Climate Change Committee

Economic impact of the Sixth Carbon Budget

cambridge econometrics
clarity from complexity

Final Report

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Contents

Executive Summary

- **Our research finds that meeting the recommended Sixth Carbon Budget on a pathway to a net-zero carbon economy by 2050 would raise economic prosperity: over the period 2020-2050, GDP would be around 2-3% higher supporting around 300,000 additional jobs.**
- This study assesses the economic impact of a transition to a net-zero carbon economy. We apply Cambridge Econometrics' proprietary E3ME model of the world's major economies to compare the economic indicators in two scenarios. In the first scenario the Climate Change Committee's (CCC's) recommended sixth carbon budget is met and the UK economy heads towards a net-zero carbon economy by 2050. This is compared to a baseline scenario which only extends current climate and energy policies.
- The modelling research shows that, despite there being an overall cost in rolling out the technologies to reduce carbon emissions especially in the earlier part of the projection period, we see an increase in economic prosperity, in terms of an aggregate pick up in GDP, jobs and real disposable incomes. This comes about because:

- The transition to a low carbon economy requires that investment is brought forward into capital-intensive (rather than energy-intensive) technologies. This private and public investment stimulus makes use of spare capacity in the economy (unemployed resources) and therefore increases the level of output (GDP)
- A particular feature of the UK economy is the high proportion of imports in the supply of oil and gas. As the economy transitions from ongoing spending on imported oil and gas in favour of low-carbon domestic investments, leakage from the UK economy is reduced and the implied economic multiplier increases, leading to increases in GDP and employment
- Of dynamic innovation, as low-carbon technologies are invested in at scale the costs fall significantly. The cost of renewable energy technologies has already fallen significantly beyond most expectations. We now expect electricity prices to be considerably lower at the end of the projection period (2050) than in the higher carbon baseline

- The increased level of economic output, as measured by GDP, creates demand for additional employment. Over the projection period employment is around 1% higher, equivalent to around 300,000 jobs. This figure represents a ***net*** increase in employment, recognising that there is a reduction in employment in some sectors, such as refining, and an increase in others that support the low carbon transition such as manufacturing and construction. Much of the increase in net jobs is simply a result of a stronger economy.
- At a broad level, we find that the scenario that meets the sixth carbon budget could be slightly more progressive than the baseline scenario, with real income increasing most in the lowest two quintiles because of lower electricity prices.
- For the purposes of this modelling exercise, we ensured that there was government budget neutrality between the two scenarios, by offsetting any

additional public spending increases with increases in tax. In other words, the increase in GDP between scenarios is not a result of a fiscal stimulus since the net fiscal position is the same in both scenarios.

- The overall scope of this study is limited. We have investigated only one possible pathway to net zero and the robustness of the findings has not been tested against uncertain external factors. The economics of a transition needs a much wider investigation to assess the plausibility of the complete restructuring of the economy: can the workforce be re-skilled and re-employed, what are the economic consequences for local areas within the UK, what could the contribution of public finance be and how might that change the economic outcomes?
- Despite these shortcomings, we are confident that investing in a transition to a low-carbon economy would increase overall economic prosperity. Moreover, given a likely continued slowdown in the UK economy because of Covid-19 and Brexit, there is more scope than ever for a green economic stimulus. During these times of higher unemployment and low interest rates, there is a strong economic rationale for the government to invest heavily to bring about the transition directly. This would lead to an even faster transition and stronger economic performance. The time to invest is now.

1 Context and Rationale

1.1 Context

Introduction to this report

In December 2020, the Climate Change Committee (CCC) set out its recommendation for the sixth carbon budget, the latest recommendation in setting a pathway for the UK to become a net-zero carbon economy by 2050. As part of that analysis the CCC commissioned Cambridge Econometrics (CE) to provide this research on the economic implications of meeting the sixth carbon budget and following a pathway to net-zero emissions by 2050.

The carbon budget recommendation comes during an unprecedented shock to the UK economy, as economies around the world grapple with the Coronavirus pandemic. The recession brought about by the pandemic, which is likely to ensue for some time to come, risks dividing the discussion on the economics of climate change into two camps: those who argue that we cannot afford to take action at this time and those who argue that an economic recovery package must be a green recovery package. In this report we shed some light on that discussion.

At a global level, countries are improving on their ambition to reduce carbon emissions over the next few decades. The EU has set out climate targets for 2030 to reduce greenhouse gas emissions by at least 55% on 1990 levels[1] and has tied part of its Coronavirus recovery package[2] to investing in climate change mitigation measures. China surprised the global environmental community in the autumn of 2020 by committing to being carbon neutral by 2060. If these ambitions are met, it could substantially reduce the cost of action for other countries because both China and the EU have the power to transform markets for new technologies and, in doing so, lower the cost for everyone.

