European Climate Foundation

# Decarbonising European transport and heating fuels - Is the EU ETS the right tool?

Final Report

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# Summary for policymakers

- The European Commission is considering including transport and (residential & commercial) buildings in the ETS as a means of accelerating emissions reductions in these sectors.
- In this study, we have explored two possible approaches to doing that through the application of bottom-up technology and a macroeconomic model: (1) through the imposition of a linked carbon price in the transport and buildings sectors that is set at a level equivalent to the ETS allowance price, and (2) directly including these sectors in an extended ETS alongside existing ETS sectors.
- Our analysis finds that inclusion within the ETS, through either method explored, would not deliver emissions reductions in buildings & transport in line with the overall aims of the ETS.
- In addition, because the buildings and transport sectors are relatively unresponsive to the carbon price, under a single extended ETS cap companies in the existing ETS sectors would have to do more to compensate, and would need to achieve an additional 250 MT of carbon reductions by 2030, and an extra 315 MT of carbon reductions by 2040. This would lead to a loss of competitiveness in these sectors, and therefore small reductions in output and employment.
- Widening the single ETS cap to include transport and buildings would push up average spending on gas-fuelled household heating by 30% and increase the cost of fuelling a fossil fuel vehicle by 16% in 2030, before taking into account reductions in demand as a result of higher prices.
- At the same time, low-income households, which are most financially constrained, are likely to be hardest hit by a single extended EU ETS, with little scope to invest in new technologies and little discretionary spending on heating and transport that can be cut without affecting their quality of life.
- We conclude that the inclusion of transport and buildings within the ETS would not achieve the desired policy goal and would simultaneously create additional challenges both to consumers and to current ETS sectors.

# 1 Background

## 1.1 The policy context

The European Commission describes the EU Emissions Trading System (EU ETS) as the "*cornerstone of the EU's policy to combat climate change and its key tool for reducing greenhouse gas emissions cost-effectively*"[1].

The EU ETS is a carbon cap and trade system, under which the Commission issues emission allowances, which economic operators in certain sectors must surrender at the end of each year to cover their emissions or face substantial fines. There is a cap on the number of allowances issued each year, which declines year on year; the aim is therefore to reduce the total emissions allowed over time.

The EU ETS currently covers operators in power and heat generation, energy intensive industries, and (at least until the end of 2023) intra-EU aviation, and covers emissions of carbon dioxide (CO2), nitrous oxide (N2) and perfluorocarbons (PFCs).

After her confirmation as president-elect of the European Commission, Ursula von der Leyen outlined her desire to expand the coverage of the EU ETS; to include aviation (in a more complete fashion) and shipping, and potentially also to include road transport and construction (by which it is assumed she is referring to space heating of buildings). The European Green Deal also explicitly states that "it will consider applying European emissions trading to road transport". The aim of such a policy would be to accelerate emissions reductions in these sectors.

Expanding the coverage of the ETS to cover road transport and buildings would entail a major restructuring of the EU ETS, and there is an existing body of evidence, including previous work by Cambridge Econometrics for the European Climate Foundation[2], which suggests that such a policy may be an ineffective way of reducing emissions in these sectors, due to the degree of 'lock-in' (i.e. that vehicles, once they enter the stock, remain there for a long period of time) and the relatively low price elasticity of transport demand (i.e. that demand for road transport is not very responsive to price changes).

## 1.2 The aims of the analysis

In this study, we aim to explore the potential impacts of an extended ETS, through the application of a macroeconomic model, E3ME, and other quantitative analysis.

This study seeks to explore three primary research questions;

- How responsive are the road transport and buildings sectors to a carbon price?

[1] https://ec.europa.eu/clima/policies/ets_en

[2] The Impact of Including the Road Transport Sector in the EU ETS, 2014
https://europeanclimate.org/the-impact-of-including-the-road-transport-sector-in-the-ets/

- In a single unified EU ETS including these sectors, what is the impact on allowance prices, and where across the ETS sectors are the emissions reductions realised?
- What are the economic and distributional impacts of including these sectors in the EU ETS?

These questions will be explored through the construction of example ETS design scenarios, and the implementation of these scenarios in a macroeconomic modelling framework. Through the macroeconomic model, we are able to assess the price elasticity of emissions from the road transport, heating and current EU ETS sectors, taking into account both short-term demand effects and long-term technology substitution effects, and how these play out against each other in a unified EU ETS, including implications for household energy bills.

## 1.3 The structure of this report

In Chapter 2, we outline the way the analysis was carried out, including a brief description of the key analytical tools. In Chapters 3 and 4 respectively we set out the environmental and economic impacts of the scenario modelling, and in chapter 5 we set out a series of conclusions from the analysis.

# 2 The analytical approach

## 2.1 The requirements

The key topics assessed in this analysis were;

- The responsiveness of sectors (including road transport and buildings) to a carbon price
- The change in the EU ETS allowance prices that results from expanding the scope of the system
- The socioeconomic and distributional impacts of the introduction of additional carbon costs in the existing ETS, road transport and buildings sectors.

This requires two different quantitative approaches, which are set out in more detail below. The bulk of the analysis uses E3ME, a macroeconomic model, to assess the responsiveness of sectors, the ETS allowance prices required to meet certain emissions targets, and the socioeconomic impacts of this policy. After this analysis has been conducted, off-model analysis uses historical data on consumer expenditure by income decile to examine in more detail the potential distributional impacts of policy.

## 2.2 Designing the scenarios to be modelled

To assess the research questions posed in Chapter 1, we designed two stylised scenarios, and implemented them on top of the model baseline. Below we briefly describe key decisions made in the design of the scenarios, how the three sets of outcomes are implemented, and the implications of our approach.

**Emission reduction targets under the EU ETS out to 2050**

The first element of the scenarios that was decided was the level of ambition of the EU ETS. The EU ETS has a stated target for 2030 of emissions 43% below 2005 levels[3]; for the period beyond 2030, a linear reduction factor of 2.2% (in fact in place from 2021) is current policy, which implies a zero cap (i.e. no emissions in ETS sectors) in 2058. This is substantially more ambitious than the emissions projections in the PRIMES 2016 Reference case, where the current ETS sectors reduce emissions by 37% in 2030, and 63% in 2050.

In the scenarios outlined below, we have chosen to use a mix of the official policy and the PRIMES 2016 Reference scenario; specifically, we target a 43% reduction in ETS emissions in 2030 (in line with the 2030 climate & energy framework) compared to 2005 levels, and a 63% reduction in ETS sectors in 2050 (i.e. aligning with the PRIMES scenario). The reasoning behind adopting a 2050 target that is less ambitious than the official policy is that in this analysis, we are seeking to introduce a single policy (a carbon price/extended ETS), and observe the different sectoral responses to that single policy. Meeting a more stringent emissions reduction target (e.g. 80-90% reduction in 2050) would require additional policy support in addition to the ETS and introducing these complicates the interpretation of the analysis.

[3] https://ec.europa.eu/clima/policies/ets_en

The scenarios described below all use the same ETS emissions reduction target, as summarised in Table 2.1. The major difference between them is the scope of that ETS.

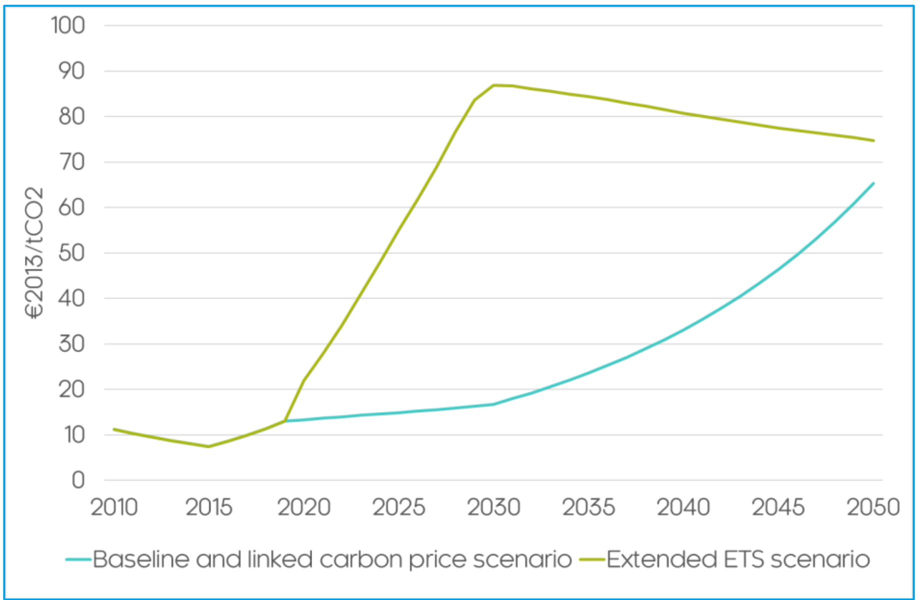
**Table 2.1 Emissions reductions achieved in ETS sectors in the scenarios**

| Scenario | Emissions reductions in ETS sectors in 2030 (%, compared to 2005) | Emissions reductions in ETS sectors in 2050 (%, compared to 2005) |
|---|---|---|
| Baseline | -43% | -63% |
| Linked carbon price in transport and buildings | -43% | -63% |
| Extended ETS | -43% | -63% |

It is clear that a more stringent 2030 and 2050 emissions targets would require a higher ETS price, and additional supporting policy, to be delivered. The scenarios described below (and the results presented in subsequent chapters) should therefore be interpreted as illustrative scenarios which explore the relative responsiveness of sectors, rather than definitive policy scenarios.

Within the modelling framework, these targets are used to calculate EU ETS allowance prices that are required to cover the emissions reduction required in the relevant sectors. The resultant ETS allowance price is a function of the responsiveness of emissions from each sector to changes in costs; so, the inclusion of less responsive sectors would, inter alia, be expected to lead to higher allowance prices. The resultant allowance prices are shown in Figure 2.1 below.

**Figure 2.1 ETS allowance prices used in the analysis**




In the baseline, the ETS allowance price rises steadily in real terms over time, as more expensive abatement measures are required in existing ETS sectors to meet the allowance cap. However, under a single extended ETS cap, a much higher allowance price is required in the short term to drive sufficient emissions reductions to meet the 2030 target across the extended range of sectors – in particularly, to encourage a more rapid take-up of low-carbon technologies in the road transport and buildings sectors. Once the 2030 target is achieved, further abatement can be delivered (most notably in the road transport and buildings sectors, through steady turnover of the stock) without a further increase in the allowance price. The price therefore falls slightly in real terms (although in nominal terms it increases slowly).

### The model baseline

The starting point for our analysis is the PRIMES 2016 Reference case. This scenario, prepared for the European Commission, has extensive detail in the public domain, and is therefore a suitable baseline from which to assess the impacts of ETS policy. More recent baselines (for example, that used in the European Commission's Long Term Strategy[4]) do not have sufficient detail available in the public domain for the relevant alignment of E3ME to be conducted.

