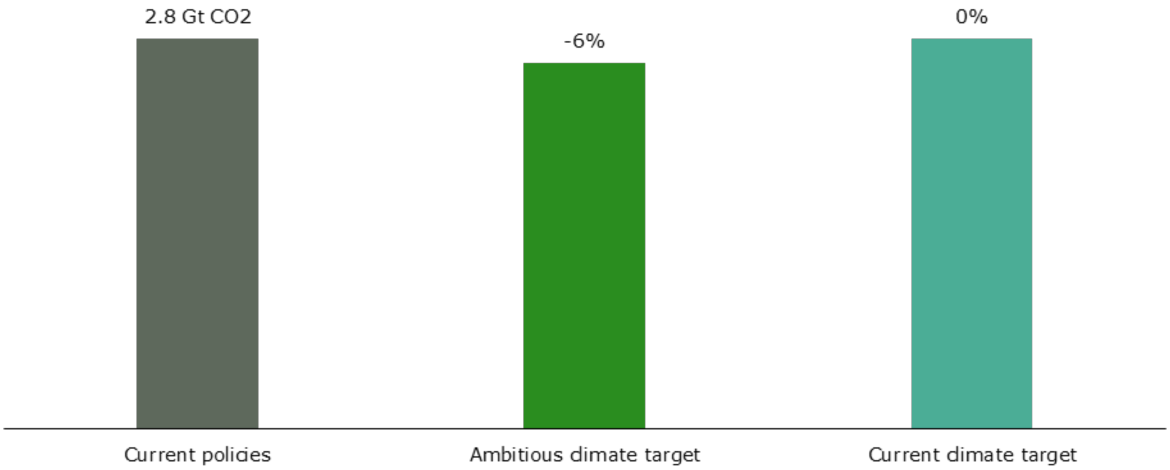


Note: Measured as sum of exports of solid fuels, petroleum products and gas divided by the sum of imports of solid fuels, petroleum products and gas. Above 100% means the country is a net exporter of fossil fuels and below 100% means the country is a net importer of fuels.
Source: Eurostat, *nrg_ 100a*.

1.7 CO_2 emissions and prices

The effect of COMBI energy efficiency actions will lead to a total fall in CO_2 emissions by 6%, see Ambitious climate target in Figure 22. The effect is a result of the direct reduction from the energy efficiency actions, as well as the dynamic effects (including rebound effects) from changed prices. This is under the assumption that the marginal cost of carbon abatement (or EUA-price) is kept at the same level as in the reference scenario (Current policies). This means the COMBI actions plus all initiatives in the Current policies scenario will be implemented in the Ambitious climate target scenario. This is unlike the Current climate target scenario, where the COMBI actions replaces other initiatives, keeping the carbon emission target to the same level as in the current policies. This scenario will redistribute production from the less energy-intensive sectors to the more energy intensive sectors. The outcome in the Current climate target scenario is thereby no different than current policies, but the carbon abatement are done through energy efficiency improvements rather than e.g. more renewable energy in the power system.

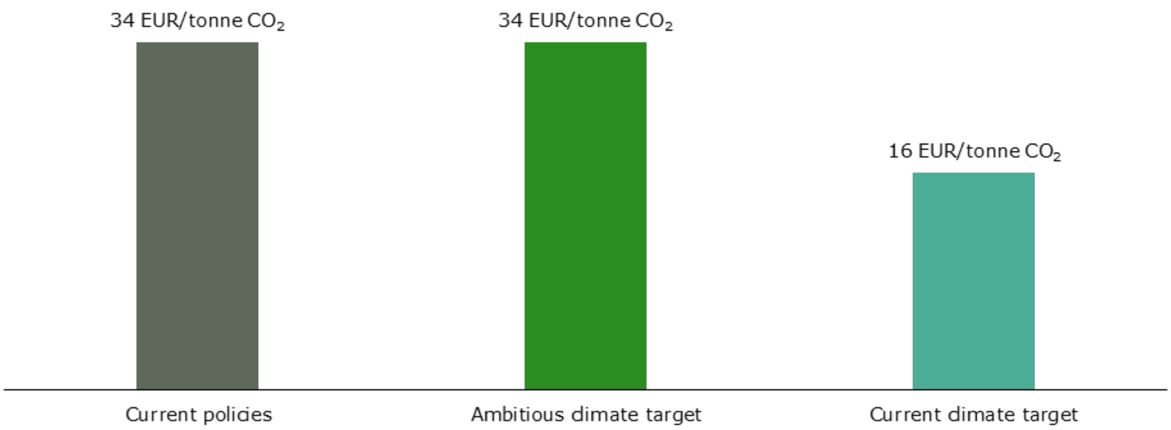
Figure 22: CO_2 emissions in EU–28 fall by 6%