1.2 Rationale for the research

The CCC has, until now, relied on an economic measure called the direct resource cost to assess the economic implications of transitioning to a low, and now zero, carbon economy. The direct resource cost is a sensible indicator for the CCC to monitor; it represents the extra cost of the technological transition from a high-carbon economy to a low-carbon economy. The CCC has calculated this cost to be less than 1% of GDP for a transition to the recommended Sixth Carbon Budget and Net Zero by 2050. However, the direct resource cost is an abstract concept that does not obviously relate to standard economic indicators[3], such as GDP, and is even further removed from people's everyday economic experiences, such as the (relative) prices of goods and services to their incomes, or job opportunities

[1] https://ec.europa.eu/clima/policies/eu-climate-action/2030_ctp_en

[2] https://ec.europa.eu/info/live-work-travel-eu/health/coronavirus-response/recovery-plan-europe_en

[3] For a further explanation, see p25 https://www.theccc.org.uk/wp-content/uploads/2019/05/Advisory-Group-on-Costs-and-Benefits-of-Net-Zero.pdf

and job security. This research will assess the implications of the sixth carbon budget against these wider indicators of economic prosperity.

Moreover, the direct resource cost measure offers nothing about the social fairness of a transition to a zero-carbon economy. It is difficult to advocate for a transition to net zero if the costs disproportionately fall onto those who can afford it least. Not only would that be unfair but it also risks being a barrier to the transition as we saw with the gilet jaune movement[4] in France in 2019.

1.3 Objectives of the research

The two objectives for this research are:

1) To assess the macroeconomic implications of meeting the recommended sixth carbon budget.
2) To draw out social indicators and comment on the fairness of the economic transition.

1.4 Report Structure

In the next section of the report, we set out our broad approach to scenario modelling using the E3ME economic model. In Section 3 we discuss the findings of the modelling analysis and the implications for the sixth carbon budget. The final section discusses the limitations of the analysis and offers the authors' own conclusions based on this, and related, research.

[4] https://en.wikipedia.org/wiki/Yellow_vests_movement

2 Approach

2.1 Overview

Our approach

Our approach is to build on the analysis already undertaken by the CCC. We construct two scenarios for energy demand and greenhouse gas emissions, which we are assessed in the macroeconomic model E3ME.

The two scenarios, described in further detail in Section 2.2, are:

- A baseline scenario (current policies[5] are pursued, leading to limited further reductions in carbon emissions)
- The recommended sixth carbon budget (6CB) scenario (the recommended sixth carbon budget is met setting a pathway to a net-zero carbon economy by 2050)

The economic implications of transitioning from one scenario to another are described by the differences between the economic variables in each scenario. We calculate these differences in an economic model that can simulate these futures and allow for an internally consistent comparison between scenarios. We have applied CE's proprietary E3ME model to do this (described in further detail in Section 2.3).

Basic objectives

The aim of the modelling exercise is to determine whether the economy will be better or worse off because of the structural transition, over time, from a high-carbon economy to a low-carbon economy. At the first level we take GDP to be the main indicator of economic prosperity. However, GDP as a standalone indicator is limited and so we also aim to determine the implications for other indicators, such as employment, trade, prices, and social factors such as income distribution.

It is (far) beyond the scope of this research to consider the economic impacts of a changing climate on economic prosperity. In the baseline, therefore, we do not attempt to estimate the economic cost of a changing climate from (global) inaction.

2.2 Scenario descriptions

For the baseline scenario, E3ME has been calibrated to the 2016 EU Reference case that was developed using the PRIMES energy system model (UK and EU countries only). For non-European countries, we matched the IEA's *World Energy Outlook* current policies scenario (2019). The UK projection has been adjusted to reflect the power generation mix in the CCC's baseline.