However, there is a major caveat to the use of this baseline; being published in 2016, it has an outdated set of policies. For example, it does *not* include the 2030 climate & energy framework, nor reflect more recent policy regarding carbon neutrality in 2050. This is most relevant to the level of emissions reduction that occurs in the current ETS sectors, and those sectors (road transport and heating) which are being considered for inclusion in the ETS. To address this, we compared the decarbonisation achieved in the baseline in current ETS sectors, transport and buildings to other existing studies[5], and adjusted the trajectory in the baseline to ensure broad consistency with existing views.

A second important caveat is that, even when the baseline is aligned to the published PRIMES 2016 Reference case, the difference in model structures, and the way that the model is parameterized (i.e. how model relationships are quantified) leads to different levels of sensitivity to policy. Most notably, the introduction of a higher ETS price in E3ME, aligned to the PRIMES 2016 Reference case, will show different impacts to the same higher price introduced into the PRIMES model.

### Scenario 1 – a linked carbon price introduced into the road transport and building sectors

In the first scenario assessed, we took baseline projections of ETS allowance prices, i.e. the allowance price required to limit emissions in current ETS sectors to the 2030 and 2050 targets outlined in Table 2.1, and introduced them as a carbon price in the road transport and buildings sector.

The aim of such a scenario is to understand the impact that a carbon price (which increases over time, reflecting increasing scarcity of allowances as the emission reduction target increases) has upon the road transport and buildings sector.

[4] https://ec.europa.eu/clima/policies/strategies/2050_en

[5] Including the IEA's World Energy Outlook 2019 , EUCalc and EURIMA

### Scenario 2 – an extended EU ETS including the road transport and buildings sectors

In the second scenario, we extend the coverage of the ETS to include road transport and the heating of buildings. Allowance prices are calculated to deliver the targeted emissions reductions across the enlarged ETS, but without prejudicing which sectors within the extended ETS realise emissions cuts (i.e. following the principles of the EU ETS that the market should determine which sectors have the lowest abatement costs, and allow the emissions reductions to happen there, and for other sectors to pay for their emissions).

The aim of this is to observe which parts of the extended EU ETS achieve different levels of emissions reduction, and to better understand the socioeconomic and distributional implications of such a policy.

### The role of revenue recycling

In both of the scenarios outlined above, there are expected to be higher government revenues; in the first scenario, a new revenue source is introduced (a linked carbon price on road transport and buildings), and in the second the ETS is extended to new sectors (so more allowances will be issued, and at a higher price, than in the baseline). This leads to higher government revenues (although net effects could be reduced if economic activity in some parts of the economy is reduced due to the competitiveness effects linked to higher costs); the net economic impact of these scenarios can be heavily dependent upon how such revenues are treated.

In this analysis we consider three potential options;

- A central case, where all revenues are recycled through tax reductions (equally split between reductions in income tax, employers' social security contributions and VAT)
- A low carbon investment variant, where 10% of the revenues are diverted away from tax cuts; 9% are used to realise energy savings, and 1% for direct subsidies of low-carbon technologies, and the remaining 90% is used for tax cuts as in the central case
- A debt paydown variant, where 90% of the revenues are still used for tax cuts, but 10% is used to held onto by governments, and assumed to be used to reduce government debt levels.

The aim of this sensitivity is to explore how the different choices of how revenues are re-used affects the ETS allowance; this is likely to be through both a rebound effect (i.e. recycling revenues to consumers is likely to increase consumption, and therefore create additional emissions, some of which will be in ETS sectors), and a technology cost effect (i.e. that subsidising low carbon technologies increases their take-up, and can reduce some emissions which are subject to the ETS).

## 2.3 The E3ME model

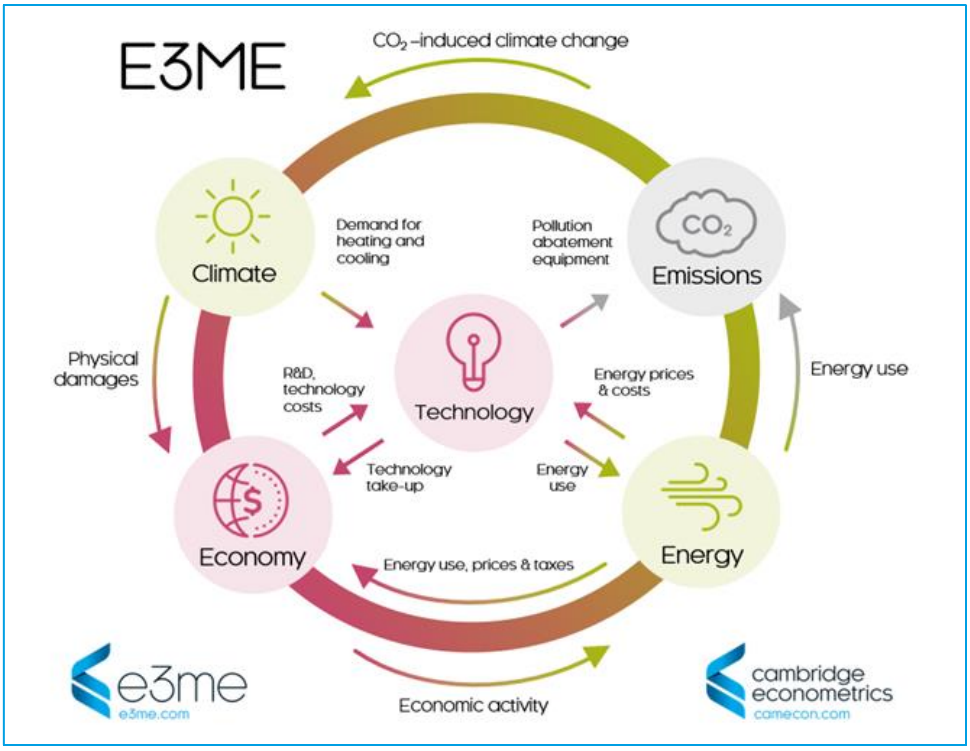
**Overview**

E3ME is a computer-based model of the world's economic and energy systems and the environment. It was originally developed through the European Commission's research framework programmes and is now widely used in Europe and beyond for policy assessment, for forecasting and for research purposes.

**E3ME as an E3 model**

Figure 2.2 shows how the three components (modules) of the model - energy, environment and economy - fit together. The economy module provides measures of economic activity and general price levels to the energy module; the energy module provides measures of emissions of the main air pollutants to the environment module, which in turn can give measures of damage to health and buildings. The energy module provides detailed price levels for energy carriers distinguished in the economy module and the overall price of energy as well as energy use in the economy.

**Figure 2.2: E3 linkages in the E3ME model**




Technological progress plays an important role in the E3ME model, affecting all three E's: economy, energy and environment. The model's endogenous technical progress indicators (TPIs), a function of R&D and gross investment, appear in nine of E3ME's econometric equation sets including trade, the labour market and prices. Investment and R&D in new technologies also appears in the E3ME's energy and material demand equations to capture energy/resource savings technologies as well as pollution abatement equipment.

**The FTT models**

In addition to the treatment of technology through TPIs, E3ME also captures low carbon technologies in the power, transport and residential heating sector through its interactions with the Future Technology Transformation (FTT) models which measure the substitution of technologies in response to changes in costs (both purchase and operational). These models can better assess shifts in technology, and the impact upon energy demand/emissions, than a simple (linear) elasticity of demand, as found in many macro models.

The FTT models have a number of important characteristics:

- Investors are modelled according to a distributed curve of preferences (i.e. investors are heterogenous, with different willingness to adopt new technologies)
- The models do not model specific non-market barriers (i.e. split incentives in rented properties which dramatically reduce the take-up of new technologies, even when they have cheaper levelized costs)
- The models assume that technologies are perfect substitutes (e.g. that a heat pump can be 'dropped in' as a replacement to a gas boiler in all circumstances, and without considering the need for energy efficiency to reduce peak heating need)
- The responsiveness to changes in technology costs is calibrated based upon historical data

Some of the assumptions (e.g. perfect substitution, lack of non-market barriers) have the potential to lead to over-estimates of the responsiveness to price changes. Therefore, the baseline rates of decarbonisation in these industries are adjusted to ensure that the model is producing results in line with other studies.

### The implications of using this modelling framework for this analysis

The use of these modelling tools, and in particular the FTT models to assess changes in demand for specific technologies in response to changes in fuel costs, has specific implications for the analysis. Using these models, we can better assess the long-term responsiveness of these sectors to changes in the costs of specific technologies, since we are able to capture changes in purchasing decisions, rather than simply assessing the short-term elasticity (which is dominated by a change in demand for the final output in response to price changes, rather than changes in the technology used). This approach also allows for non-linear responses, i.e. for elasticities to change, which is a key critique of the standard approach, where a single coefficient is estimated based on historical data.

However, these models also make some simplifying assumptions which could conversely lead to the over-estimation of elasticities. In particular, the models assume that technologies are perfect substitutes (e.g. a heat pump can be 'dropped in' to replace a gas boiler, while in most cases substantial energy efficiency improvements are required to a property in order to shift to a heat pump for heating) and a lack of non-market barriers (e.g. split incentives in rented properties which severely depress the take-up of low-carbon heating technologies in this type of building).

We do not explicitly correct for this non-market barriers to take-up; instead, the model baseline is calibrated to ensure broad consistency with other modelling exercises which have more formally included these barriers. The implication of this approach is that while the baseline is broadly in line with other modelling approaches, there is the potential that our modelling over-estimates the responsiveness of investors to changes in the price of heating technologies; i.e. that the higher cost of fossil fuel-based technologies leads to a greater degree of fuel switching in the modelling than would be observed in reality.

The approach taken through the combination of E3ME and FTT models is a more detailed top-down approach; but while the FTT models do not treat consumers as a homogeneous mass (a typical shortcoming of macro models), they fail to take into account the full details of specific individual investment decisions in the way that a bottom-up stock model might. This modelling should not be interpreted as a perfect representation of these sectors, but as a less simple representation than is typically included in macro models.

## 2.4 Assessing the distributional impacts

The introduction of a carbon price onto transport and heating fuels affects households differently depending upon their individual circumstances, such as their demand for these fuels and their household incomes. A key policy consideration is the distributional effects of such policy; specifically, whether policy has an unduly large impact upon the worst off in society.

In this analysis, we use a combination of E3ME results (for changes in fuel prices) and evidence from the literature on the responsiveness of households to changes in fuel prices to assess potential impacts on example households.

We construct a decomposition of impacts through a two-stage process. First, we take changes in the price of transport and heating fossil fuels from the macroeconomic modelling work described previously. We then consider, based upon reviewed literature, the demand response that such a price increase will elicit (i.e. by how much households might reduce demand when faced with a price increase) to assess the overall change in fuel costs as a result of the policy.

The heating fuel price increase is incorporated in the gas, liquid fuel and solid fuels consumption categories, while the road transport price increase is incorporated in the diesel, petrol and other fuels and lubricants for personal transport equipment consumption categories.