Note: The current policies scenario represents the IEA four degree scenario. "Ambitious climate target" represent a scenario, where the COMBI energy efficiency savings are additional to the current policies. "Current climate target" represent a scenario, where the carbon abatement target stays the same, and the COMBI energy efficiency savings are replacing other efficiency improvements.
Source: Copenhagen Economics based on CECEM model

By introducing the Current climate target scenario, where the energy efficiency initiatives will replace current policy, there will be many other low-cost abatement possibilities that are being crowded out and are not collected. This includes, e.g., reduction of the use of coal in power production. The marginal abatement costs fall from 34 EUR/tonne CO_2 to 16 EUR/tonne CO_2, see Figure 22. This means in the Current climate target scenario, one can reduce one additional tonne of CO_2 for almost half the cost in the current policies scenario. This should motivate a more ambitious carbon abatement targets, which is presented with the Ambitious climate target scenario.

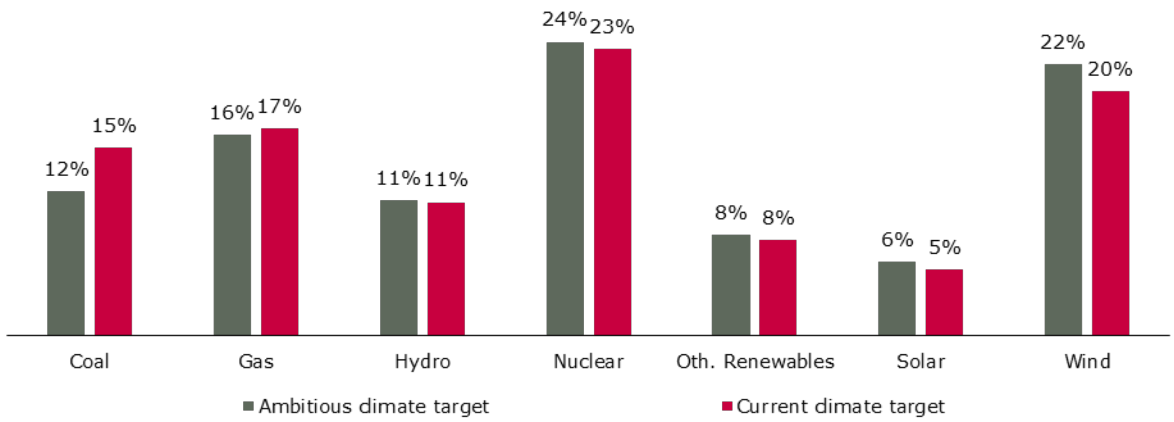
Figure 23: Marginal abatement costs of each scenario



Note: The current policies scenario represents the IEA four degree scenario. "Ambitious climate target" represent a scenario, where the COMBI energy efficiency savings are additional to the current policies. "Current climate target" represent a scenario, where the carbon abatement target stays the same, and the COMBI energy efficiency savings are replacing other efficiency improvements.
Source: Copenhagen Economics based on CECEM model

In the Ambitious climate target scenario, where the COMBI energy efficiency improvements are made on top of the existing policies, renewables are squeezing coal out of the power generation mix, see Figure 24. However, in the less ambitious Current climate target scenario, the lower marginal abatement cost (and thereby EUA price) will make coal more cost efficient compared to the ambitious scenario, and coal will remain in the power generation mix.