For the sixth carbon budget (6CB) scenario we modelled a series of policies put forward by the CCC as indicative measures required to meet the sixth carbon budget pathway, summarised as follows:

[5] Excluding recent announcements such as the Prime Minister's "Ten Point Plan"

- Power generation: Continued investment in renewables and other low-carbon options. Gas-fired power plays only a back-up role and is replaced by hydrogen and carbon capture and storage (CCS) options.
- Surface transport: All new cars, vans and motorcycles are electric by 2032 and heavy goods vehicles shortly after. The demand for road transport is reduced through improved logistics and a shift towards active travel and public transport.
- Industry: CCS clusters operate from 2025, which provides the inertia for investment in the hydrogen industry. Efficiency measures and electrification continues over the whole period to 2050 as the capital stock is replaced.
- Agriculture and land use: consumers' diets change away from the most carbon-intensive products (i.e. beef, lamb and dairy). Farmers increasingly take up low-carbon farming practices and use low-carbon machinery. Marginal land and some pasture freed up by changing diets is reallocated to afforestation and bioenergy production; peatlands are extensively restored.
- CO_2 removal: As well as land-based sequestration through forests and peatland, engineered removals scale up from the early 2030s, largely through bioenergy with carbon capture and storage (BECCS).
- Aviation: Improvements to efficiency, both technical and operational, more than offset passenger demand growth, which is below BAU levels. Biofuels increase to a 10% share. Synthetic fuels are not expected to play a major role in this scenario, so emissions remain well above zero by 2050.
- Shipping: Falling demand for oil and gas reduces demand, along with some logistical gains. The industry improves efficiency and switches over to ammonia fuel (based on low-carbon hydrogen).
- Waste: Behaviour changes reduce the amount of waste arisings, and disposal shifts away from landfill and incineration, with a major increase in recycling.
- F-gases: Use of F-gases is phased out over time.
- Hydrogen: A market for low-carbon hydrogen emerges from 2025 onwards, reaching around 300 TWh per year by 2050.

In each sector, detailed policies were implemented to simulate these broader narratives. These are described in Appendix A.

2.3 Other assumptions

To undertake the modelling, it was necessary to make a series of further assumptions, some broad and others very specific:

- That there is no additional climate action in the rest of the world beyond that captured by the E3ME baseline.
- The economic implications of COVID-19 are not captured (uncertainty was too high at the time of modelling).
- Hydrogen demand is wholly serviced by a UK based hydrogen industry

- Investments in Agriculture, Aviation, Shipping, and Non-residential Buildings are paid for by businesses in those sectors.
- Investments in Residential Buildings, Industry, Surface Transport, F Gas, LULUCF, and Waste are publicly financed.
- Government raises tax rates (income tax and employers' social security rates) so that there is government budget neutrality between the scenarios.
- Electricity investment requirements are paid for by changes in the outturn electricity prices, calculated in the E3ME model reflecting the power capacity and generation described in the scenarios.

2.4 The E3ME model

E3ME is a computer-based model of the world's economic and energy systems and the environment. It was originally developed through the European Commission's research framework programmes and is now widely used in Europe and beyond for policy assessment and for research purposes. A technical model manual of E3ME is available online at www.e3me.com.

E3ME is often used to assess the impacts of climate mitigation policy on the economy and the labour market. The basic model structure links the economy to the energy system to ensure consistency across each area.

As a global E3 (energy, environment, economy) model, E3ME can provide comprehensive analysis of policies:

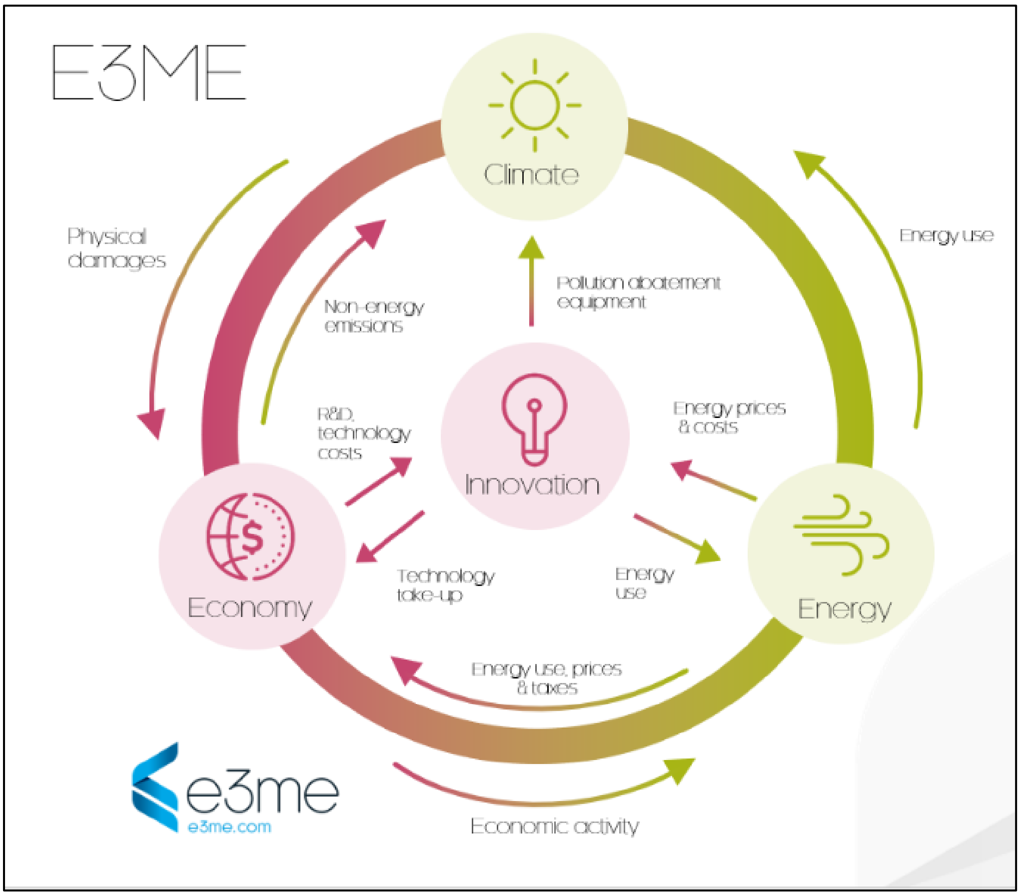
- direct impacts, for example reduction in energy demand and emissions, fuel switching and renewable energy
- secondary effects, for example on fuel suppliers, energy prices and competitiveness impacts
- rebound effects of energy and materials consumption from lower prices, spending on energy or higher economic activities
- overall macroeconomic impacts; on jobs and the economy including income distribution at macro and sectoral level