We make a number of assumptions to assess these impacts;

- The passthrough rate of fuel price changes from industry to consumers is 100% in both the road transport and heating sectors.
- The elasticity of demand of the lowest-income households to changes in heating costs is between -0.21 and -0.32[6], i.e. a 1% increase in the price of gas for heating leads to a decrease of between 0.21% and 0.31% in demand.
- The elasticity of demand of households to changes in road transport costs in the lowest quintile ranges from -0.30 to -0.37, depending upon the make-up of the household[7].
- In both transport and buildings, price elasticities increase as income increases; this behaviour can be attributed to the reduced role of ‘essential’ consumption as incomes increase (i.e. a smaller proportion of total usage is to meet essential needs, and therefore a larger proportion is discretionary and can be cut in response to price changes).
  For the purposes of this analysis, we examine the impact in 2030, and take

[6] Schulte, I. and Heindl, P. (2016) Price and Income Elasticities of Residential Energy Demand in Germany. ZEW Discussion Paper No. 16-052.

[7] ibid.

an example household which has not shifted their heating or road transport technology. The aim of this exercise is to consider impacts on those who might be worst affected by the policy; it is well understood that the lowest income households are, in the absence of specific mitigating policy, unlikely to have the financial means to change technologies (for either heating or road transport) before the end of the natural life of their current assets, and therefore are less likely to be able to respond to changes in fuel prices through adopting new low-carbon technologies, and it is precisely these kinds of consumers that we seek to examine through this analysis. In housing, low-income households are also more likely to be in rental properties[8], where split incentives (the owner pays for the installation of the heating technology, but the tenant pays the ongoing bills) substantially reduce the take-up of low-carbon technologies when these have higher purchase prices.

- Our analysis focuses on 2030 because this is when the distributional effects are likely to be most pronounced; in the case of road transport, there are unlikely to be large volumes of second-hand electric vehicles available to purchase for low-income households, and the price-competitiveness of low-carbon heating and transport technologies will still be evolving, meaning that not all low-income households that need replacement technology by 2030 will elect for (or have installed by building owners) the low-carbon option.
- We assess only the response of households to changes in the costs of fuels that they consume. There will also be indirect effects of the different policy options explored; for example, increased transportation costs for goods as a result of higher transport fuel prices, but these effects are complex and better assessed entirely through the macroeconomic modelling (where all policy effects, including changes in consumer income and expenditure as a result of changes in employment, can net off against each other).

[8] See, for example, HM1.3 Housing Tenures (2019), OECD Affordable Housing Database, available at http://www.oecd.org/social/affordable-housing-database/housing-market/

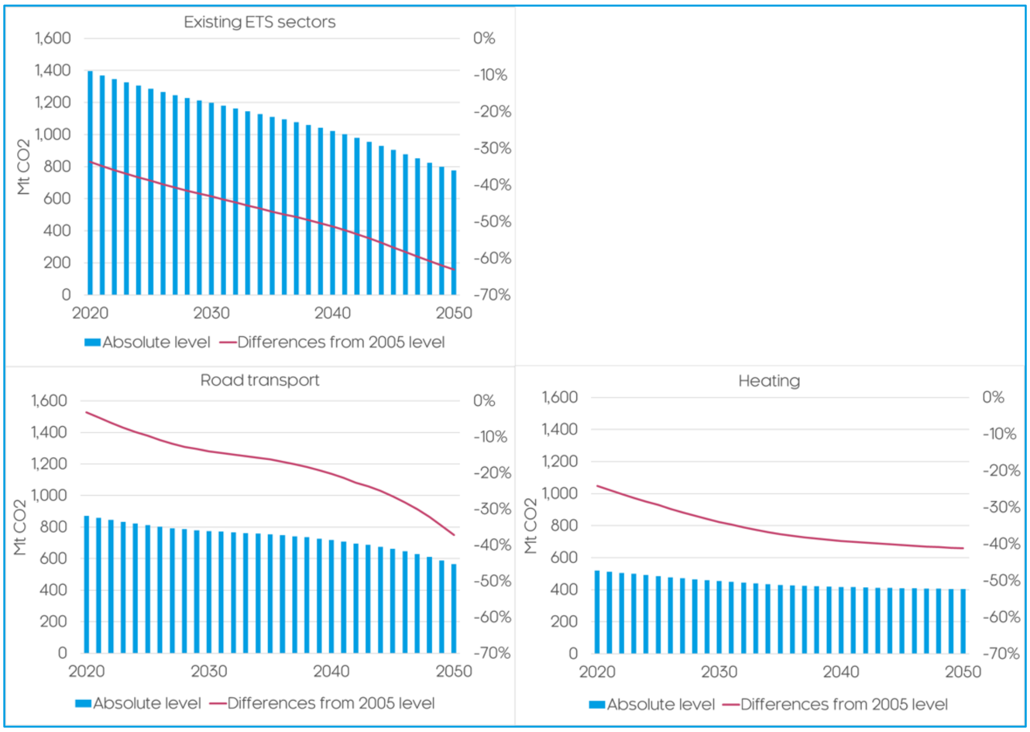
# 3 Environmental impacts

## 3.1 Emissions trends in the baseline

In the baseline (see Figure 3.1), emissions in existing ETS sectors are calibrated to the 2016 PRIMES Reference emissions reduction targets (a 43% reduction from 2005 levels by 2030 and a 63% reduction by 2050). This is equivalent to total $CO_2$ emissions of just under 800Mt across current EU Member States and the UK by 2050.

Emissions from road transport and buildings sectors are also sense-checked against and calibrated to publicly available projections[9]. In comparison with existing ETS sectors, emission reductions in these sectors are assumed to take place at a much slower pace, representing approximately a 40% reduction from 2005 levels by 2050. By 2050, the absolute levels of emissions are projected to be slightly above 550Mt$CO_2$ in road transport and 400Mt$CO_2$ in buildings.

**Figure 3.1: Baseline emissions projections**




## 3.2 Impacts of applying a linked carbon price in the transport & buildings sectors

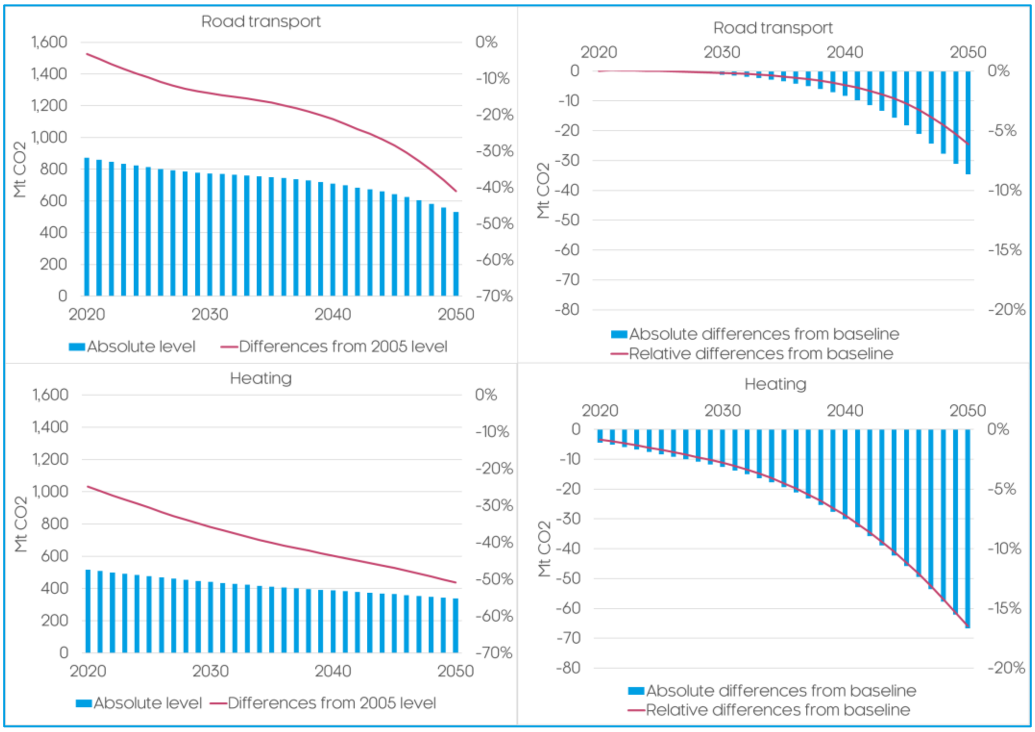
In the first scenario modelled, a carbon price equivalent to the baseline ETS price is applied in the transport and buildings sectors through the FTT models. This makes technologies with high emission factors, namely those using fossil fuels, more expensive, therefore creating more incentives for consumers to switch to low-carbon technologies, reducing emissions in these sectors further.

[9] These include reference case scenario projections by EUCalc and EURIMA.

*A carbon price has a limited effect on decarbonisation in both road transport and buildings*

Figure 3.2 shows that at the EU aggregate level, the additional reduction in transport compared to the baseline is small, while in the buildings sector it is expected to have a more substantial response, but still below the emissions reductions delivered by this price in the existing ETS sectors.

**Figure 3.2: Transport and buildings emissions in the linked carbon price scenario**




*Both transport and buildings lag behind existing ETS sectors*

Nevertheless, in terms of emission reductions, both sectors are projected to lag behind existing ETS sectors, achieving just over 40% and 50% reductions from 2005 levels by 2050, respectively.

Because these sectors are assumed to remain outside of the ETS in this scenario, the implication is that there is no impact on the ETS price, which means relatively little impact on emissions from existing ETS sectors.

## 3.3 Impacts of a single extended ETS including transport & buildings

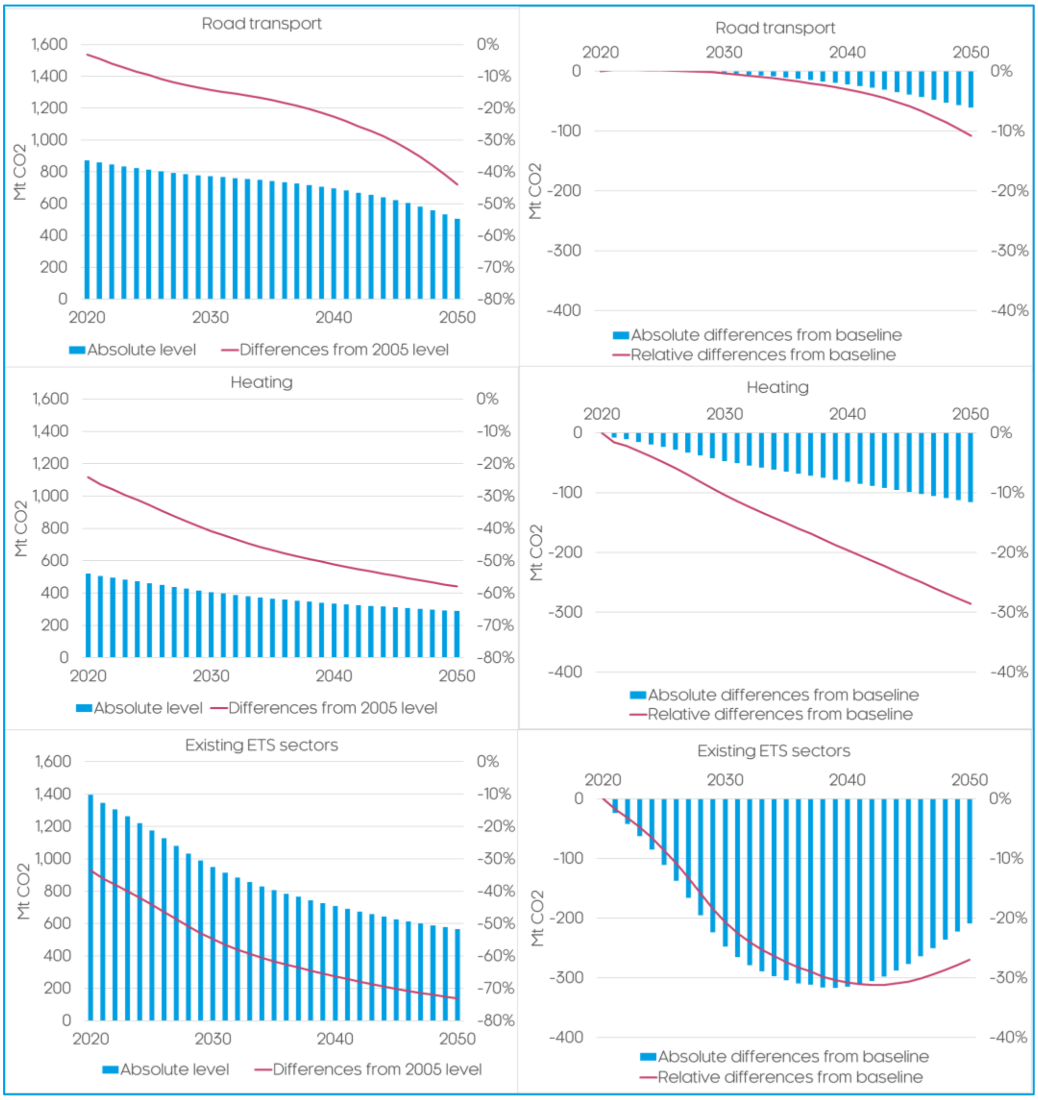
This scenario assumes transport and buildings are included in an extended ETS which also has a higher permit price. The ETS prices are designed to deliver emissions reductions consistent with the 2016 PRIMES Reference reductions for existing ETS sectors (so the more ambitious the target, the higher the ETS price).