Figure 24: Energy efficiency measures under fixed GHG cap leads to increased coal use in electricity production



Note: Generation mix in EU–28 under the two energy efficiency scenarios.
Source: Copenhagen Economics based on CECEM model

1.8 Structural change and competitiveness

Seen from an economic perspective, an energy efficiency improvement represents an investment in an asset that can reduce costs going forward (the energy savings).[12] For some investments, the value of the energy savings will be higher or equal to the costs, and for others the costs will be higher. From a climate economic perspective, such additional cost should not be much higher than alternative mitigation technologies (unless additional multiple benefits exist). In addition, the effect might differ within the EU, with some countries benefitting more than others.

If the EU pursues a large-scale energy efficiency programme, this will lead to significant structural changes in the economy. The sectors where the energy efficiency improvements are relatively more cost-effective will increase their competitiveness compared to other sectors. We find that most sectors will decrease their output. The sectors which will lose out the most are transport services (freight transport) and services (tertiary sectors) where output is expected to decrease by 0.7% and 0.6% respectively, see Figure 25. The energy efficiency investments in industries are more cost efficient but will still result in a decrease in output.

[12] Adding to this is of course corresponding reductions in greenhouse gas emissions.

Figure 25: Changes in output by sector

Note: Industry include several sectors, including e.g. chemicals and metals production.
Source: Copenhagen Economics based on CECEM model

1.9 Employment and GDP

Employment will not be affected in the long run. The energy efficiency improvement will increase demand for labour, which will increase employment in the short-run. In the longer run however, the labour force and structural unemployment (the unemployment present in a regular business cycle) stay fixed. This means the business will raise the wages to attract employees. However, since the supply of labour is fixed, if the wages are increasing in one sector, it can only attract labour from other sectors.[13]

In the CECEM modelling, EU's GDP in the ambitious energy efficiency scenario will decrease by 0.4%. The negative effect on GDP is larger in the ambitious energy efficiency scenario, where carbon is abated until the marginal abatement cost is equal to the current policies scenario. In the scenario where the abatement target is kept at the current level, the Current climate target, GDP is reduced by 0.2%. The changes in GDP are due to replacement of energy as input in production with e.g. capital goods and other processes. In addition to the effect on productivity and GDP, there are other benefits related to, e.g., improved health conditions. The effect of improved health conditions on productivity and GDP is quantified in other WPs of the COMBI project and will not be studied here.

1.10 Comparison to the Commission's impact assessment

In parallel to our work, the Commission undertook an impact assessment behind its revised energy efficiency directive (EC 2016). The results of its analysis differ from our findings on a few accounts, in particular regarding employment effects. The study used a CGE model (GEM-E3) as well as a macro-econometric model (E3ME), to analyse the long-run impact. Both models show positive impact on GDP and employment in 2030 (except for one scenario). The E3ME model shows an increase in employment of 0.17%, whereas the GEM-E3 model varies from positive

[13] Immigration is considered fixed as wages are expected to have a negligible effect on the immigration level.

0.20% to -0.18% whether the investments are loan-based or self-financed. GDP is increasing by 0.39% in the E3ME model and varies from +0.26% to -0.22% for the GEM-E3 model.

Table 5: Comparison of long-run effects to the EU EED Impact Assessment

	GDP	Employment
Copenhagen Economics – Global Climate and Energy model (CE-CEM) *(Ambitious climate target)*	-0.40%	-
Copenhagen Economics – Global Climate and Energy model (CE-CEM) *(Current climate target)*	-0.23%	-
GEM-E3 (self-financing)	-0.22%	-0.18%
GEM-E3 (loan-based)	+0.26%	+0.20%
E3ME	+0.39%	+0.17%

Note: The numbers presented here are based on the EUCO30 scenario of the EU Commission's EED Impact Assessment, which is used as a comparison to COMBI.
Source: European Commission (2016), EED Impact Assessment

The differences can be ascribed to several drivers, such as differences in scenarios (including baseline scenario) and differences in modelling assumptions. The CECEM model uses the traditional way of modelling long-run effects where the economy is initially in an equilibrium with no output gap or idle resources. The GEM-E3 and the E3ME models uses an assumption of idle resources for its long-run impacts, which can create positive GDP effects. The assumptions are in principle similar to the maximum effects for 2030 presented in Chapter 1.