Theoretical underpinnings

Economic activity undertaken by persons, households, firms and other groups in society has effects on other groups after a time lag, and the effects persist into future generations, although many of the effects soon become so small as to be negligible. But there are many actors and the effects, both beneficial and damaging, accumulate in economic and physical stocks. The effects are transmitted through the environment (with externalities such as greenhouse gas emissions contributing to global warming), through the economy and the price and money system (via the markets for labour and commodities), and through the global transport and information networks. The markets transmit effects in three main ways: through the level of activity creating demand for inputs of materials, fuels and labour; through wages and prices affecting incomes; and through incomes leading in turn to further demands for goods and services. These interdependencies suggest that an E3 model should be comprehensive and include many linkages between different parts of the economic and energy systems.

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.

Figure 2.1: Overview of Cambridge Econometrics' E3ME model



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 and rebound effects, which are included as standard in the model's results.

Basic Structure and data used

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 1970-2018 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 E3ME are:

- 61 countries – all G20 countries, the EU27 and candidate countries plus other countries' economies grouped
- 70 industry sectors, based on standard international classifications
- 43 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

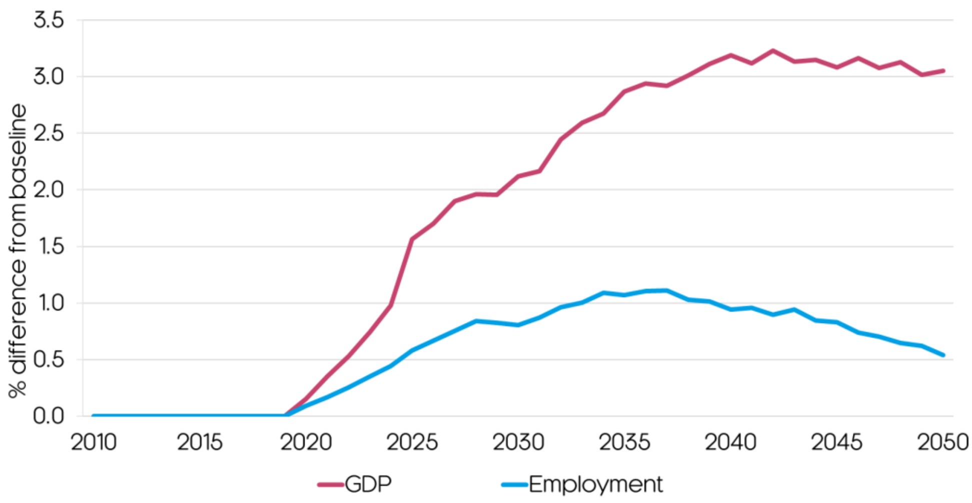
3 Socio-economic impacts

3.1 Summary findings

GDP impacts

We find that a transition to a net-zero economy, as described by the CCC's scenario for the sixth carbon budget (6CB), would lead to an ***increase*** in GDP of about 2-3% over the period from now, through 2030, to 2050 (see Figure 3.1).