*A higher ETS price results in larger emission reductions in all ETS sectors but the trajectories vary by sector*

According to Figure 3.3, road transport emissions are projected to decline more rapidly after 2040 and additional reductions in buildings emissions are projected to be slow and steady, reflecting the long operational life of heating installations and the low rate of renovations.

In other ETS sectors (which include power generation and energy-intensive manufacturing industries), emission reductions are expected to take place at a faster rate than in the baseline. However, additional reductions plateau around 2040 and start moving back towards the baseline due to increased demand for electricity in the long term as emissions by final energy users (particularly transport) continue to fall.

**Figure 3.3: Emissions in transport, buildings and existing ETS sectors in the extended ETS scenario**



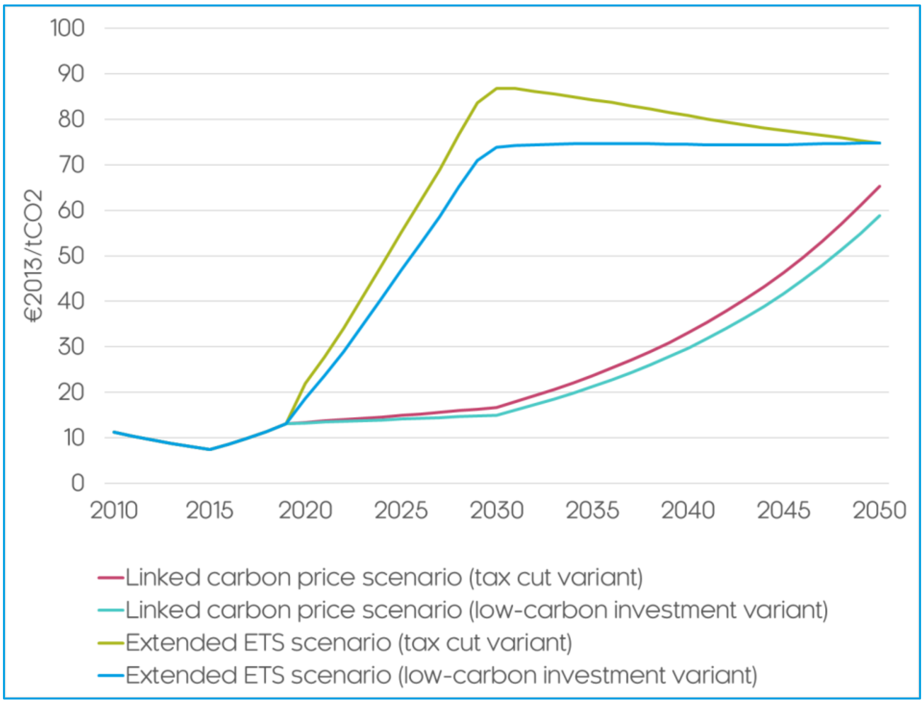

## 3.4 The change from different revenue recycling options

As outlined in section 2.2, three revenue recycling options were modelled to demonstrate potential macroeconomic impacts in each scenario.

All options modelled involve making reductions to direct and indirect taxes, which translate into lower prices and more disposable income for consumers. In principle, this leads to an increase in total demand, which means lower abatement efforts given the same technology choices. Nevertheless, the impact of these rebound effects is estimated to be small (see section 2.2).

Meanwhile, a lower ETS price is required to achieve the same emissions reduction when some of the revenues are used to invest in energy efficiency and low-carbon technologies, as in the low-carbon investment variant (see Figure 3.4). In particular, the price would be consistently lower in the linked carbon price scenario and increase less sharply in the short and medium term in the extended ETS scenario.

**Figure 3.4: ETS prices under different revenue recycling options**




This occurs through two mechanisms. On the one hand, reinvesting a proportion of the ETS revenues into efficiency improvements reduces overall demand for energy, meaning that less energy is needed to be sourced from fossil fuels and reducing emissions. On the other hand, subsidies for renewables provide added fiscal incentives for investors to take up those options, increasing the share of low-carbon technologies in electricity generation and pushing out fossil fuel generation more rapidly. Given the same ETS price, both of these channels lead to larger emissions reductions in all sectors (including road transport and buildings) than in the tax cut variants.

# 4 Socioeconomic impacts

Rather than assessing the impacts of different decarbonisation policies, the modelling is intended to quantify the macroeconomic impacts of the two scenarios in comparison with the baseline where no additional policy is implemented in the future, through changes in assumptions for sectoral coverage and permit prices.

The implication therefore is that some of the impacts that are outlined below arise as a result of *more decarbonisation*, rather than specifically because of the policy route chosen (i.e. via a linked carbon price/ETS). We do not evaluate the potential economic impacts of alternative methods of achieving the same emissions reductions through other policy pathways; such analysis is beyond the scope of this work.

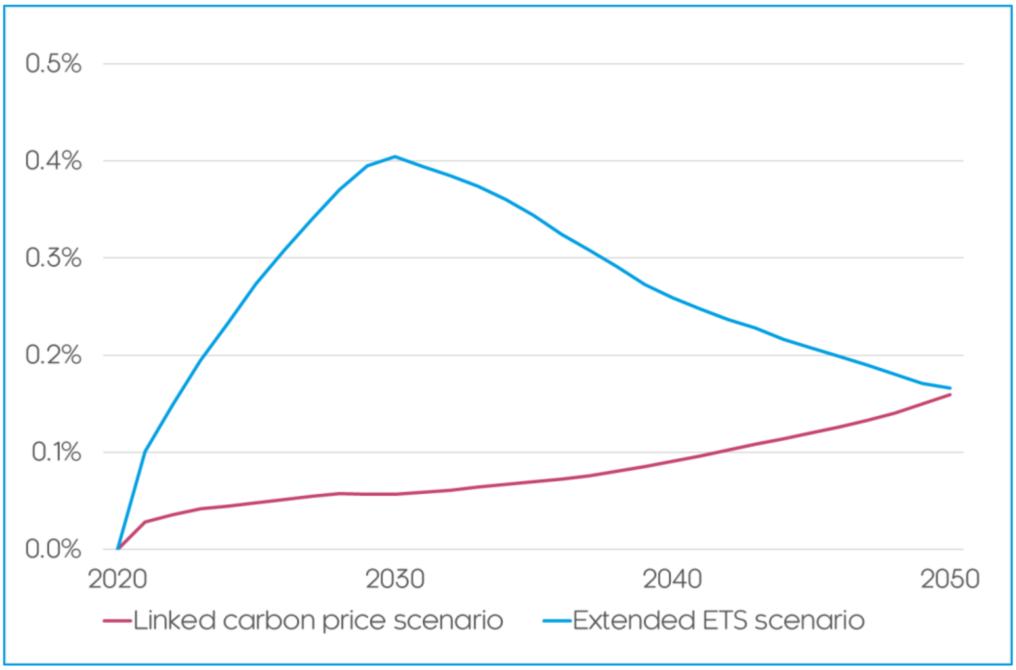
## 4.1 The impacts on GDP

It is assumed that revenues collected from the linked carbon price or ETS are re-used by government. As a result of this, for Europe as a whole, the impacts on total GDP relative to a 'do nothing' baseline are expected to be positive in both scenarios.

*GDP impacts are strongly linked to the ETS prices*

The GDP impacts reflect the trends for the ETS price assumptions, as higher allowance prices lead to more revenues being recycled than in the absence of such policy(see Figure 4.1). Particularly, the relative impact of the extended ETS scenario is expected to be more positive for most of the forecast period but becomes more similar to that for the linked carbon price scenario in the long term as the ETS price assumptions converge.