In addition, CECEM considers labour supply as fixed in the long run, and that wage levels reflect the productivity. In the GEM-E3 model, involuntary unemployment is assumed, and positive employment effects can be obtained from this assumption.[14] In addition the energy efficiency actions are likely implemented differently. We implement the energy efficiency improvement actions as investments, providing a reduction in energy consumption, but also accounting for the actual investment costs. It is unclear how the GEM-E3 and E3ME considers the cost side of the energy efficiency actions.

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[14] More specifically, GEM-E3 is based on the theory of efficiency wages. It assumes that employers set wages above market clearing in order to increase labour productivity. A higher wage would e.g. motivate a worker to increase their productivity or make it more costly to quit the job.

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3. Appendix: Methodology

This appendix describes the methodology used throughout the report.

A.1 Input-Output (IO) modelling

The use of an input-output (IO) model enables us to estimate to which extent the investment spending due to EEI actions translates into an immediate (domestic) demand stimulus.

An input-output model is a quantitative economic technique that accounts for the interdependencies between different industries of a national economy or different regional economies. The model depicts how output from one industry may become an input to another industry. Because of the underlying assumptions of the model (see below) the results calculated by this method should be regarded as approximations.

The IO model is based on the input-output table, which is a snapshot of all transactions in an economy within a given time period. Column entries in the table typically represent inputs to an industry (the industry's purchases of goods and services), while row entries represent outputs from a given industry. This format therefore shows how dependent each industry is on every other industry, both as a customer of outputs from other industries and as a supplier of inputs.

Modelling the immediate demand stimulus caused by the investment spending involves three steps: *Firstly*, each of the 21 energy efficiency actions is matched to one of the 35 industries in the model (IO-Table). For example, "Non-residential new buildings" (Action 6) is matched to "construction" (industry I-18). *Secondly*, the investment spending calculated for each action is entered as an increase in output in each of the respective (matched) industries. *Thirdly*, the impact on each of the other industries of the economy is modelled based on the underlying input-output-relations of the table.

The input-output tables we use in the study are from the World Input-Output Database (WIOD), which provides comparable input-output tables for most of the countries in the world – including the 28 EU Member States. The table comprises 35 industries, which allows for a relatively high degree of detail in the analysis.

As every model, the IO model is a simplification of reality and is based on several assumptions. Those assumptions include:

1. No supply-side constraints (prices are fixed)
2. Technology is the same for all firms in each industry
3. Fixed ratios for inputs and production
4. Fixed consumption shares
5. No increase in activity from investments
6. No time dimension
7. The structure of the economy remains unchained

A.2 Keynesian multiplier dynamics

The immediate stimulus calculated with the IO model will entail a so-called aggregate demand (AD) effect in the country's economy. The AD effect is calculated by multiplying the immediate stimulus with the Keynesian multiplier.