**Figure 4.1: EU+UK total GDP impacts**

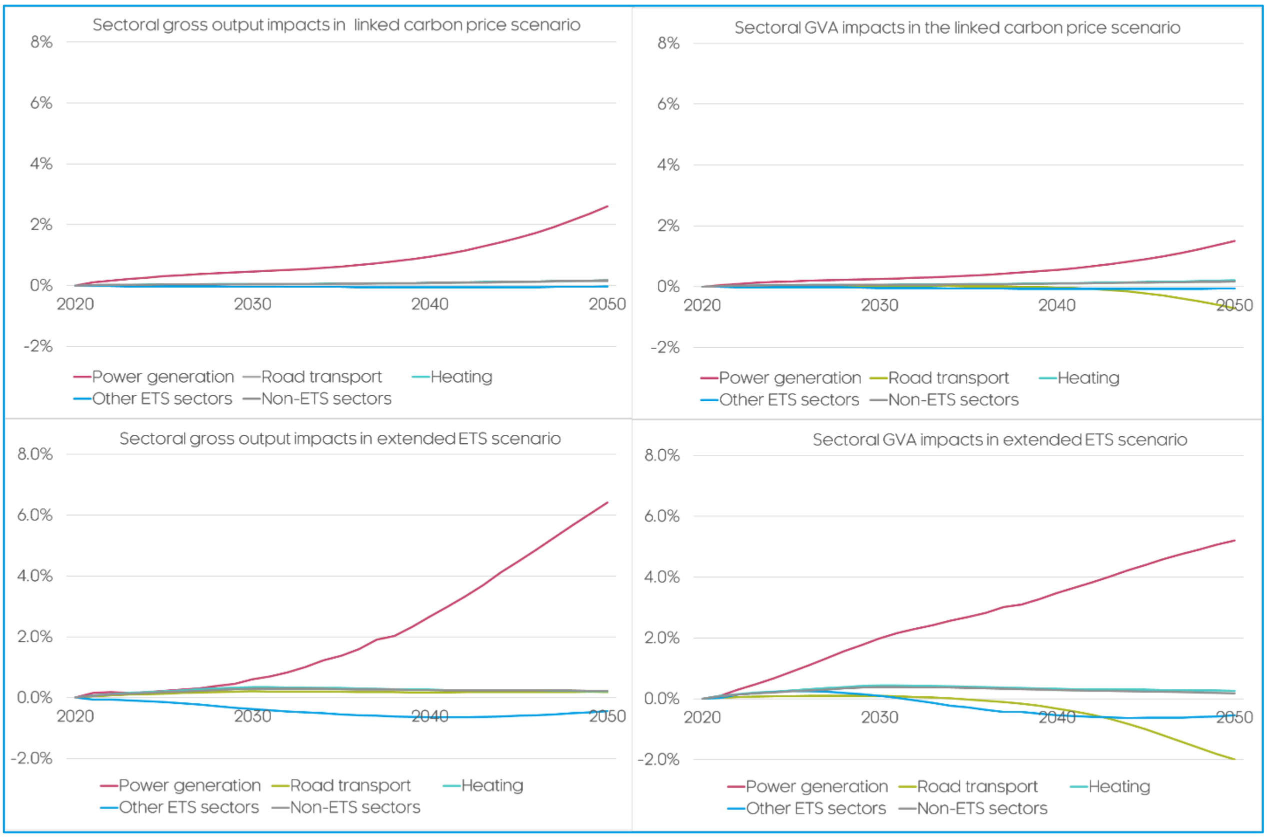


*Sector-level impacts vary*

These trends are also observed at the sector level, although there is some variation between sectors (see Figure 4.2):

- Power generation output as measured by either gross output or gross value added (GVA) is expected to be higher than in the baseline as a result of increased electrification (and therefore higher demand in new generation capacity).
- Impacts on sectors that supply and demand heating services (which make up the majority of the economy and consist of most service sectors) are small, reflecting offsetting impacts of reduced consumption (in response to the linked carbon price or the ETS price) and higher investment (as part of decarbonising the technology mix).
- Impacts on road transport gross output are also small, as with buildings. However, GVA impacts are slightly negative, suggesting that the sector is likely to maintain its level of economic activity in response to the higher costs, albeit with a squeeze on profits and wages.
- Other ETS sectors (which consist of energy-intensive manufacturing industries) are expected to suffer poor outcomes due to higher costs.

**Figure 4.2: EU+UK GVA impacts by sector**



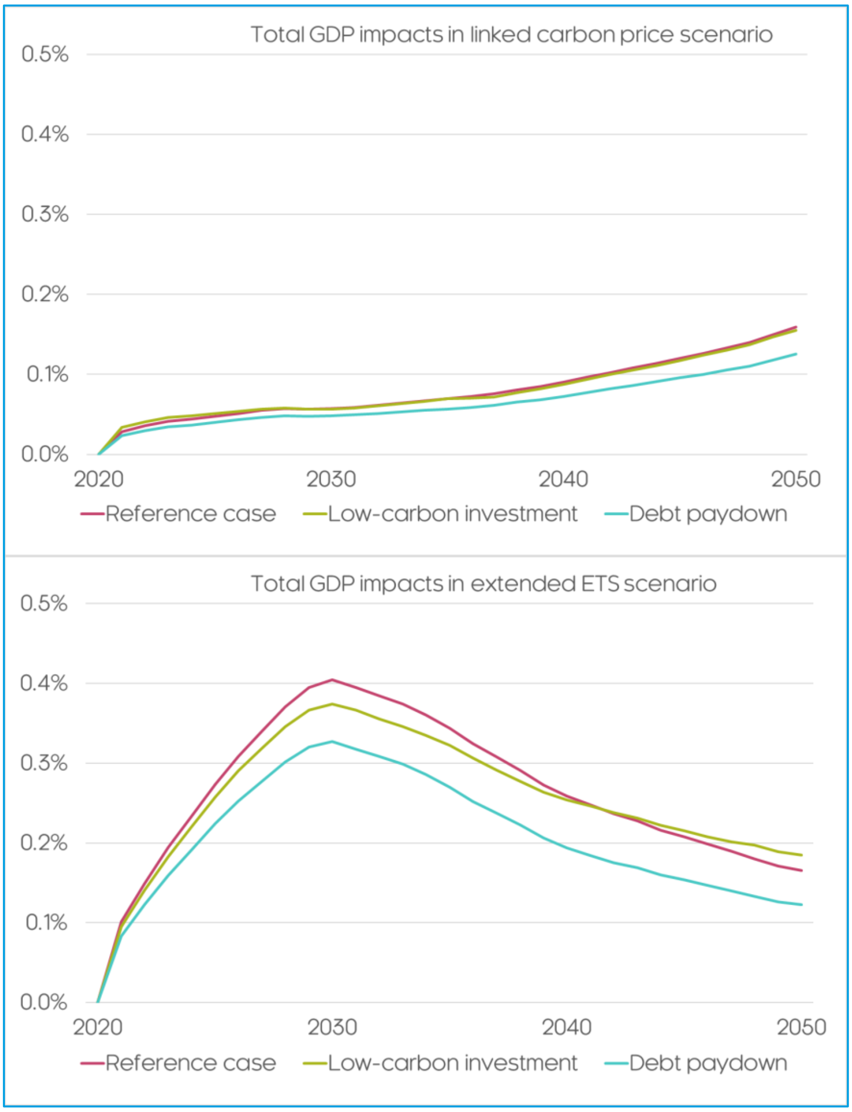

*Different uses of recycled revenues alter macroeconomic outcomes*

As a sensitivity, two other options for revenue recycling are modelled (see Figure 4.3).

In the Low-carbon investment variant, recycling some revenues to this channel is expected to lead to a higher share of renewables in generation, lower demand for energy (due to improved energy efficiency) and a lower ETS price (because abatement costs are reduced). On the other hand, the Debt paydown variant is expected to generate less positive GDP impacts without material influence on the ETS price.

This means that for a similar level of emission reductions, the Reference case and the Low-carbon investment variant have similar outcomes while the variant with some debt paydown has slightly lower economic impacts because money is taken out of the economy.

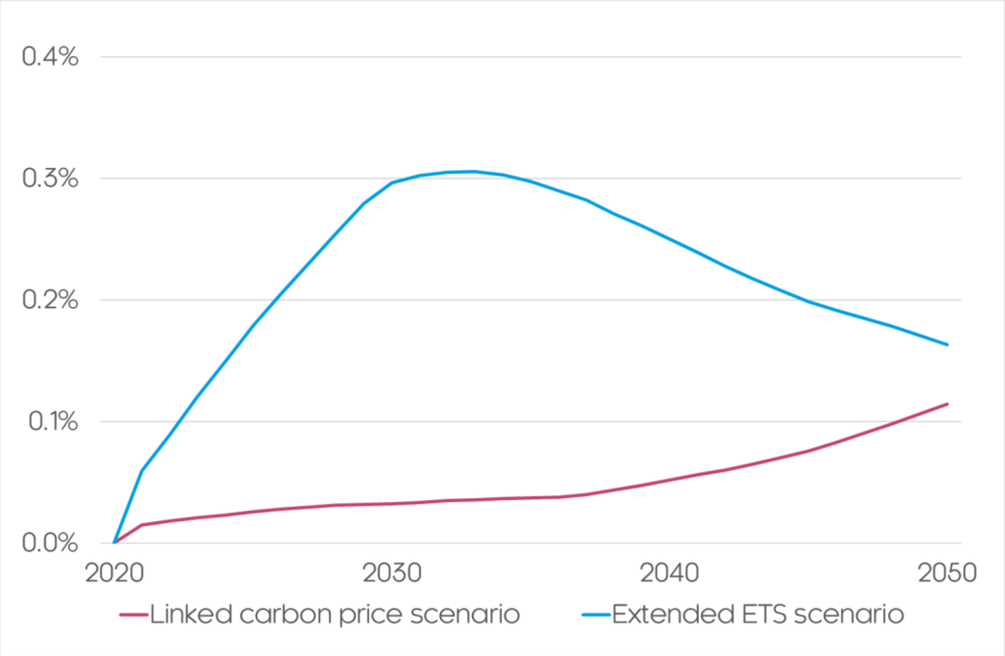
**Figure 4.3: Impacts of different revenue recycling options on EU+UK GDP**



## 4.2 The impacts on employment

At the EU aggregate level, total employment impacts mirror GDP impacts in both scenarios (see Figure 4.4). The relative differences from baseline for employment are slightly smaller overall, due to positive wage adjustments in response to higher output.

**Figure 4.4: EU+UK total employment impacts**

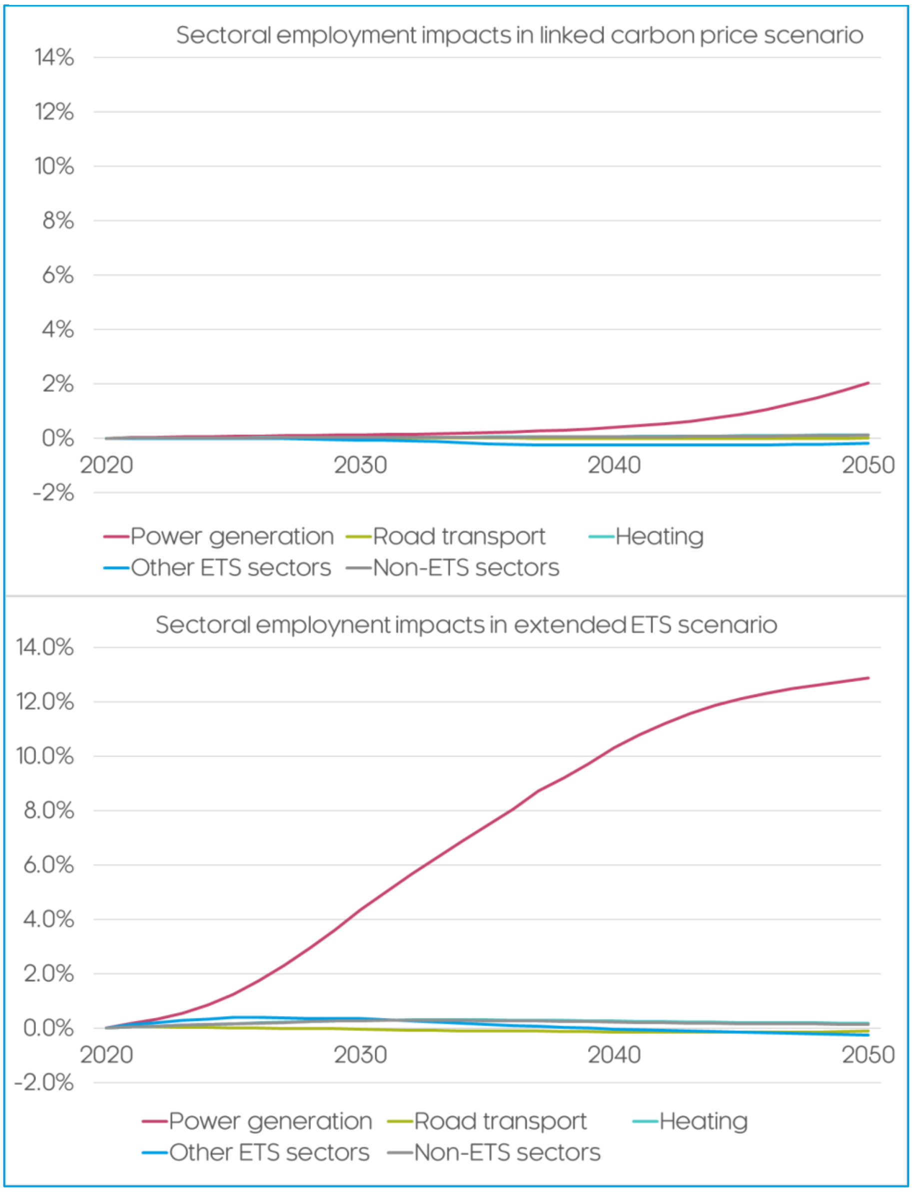



*Employment impacts are in line with GDP impacts, but relatively stronger for power generation*

The EU-wide sector level impacts also follow the trajectories of the impacts on gross output, with power generation benefiting the most and other ETS sectors seeing lower employment, while impacts on transport and buildings are negligible (Figure 4.5).

In the Extended ETS scenario, the employment impact for power generation is particularly strong and larger than the impact for this sector's output (on both gross output and GVA measures). This may seem counter-intuitive but can be explained by changes in the generation mix in response to high demand for electricity and a high ETS price in this scenario. As renewables are more labour-intensive than their fossil fuel counterparts, there is a strong increase in demand for labour associated with their take-up over time.

**Figure 4.5: EU+UK employment impacts by sector**




## 4.3 Distributional effects

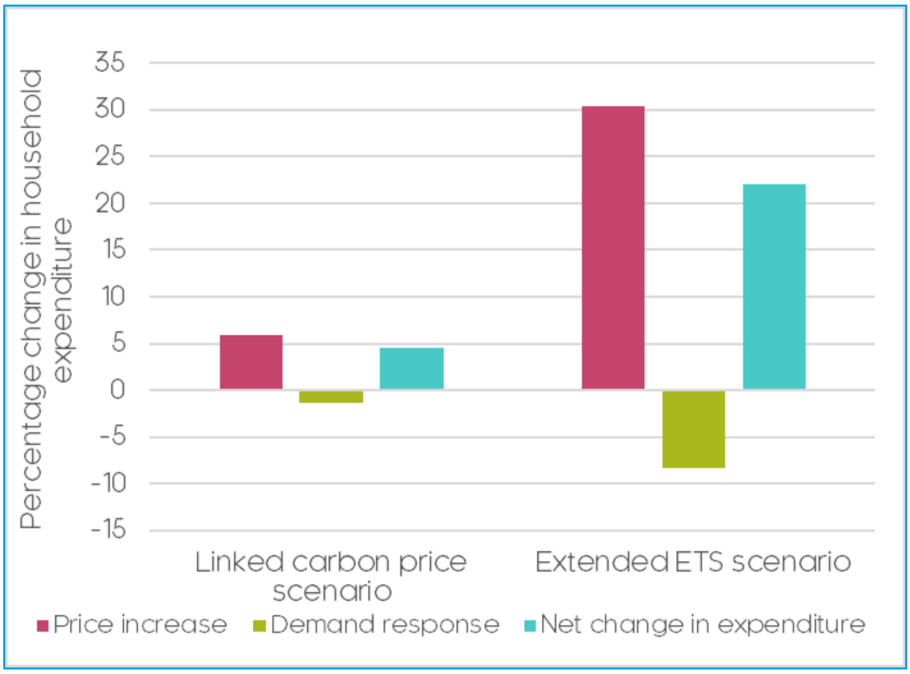
The impacts on expenditure occur through two mechanisms; first, the introduction of the carbon charge (whether through a linked carbon price or ETS allowance) increases the costs of household heating or vehicle refuelling. Then, there is a demand response to the higher price. As a result, the final impact is a balance of change in cost and demand response.

In this analysis, we consider what is likely to be the worst-hit type of consumer; those in the lower income deciles, who have tight constraints on their expenditure, and therefore are less likely than a typical consumer to have the financial capital to purchase a low-carbon technology; or are more likely to be in rented accommodation, and therefore not able to explicitly choose low-carbon technologies (which are typically more expensive up-front purchases). We use data on changes in fuel costs from E3ME and apply short-term price elasticities drawn from the literature to measure the impact on the typical household that does not have access to low-carbon technologies in 2030, as outlined in section 2.4. The reason for choosing 2030 for this analysis is that in this year, according to our modelling, most consumers will still hold high-carbon technologies, either because their existing technology has not reached end-of-life, or because when it did they chose to re-invest in a high-carbon technology (for cost or other reasons). By later on (e.g. 2050), costs of low-carbon technologies have fallen, and even low-income households are likely to have replaced their technologies at least once and had the option (where they are the ultimate decision maker) to take-up a low-carbon technology.

**Heating**

Looking first to impacts on household expenditure on heating; in the linked carbon price scenario, the price of gas for household heating increases in 2030 by 6%; without a demand response, this would be the increase in household bills. However, assuming a price elasticity of 0.21[10], demand reduces such that the total increase in household heating expenditure across the low-income deciles is reduced to less than 5% (see Figure 4.6).

**Figure 4.6 Decomposition of impacts on low-income households heating expenditure**




In the extended ETS scenario, where the ETS allowance price is substantially higher in 2030, the impacts are much more pronounced. Household natural gas prices are 30% higher in 2030; and while the demand response reduces expenditure by just over 8%, the net impact is an increase on expenditure on heating of around 22%.

In both cases above, we have taken the price elasticity from single adult households with no dependents. Other household types have higher price elasticities; for example, in the same study, the price elasticity of households with two adults and two dependents (the highest report for this income quartile) was -0.32. Under such an assumption, the net change in expenditure in 2030 is 4% higher in the linked carbon price scenario, and almost 18% higher in the extended ETS scenario.

Similarly, higher-income households also have higher price elasticities; in the case of heating, the highest price elasticity from the study used was -0.92, for

[10] Drawn from Schulte, I. and Heindl, P. (2016) Price and Income Elasticities of Residential Energy Demand in Germany. ZEW Discussion Paper No. 16-052.

households in the highest income quartile with two adults and three children in the household. This implies that for every 1% increase in price, there is a 0.92% decrease in consumption of heating.

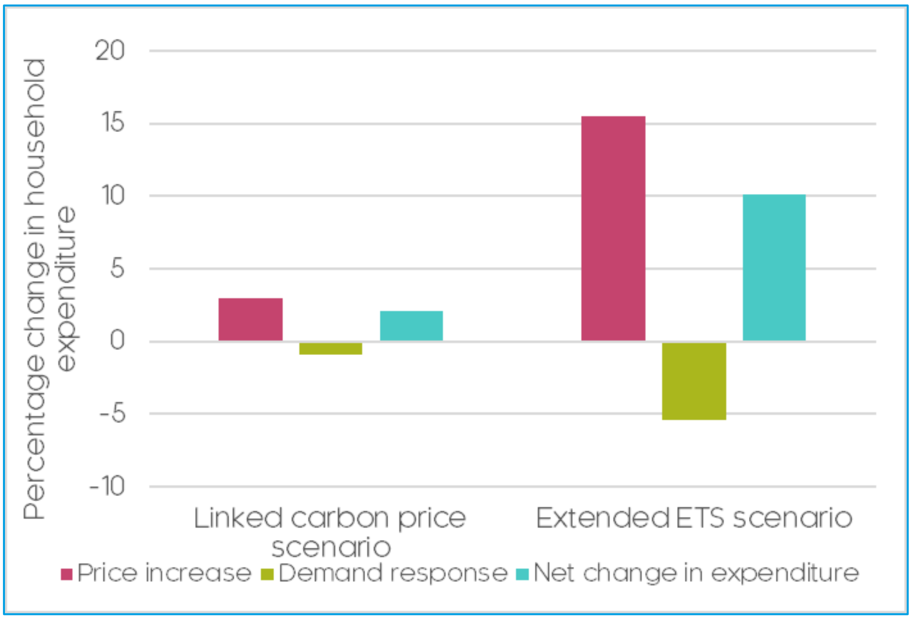
In all cases, this is explained through the proportion of use which is ‘essential’. Ultimately there are minimal uses of heating which a typical household will require (e.g. during the coldest nights), and the price elasticity of consumers at this point is very high (i.e. there would have to be a very substantial price increase for them to forego this heating use, since the welfare impacts are likely to be substantial). Across different household income levels and type, the proportion of discretionary usage above this minimum differs, and therefore their overall sensitivity to price increases.

## Road transport

In our analysis of the road transport sector we take an income elasticity of -0.30 for the lowest income quartile[11]. As outlined above for heating, there are greater changes in demand across different household make-ups (e.g. demand is most price-sensitive across all income quartiles for households with two adults and no children) and income levels (e.g. the price elasticity of the highest-income households, for single adult households, is -0.7). This leads to greater changes in demand in the higher quartiles, primarily because the trips being taken by the lowest-income households will already be limited (i.e. a higher proportion of their trips will be for ‘essential’ purposes, such as commuting, and discretionary use will be lower).

In the lowest income quartile, the addition of carbon pricing to fossil fuels increases the costs of refuelling by an average of 3% in the linked carbon price scenario, and almost 16% in the extended ETS scenario; however the reduction in demand results in an increase in expenditure on transport fuels of 2% and just more than 10% in the linked carbon price and extended ETS scenarios respectively (see Figure 4.7.)

**Figure 4.7 Decomposition of impacts on low-income households road transport expenditure**




[11] From Schulte, I. and Heindl, P. (2016) Price and Income Elasticities of Residential Energy Demand in Germany. ZEW Discussion Paper No. 16-052.

In all cases, the key messages are the same; any consumer that is locked-in to a high-carbon technology (whether for reasons of technology lock-in, living in rented accommodation, or financial limitations) is facing higher bills for household heating and transport (in particular the latter), and for lower levels of consumption (i.e. they are paying more for less). This has substantial impacts on consumer welfare for this segment of the population, and points to the need for supporting policy to help these consumers manage higher costs (in the short term) and transition to new technologies (in the long term).