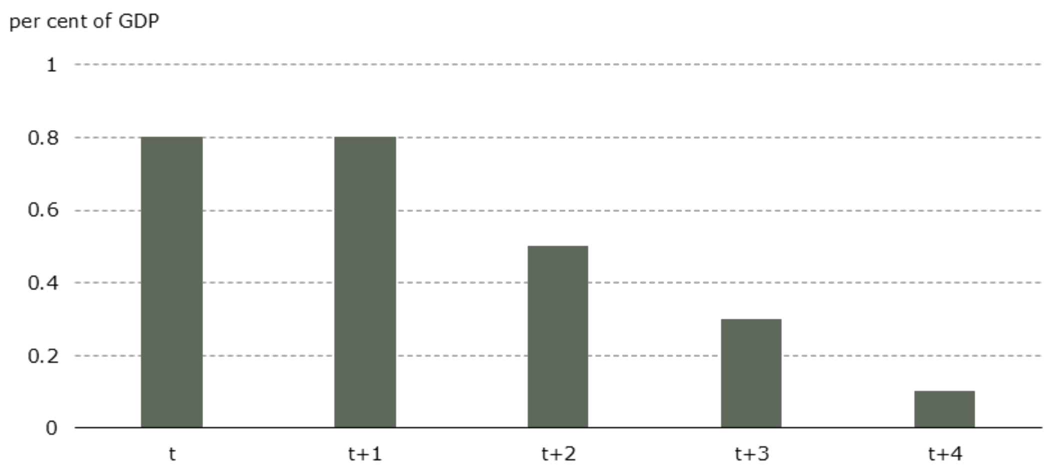
The Keynesian multiplier describes the dynamics initiated by (government) spending. The (exogenous shift in) spending will entail increased production and employment; the rise in total wages leads to increased demand, which in turn entails increased production and employment, and so on and so forth. A Keynesian multiplier of 0.8% means that a shift in spending by 1% of GDP will lead to an aggregate demand (AD) increase of 0.8% of GDP. For a Keynesian multiplier <1, the AD effect will be smaller than the initial stimulus, while it will be larger for a multiplier >1.

The magnitude of the Keynesian multiplier depends mainly on

- the population's propensity of consumption – the more people spend of their income as compared to savings, the larger the multiplier
- the share of domestic production and employment – the larger the share of domestic as compared to foreign production and employment the shift in spending and demand spurs, the larger the multiplier.

We apply the Keynesian multipliers used in the OECDs new global macroeconomic model from 2010, which are 0.8% for the year of the shift in spending and the year after, decreasing to 0.1% in t-4.

Figure 26: Keynesian multipliers in Europe



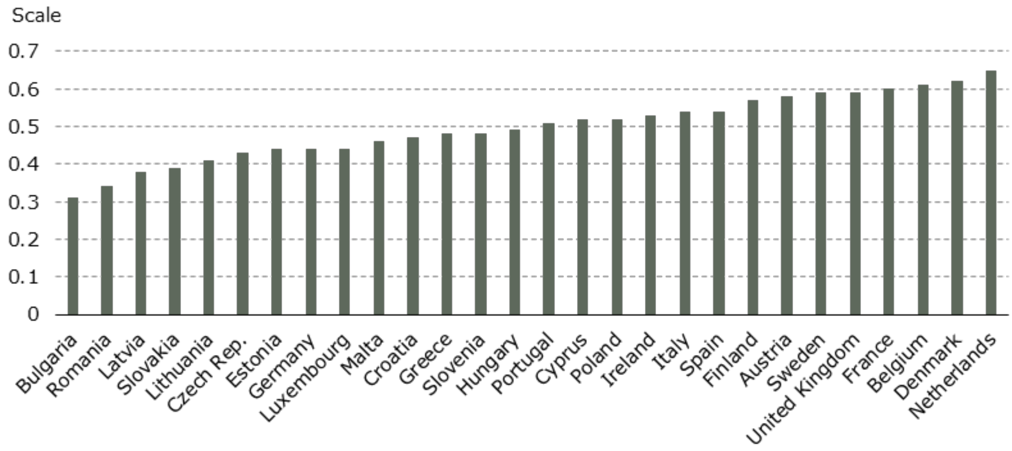
Note: The unit is % of GDP following a 1% of GDP shift in spending
Source: Hervé et al (2010) The OECDs new global model

A.3 Budgetary semi-elasticities

Budgetary semi-elasticities indicate to what extent an increase in GDP will entail an increase in the public budget. A budgetary semi-elasticity of 0.5 for example means that an increase in GDP by 1% leads to an increase in the public budget by 0.5% of GDP.

The budgetary semi-elasticities applied in this study follow DG ECFIN's estimations from 2014 and vary between 0.31 (Bulgaria) and 0.65 (Netherlands).