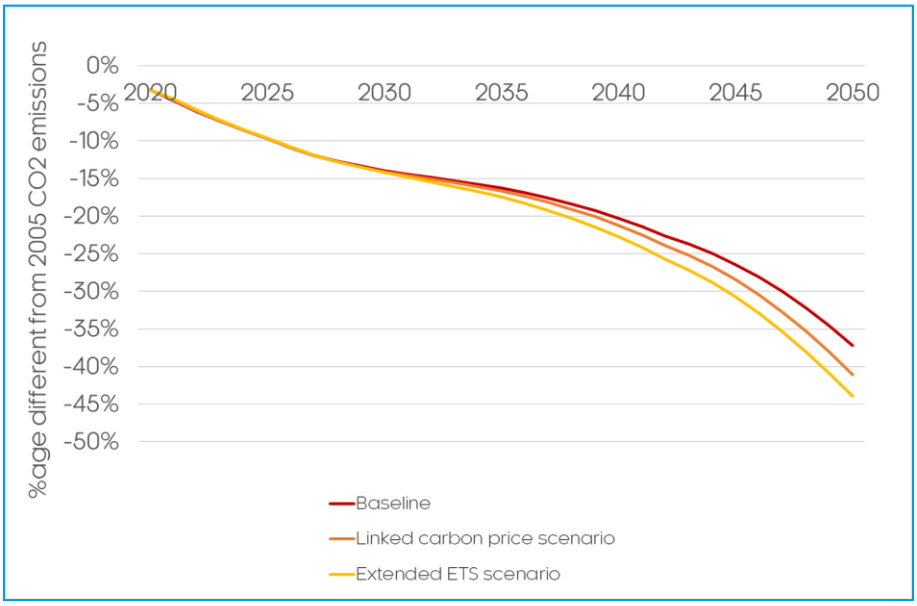
# 5 Conclusions

The European Commission is interested in potentially extending the EU ETS with the aim of accelerating the reduction in emissions realised in the road transport and buildings sector. In this report, we have assessed the impacts of two potential designs for an extended ETS, and examined the impact on emissions from the transport, buildings and current ETS sectors, as well as the socioeconomic and distributional effects of the policy.

**Impacts on emissions**

In our baseline analysis, neither the road transport nor buildings sectors are on track to meet the EU ETS emissions reduction target of emissions 43% below 2005 levels in 2030. According to our baseline projections, in road transport, emissions are expected to be around 14% below 2005 levels in 2030; the equivalent figure for heating is 34%. In 2050 these sectors are expected to achieve emissions 37% (road transport) and 41% (heating) below 2005 levels. Our analysis has shown that a carbon price mirroring the ETS allowance price in these sectors does not substantially shift this trajectory; there is no impact in road transport in 2030, and by 2050 it increases the emissions reduction realised to only 41% below 2005 levels (see Figure 5.1). In the heating sector, emissions reductions in 2030 hit 36% below 2005 levels, still short of the target, and reach 51% by 2050 (see Figure 5.2).

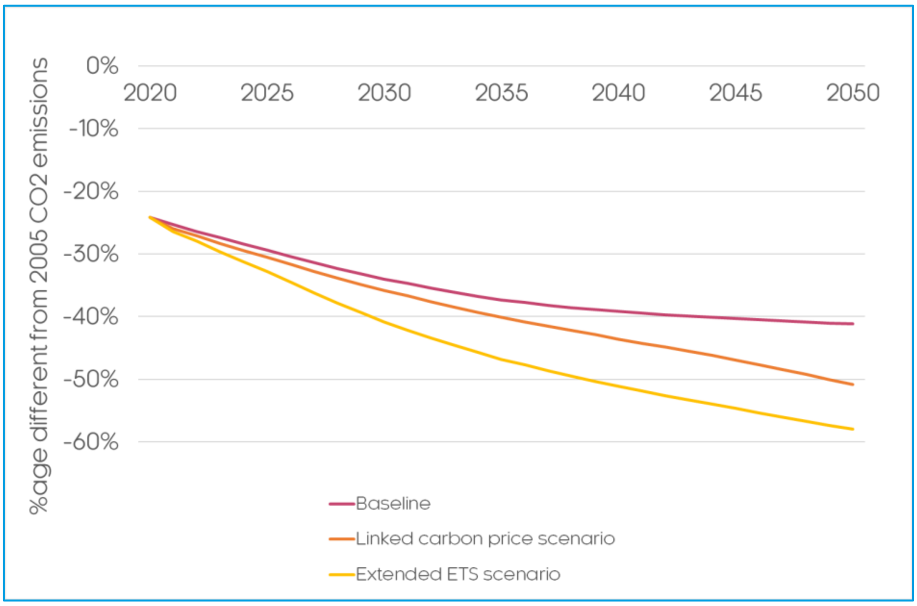
**Figure 5.1 Emissions from road transport**




Introducing an extended ETS, which includes road transport and buildings alongside existing ETS sectors, leads to some further emission reductions, although neither sector achieves the 43% reduction target for 2030, placing greater weight on the existing ETS sectors. Because there is a hard cap on emissions, and road transport and buildings do not deliver their share of emissions reductions, greater reductions are achieved in other sectors. In 2030, the existing ETS sectors reduce emissions by 55% compared to 2005 levels, ensuring that the combined ETS achieves the 43% target. A similar trend is observed in 2050, where an unambitious target of 63% reductions in ETS emissions compared to 2005 levels is only achieved through a 73%

reduction in emissions from existing ETS sectors, to make up the shortfall in the transport and buildings sectors.

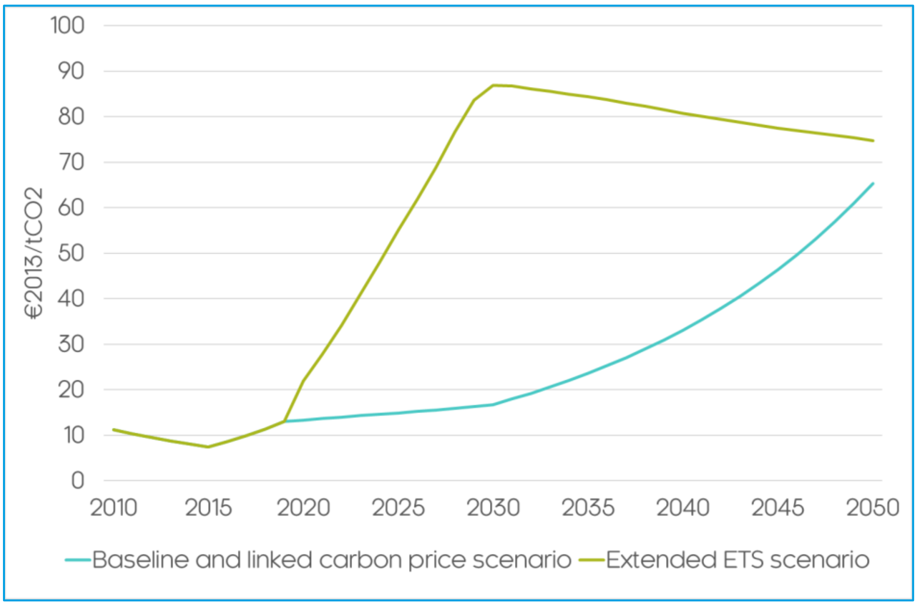
**Figure 5.2 Emissions from heating**




## Socioeconomic impacts

Achieving the emissions reductions required of an extended ETS (i.e. emissions 43% below 2005 levels in 2030, and 63% below in 2050, in our scenarios) requires a substantially higher ETS allowance price than is the case in the existing ETS sectors (see Figure 5.3). This has implications both for the generation of revenues, but also upon the competitiveness of the existing ETS sectors.

**Figure 5.3 ETS allowance prices used in the analysis**




The overall economic impacts of the imposition of an explicit carbon price in the road transport and buildings sectors are positive; GDP is 0.4% higher in 2030, decreasing to below 0.2% by 2050. These economic impacts are largely driven by the additional government revenues collected through the policy measures, and reflect potential benefits of (mildly) accelerated decarbonisation of the road transport and buildings sectors; without comparing them to alternative policy measures, it is not possible to say whether such a policy is economically the best, or the worst, way to achieve such a decarbonisation.

What is notable in the analysis, however, is the impact that such a policy has on the existing ETS sector. When an extended ETS is modelled, the higher ETS price leads to lower output and employment in existing ETS sectors. Gross value added in these sectors is around 0.5% lower consistently between 2030 and 2050 due to the loss of competitiveness from the imposition of this higher carbon price.

At the same time, an extended ETS which includes consumers directly is likely to lead to potentially uneven distributional effects. The lowest-income households are likely to be financially constrained, and therefore find it difficult to adopt low-carbon technologies until prices of these technologies have fallen further (and/or, in the case of cars, a competitive second-hand market for them has emerged). Furthermore, households living in rental property do not have autonomy over the adoption of low-carbon technologies, they are dependent on decisions of the owner of the property. Those households that are stuck with existing high-carbon technologies are likely to face substantially higher household bills; the cost of fossil fuel heating, for those unable to switch to low carbon alternatives, are expected to be 22% higher in 2030 – but facing prices which are 30% higher, some of the effect is only mitigated by a reduction in demand, which in the case of low income households could lead to under-heating and therefore a substantial loss of welfare. Similarly, while the cost of refuelling an ICE is expected to be 16% higher in 2030 as a result of transport fuels featuring in an extended ETS, bills will increase by 10% for the lowest income deciles; but this more limited increase is only achieved through a reduction in the use of cars for private transportation. As such, consumers across the income distribution end up paying more for less, where they remain reliant upon high-carbon technologies.

**In summary**

An extended ETS would not, by itself, deliver the substantive reductions in emissions required of road transport and buildings. Our analysis suggests that there is no scope for relaxing existing policies, if the ETS were widened. Indeed, the extended ETS would require substantive additional support to deliver the required savings. Such policy must consider sector-specific challenges, such as the slow rate of fleet renewal, and the challenge that this causes to low-income consumers.

Given the minor improvements in emissions an extended ETS causes in road transport and buildings, such a policy would force additional decarbonisation onto existing ETS sectors and damage their competitiveness.

However, the ETS has a major role to play in other sectors. In particular, it continues to drive decarbonisation of the electricity sector. Achieving a low-carbon electricity sector is the only way to decarbonise (through electrification) transport and buildings, so the ETS should continue to play a role where it can deliver in a cost-effective way such outcomes.

# Appendices

# Appendix A References

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# Appendix B E3ME model description

## Overview

E3ME is a computer-based model of the world's economic and energy systems and the environment. It was originally developed through the European Commission's research framework programmes and is now widely used in Europe and beyond for policy assessment, for forecasting and for research purposes. The latest version of E3ME provides:

- global geographical coverage
- feedbacks between individual European countries and other world economies
- treatment of international trade with bilateral trade between regions
- new technology diffusion sub-modules

The full model manual is available online from www.e3me.com.

## Applications of E3ME

Although E3ME can be used for forecasting, the model is more commonly used for evaluating the impacts of an input shock through a scenario-based analysis. The shock may be either a change in policy, a change in economic assumptions or another change to a model variable. The scenarios represent alternative versions of the future based on a different set of inputs. By comparing the outcomes to the baseline (usually in percentage terms), the effects of the change in inputs can be determined.

Model-based scenario analyses often focus on changes in price because this is easy to quantify and represent in the model structure. Examples include:

- changes in tax rates including direct, indirect, border, energy and environment taxes
- changes in international energy prices

All of the price changes above can be represented in E3ME's framework reasonably well, given the level of disaggregation available. E3ME could then be used to determine:

- secondary effects, for example on consumers of fuels
- rebound effects
- overall macroeconomic impacts

## Comparison with CGE models and econometric specification

E3ME is often compared to Computable General Equilibrium (CGE) models. In many ways the modelling approaches are similar; they are used to answer similar questions and use similar inputs and outputs. However, underlying this there are important theoretical differences between the modelling approaches.