Figure 27: Budgetary semi-elasticities 2014



Source: DG ECFIN (2014) Adjusting the budget balance for the business cycle: the EU methodology. Economic Papers 536, by Gilles Mourre, Caterina Astarita and Savina Princen

A.4 Copenhagen Economics Global Climate and Energy model, technical description

The Copenhagen Economics Global Climate and Energy model (CECEM) is a multisector and multiregional CGE model with bilateral trade flows, taxes and carbon accounting. The base model is a static general equilibrium models calibrated for the year 2030. The model is based on the GTAP model and database, and features the entire world. Each country is featured with input/output-tables describing sectoral supply and demand consistent with trade flows. The model presented here is built based on the GTAP model, though some features such as the banking sector and consumer preferences are modelled differently.[15]

The model features bottom-up technologies for transportation and electricity generation. It also features a combination of Armington and Heckscher-Ohlin trade formulation for select manufacturing sectors. Aside from accounting carbon emissions by sector, the model is particularly well suited to analyse impacts on carbon leakage and effects of different global climate policies (e.g. emission allowance trading schemes). The model is written in GAMS/MPSGE and solved with the PATH solver (Dirkse and Ferris 1995).

The version used in this report features 16 regions and 16 industries. Table 6 below shows current regional and sectoral aggregation.

Table 6: Regions and sectors in the CECEM model

Regions	Sectors
EU-28	Agriculture and animal products
United States of America	Food products
Canada	Natural gas
China	Electricity and heat

[15] See Lanz and Rutherford (2016) for a more thorough documentation of the base model.

Regions	Sectors
Russia	Refined oil
Japan	Crude oil
Australia and New Zealand	Solid fuels
Brazil	Minerals
Eastern Europe and EFTA	Chemical products
India	Ferrous and non-ferrous metals
Mexico	Other energy intensive goods
Higher Income East Asia and Dynamic Asian Economies	Transport equipment
Africa	All other goods
Latin America	Transport services (freight)
Middle East	Transport services (private)
Rest of the world	Other market and non-market services

Note: In addition to the depicted sectors, there are also four sectors producing private consumption goods, government consumption goods and investment goods.
Source: Copenhagen Economics

The private transportation services are demanded by the private consumer and features four different technologies of which two are active in the baseline.[16] Each transport technology is in perfect competition with other transport technologies.

The electricity generation is in demand from all sectors as well as private consumption. The model features ten active technologies of which eight are active in the baseline.[17] As with the private transportation, the electricity generation technologies are in perfect competition with other electricity generation technologies. As with the transportation technologies, electricity is produced by a mix of inputs consisting of capital, fossil fuels (emitting CO_2) and existing capacity.