In a typical CGE framework, optimal behaviour is assumed, output is determined by supply-side constraints and prices adjust fully so that all the available capacity is used. In E3ME the determination of output comes from a post-Keynesian framework and it is possible to have spare capacity. The model is more demand-driven and it is not assumed that prices always adjust to market clearing levels.

The differences have important practical implications, as they mean that in E3ME regulation and other policy may lead to increases in output if they are able to draw upon spare economic capacity. This is described in more detail in the model manual.

The econometric specification of E3ME gives the model a strong empirical grounding. E3ME uses a system of error correction, allowing short-term dynamic (or transition) outcomes, moving towards a long-term trend. The dynamic specification is important when considering short and medium-term analysis (e.g. up to 2020) and rebound effects, which are included as standard in the model's results.

*Key strengths of E3ME*

In summary the key strengths of E3ME are:

- the close integration of the economy, energy systems and the environment, with two-way linkages between each component
- the detailed sectoral disaggregation in the model's classifications, allowing for the analysis of similarly detailed scenarios
- its global coverage, while still allowing for analysis at the national level for large economies
- the econometric approach, which provides a strong empirical basis for the model and means it is not reliant on some of the restrictive assumptions common to CGE models
  the econometric specification of the model, making it suitable for short and medium-term assessment, as well as longer-term trends

*Limitations of the approach*

As with all modelling approaches, E3ME is a simplification of reality and is based on a series of assumptions. Compared to other macroeconomic modelling approaches, the assumptions are relatively non-restrictive as most relationships are determined by the historical data in the model database. This does, however, present its own limitations, for which the model user must be aware:

- The quality of the data used in the modelling is very important. Substantial resources are put into maintaining the E3ME database and filling out gaps in the data. However, particularly in developing countries, there is some uncertainty in results due to the data used.

- Econometric approaches are also sometimes criticised for using the past to explain future trends. In cases where there is large-scale policy change, the 'Lucas Critique' that suggests behaviour might change is also applicable. There is no solution to this argument using any modelling approach (as no one can predict the future) but we must always be aware of the uncertainty in the model results.

The other main limitation to the E3ME approach relates to the dimensions of the model. In general, it is very difficult to go into a level of detail beyond that offered by the model classifications. This means that sub-national analysis is difficult and sub-sectoral analysis is also difficult. Similarly, although usually less relevant, attempting to assess impacts on a monthly or quarterly basis would not be possible.

## E3ME basic structure and data

The structure of E3ME is based on the system of national accounts, with further linkages to energy demand and environmental emissions. The labour market is also covered in detail, including both voluntary and involuntary unemployment. In total there are 33 sets of econometrically estimated equations, also including the components of GDP (consumption, investment, international trade), prices, energy demand and materials demand. Each equation set is disaggregated by country and by sector.

E3ME's historical database covers the period 1970-2016 and the model projects forward annually to 2050. The main data sources for European countries are Eurostat and the IEA, supplemented by the OECD's STAN database and other sources where appropriate. For regions outside Europe, additional sources for data include the UN, OECD, World Bank, IMF, ILO and national statistics. Gaps in the data are estimated using customised software algorithms.

*The main dimensions of the model*

The main dimensions of E3ME are:

- 61 countries – all major world economies, the EU28 and candidate countries plus other countries' economies grouped
- 44 or 70 (Europe) industry sectors, based on standard international classifications
- 28 or 43 (Europe) categories of household expenditure
- 22 different users of 12 different fuel types
- 14 types of air-borne emission (where data are available) including the 6 GHG's monitored under the Kyoto Protocol

*Standard outputs from the model*

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

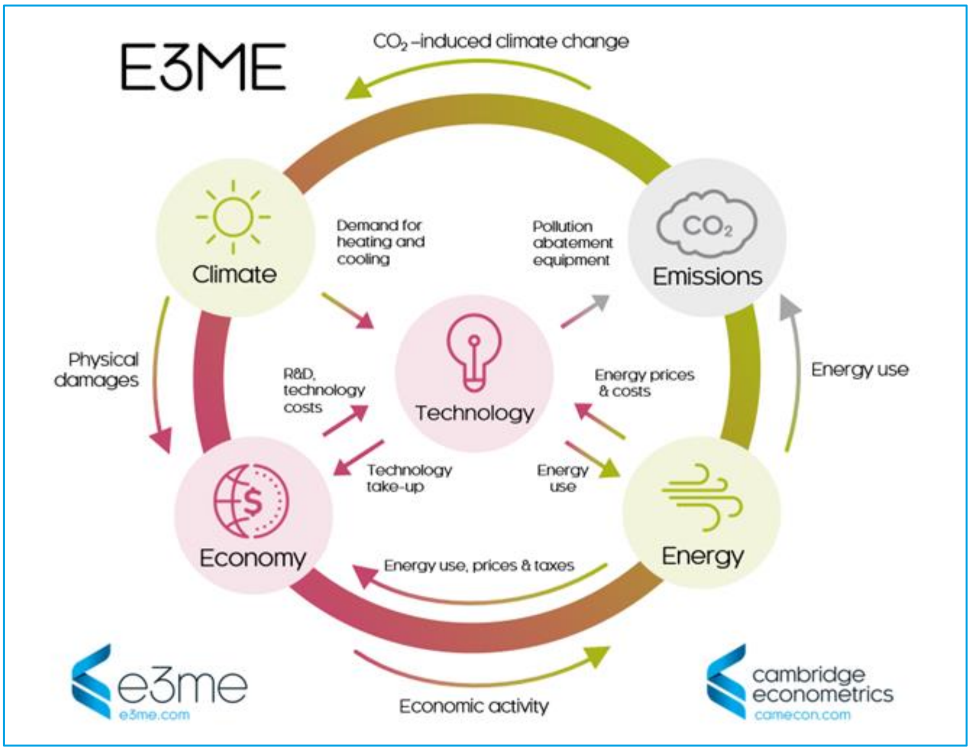
- GDP and the aggregate components of GDP (household expenditure, investment, government expenditure and international trade)
- sectoral output and GVA, prices, trade and competitiveness effects
- international trade by sector, origin and destination
- consumer prices and expenditures
- sectoral employment,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

This list is by no means exhaustive and the delivered outputs often depend on the requirements of the specific application. In addition to the sectoral dimension mentioned in the list, all indicators are produced at the national and regional level and annually over the period up to 2050.

**E3ME as an E3 model**

Figure 2.2 shows how the three components (modules) of the model - energy, environment and economy - fit together. The economy module provides measures of economic activity and general price levels to the energy module; the energy module provides measures of emissions of the main air pollutants to the environment module, which in turn can give measures of damage to health and buildings. The energy module provides detailed price levels for energy carriers distinguished in the economy module and the overall price of energy as well as energy use in the economy.

**Figure 0.1: E3 linkages in the E3ME model**




Technological progress plays an important role in the E3ME model, affecting all three E's: economy, energy and environment. The model's endogenous technical progress indicators (TPIs), a function of R&D and gross investment, appear in nine of E3ME's econometric equation sets including trade, the labour market and prices. Investment and R&D in new technologies also appears in the E3ME's energy and material demand equations to capture energy/resource savings technologies as well as pollution abatement equipment.

## The FTT models

In addition to the treatment of technology through TPIs, E3ME also captures low carbon technologies in the power, transport and residential heating sector through its interactions with the Future Technology Transformation (FTT) models which measure the substitution of technologies in response to changes in costs (both purchase and operational). These models can better assess shifts in technology, and the impact upon energy demand/emissions, than a simple (linear) elasticity of demand, as found in many macro models.

The FTT models have a number of important characteristics:

- Investors are modelled according to a distributed curve of preferences (i.e. investors are heterogenous, with different willingness to adopt new technologies)
- The models do not model specific non-market barriers (i.e. split incentives in rented properties which dramatically reduce the take-up of new technologies, even when they have cheaper levelized costs)
- The models assume that technologies are perfect substitutes (e.g. that a heat pump can be 'dropped in' as a replacement to a gas boiler in all

circumstances, and without considering the need for energy efficiency to reduce peak heating need)

- The responsiveness to changes in technology costs is calibrated based upon historical data

Some of the assumptions (e.g. perfect substitution, lack of non-market barriers) have the potential to lead to over-estimates of the responsiveness to price changes. Therefore, the baseline rates of decarbonisation in these industries are adjusted to ensure that the model is producing results in line with other studies.

*Road transport*

For passenger car transport, which accounts for by far the largest share of transport emissions, FTT:Transport provides a range of policy options. FTT:Transport assesses the types of vehicles that are purchased in three size bands (small, medium and large) and several technology classes (including basic and advanced forms of ICE, hybrid and electric cars). The policy options cover ways of differentiating costs between the different vehicles (either in terms of capital costs through variable taxation or fuel/running costs) or regulations on the sales of certain types of vehicles (e.g. phasing out inefficient old cars).

Biofuel mandates can also be imposed. These are modelled as a means of forcing a switch from consumption of motor spirit to consumption of biomass.

E3ME does not include any means for assessing mode switching, however, if the effects of mode switching can be estimated off-model, then the model could then estimate the indirect effects on the wider economy.

*Household heating*

FTT:Heat is a tool that was developed for European Commission work in 2016/17. Rather than assuming that the energy efficiency happens (e.g. due to public mandate), it provides a range of policy options for heating appliances (e.g. boilers, heat pumps) including subsidies, specific taxes or phase-out of old products. It thus assesses the take-up rates of the different technologies around the world.

The basic philosophy of FTT:Heat is similar to the other FTT models. Technologies diffuse according to how well they are established in the market, which is based on price differentials and other policy stimuli.

## The implications of using this modelling framework for this analysis

The use of these modelling tools, and in particular the FTT models to assess changes in demand for specific technologies in response to changes in fuel costs, has specific implications for the analysis. Using these models, we can better assess the long-term responsiveness of these sectors to changes in the costs of specific technologies, since we are able to capture changes in purchasing decisions, rather than simply assessing the short-term elasticity (which is dominated by a change in demand for the final output in response to price changes, rather than changes in the technology used). This approach also allows for non-linear responses, i.e. for elasticities to change, which is a key critique of the standard approach, where a single coefficient is estimated based on historical data.

However, these models also make some simplifying assumptions which could conversely lead to the over-estimation of elasticities. In particular, the models assume that technologies are perfect substitutes (e.g. a heat pump can be ‘dropped in’ to replace a gas boiler, while in most cases substantial energy efficiency improvements are required to a property in order to shift to a heat pump for heating) and a lack of non-market barriers (e.g. split incentives in rented properties which severely depress the take-up of low-carbon heating technologies in this type of building).

The approach taken through the combination of E3ME and FTT models is a more detailed top-down approach; but while the FTT models do not treat consumers as a homogeneous mass (a typical shortcoming of macro models), they fail to take into account the full details of specific individual investment decisions in the way that a bottom-up stock model might. This modelling should not be interpreted as a perfect representation of these sectors, but as a less simple representation than is typically included in macro models.