A.4.1 Economic flows

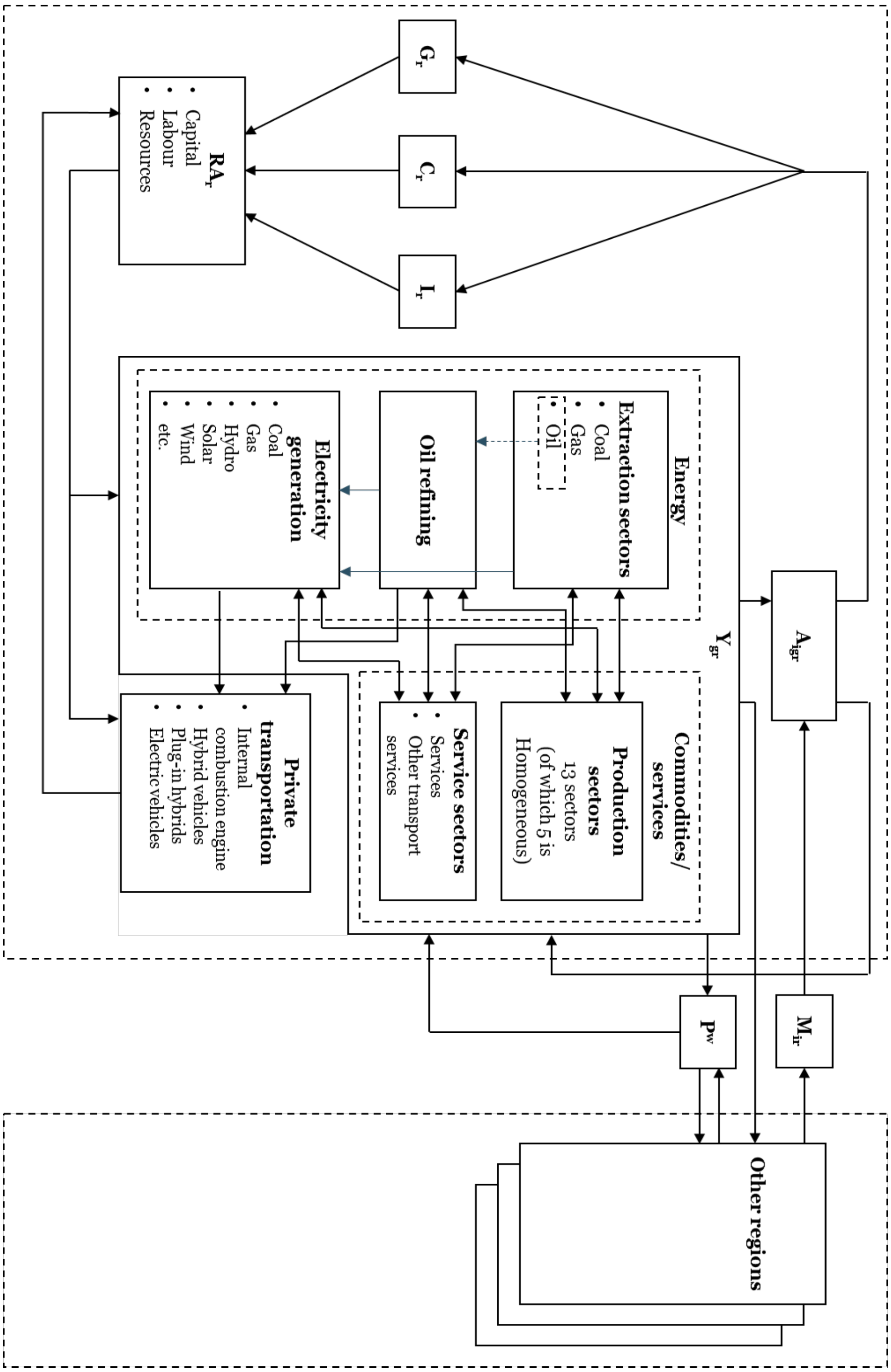
Figure 28 below shows the economic flows in the model. In this illustration, taxes, subsidies, tariffs etc. are not shown in an effort to try to focus on the overall flows.

Each country has a representative agent that has an initial endowment of labour, capital and resources. The agents sell their endowment to the production sectors. Each production sector produces one type of good from intermediate input and value-added (labour, capital and resources). The output of the production is either exported to other countries or sold on the domestic market. The Heckscher-Ohlin sectors export to the world market, which only features one price. The domestic and foreign market creates the total market supply faced by all sectors. The market supply is demanded by the production sectors and the “conversion” sectors. The conversion sectors are the three sectors that produce government goods, investment goods and consumption goods. These goods are demanded by the representative agent, who pays for the goods with their endowment.

16 Internal combustion engine, Hybrid electric vehicle, Plug-in hybrid vehicle and Electric vehicles.

17 Coal, Oil, Natural gas, Nuclear power, Hydroelectric power, Other renewables, Wind, Solar, Coal CCS and Natural gas CCS.

Figure 28: Economic flows in the model



Note: Taxes, subsidies and tariffs are not shown. G: Public consumption, I: Investment consumption, C: Private consumption, RA: Representative agent, A: Armington aggregate, Y: Production, M: Imports, P^w: World price

Source: Copenhagen Economics