Figure 3.1: GDP and employment



Jobs and incomes

In turn, the overall economic boost leads to increases in jobs with employment higher by around 1% (300,000 jobs) in the 6CB scenario compared to the baseline. This figure represents a net increase in employment, recognising that there is a reduction in employment in some sectors, such as refining, and an increase in others that support the low carbon transition such as manufacturing and construction. Much the increase in net employment is simply a result of a stronger economy.

As a package of measures, the 6CB is mildly progressive compared to the baseline, such that income inequality narrows slightly despite every income group being better off. It is worth noting that for the purposes of this modelling exercise, we ensured that there was government budget neutrality between the two scenarios by offsetting any government spending increases with increases in tax receipts over the thirty year projection period.

3.2 Understanding Direct Resource Costs and the GDP impact

Estimating costs

The typical narrative around climate change mitigation action sets taking any action to reduce carbon emissions against the economy, with an implication that any action leads to negative impacts: the ***costs*** of decarbonising the economy.

This idea is reinforced using the Direct Resource Cost as the principal measure of economic cost. It is an intuitive measure that represents the net cost to companies/households of switching from each high-carbon technology to low or zero-carbon technology options, aggregated across the whole economy.

However, a net Direct Resource Cost does not necessarily imply a negative impact on GDP. There are two reasons for this:

- the direct resource cost ignores the changing structure of the economy brought about by the transition
- the direct costs to industry/households are business opportunities to companies in other sectors
- the direct resource cost ignores that any cost is an income to the other party

The transition to a low-carbon economy requires large-scale investment in new technologies. Importantly, across nearly all sectors, low-carbon options are more capital-intensive than the high-carbon baseline scenario options. To meet the 6CB pathway, investments must be brought forward as we invest in these (relatively) high-capital technologies. Two examples illustrate this, first offshore wind has higher initial investment requirements (capital costs) and lower running costs than the fossil fuel alternative of gas-fired power plants which have relatively low capital requirements and higher ongoing operating costs on the required natural gas. Second, electric vehicles have a higher purchase price (capital investment) but because they are considerably more efficient than internal combustion engines the ongoing running costs are significantly lower. The transition to a lower carbon society thus creates an investment demand stimulus that draws upon unused economic resources and leads to an increase in GDP.

Over time, these capital investments must be paid for, and money that is used to repay debts rather than purchase new products depresses economic activity and GDP. In the electricity sector, for example, companies may cover investment costs through higher prices for electricity, spread out over a 20-year period. For private cars, we could see higher financing costs to pay for an electric vehicle initially reducing disposable incomes. Where the investment is publicly funded, governments can decide whether to increase taxes to balance their budgets (and to make fair comparisons across our two scenarios, we assume that they do this) which also reduces aggregate demand and puts downward pressure on GDP.

Given these patterns, we might expect GDP to be initially higher in the 6CB scenario and then for the positive GDP impact to diminish as these investments are paid for over their economic lifetime. However, to reach net zero by 2050, additional capital investments need to be made every year, which are then subsequently paid for over the economic lifetime of the asset.

We see this in Figure 3.1 where the initial GDP impact is strong and then flattens over the projection period.

Comparing our results to Direct Resource Cost

Taking a Direct Resource Cost of around 1% of GDP, we might expect that over the whole period GDP would be 1% lower on average, but we do not find that to be the case for two reasons. First, as noted above, the investment opportunity creates demand for unemployed resources (labour and capital) which are drawn into the economy leading to the increase in GDP (the capital finances the investment, the employment services the increased investment demand without giving rise to inflation). We do not assume that these investments crowd out other investments and empirical analysis also shows that there is spare capacity in manufacturing sectors that can be tapped into[6].

Second, the transition to a low carbon economy necessitates a large reduction in fossil fuel consumption. The UK is a large net importer of oil and gas and the switch from spending money on imported oil and gas in the baseline to new capital equipment[7] reduces the flow of money leaving the UK economy and therefore, implicitly, increases the spending power retained within the UK. As a result, we see an increase in GDP and jobs over the whole period.

Of course, not all measures carry additional cost. Some measures, like energy efficiency measures, will show net direct financial benefits compared to not acting (the baseline). As new technologies reach scale, this is increasingly the case: Low carbon electricity generation is already cheaper than the fossil-fuel-based alternative. Electric vehicles are close to reaching cost parity with internal combustion engines over the lifetime of the vehicle and are expected to become cheaper still.

The positive economic story, therefore, is an outcome of a combination of these factors:

- **Dynamic innovation**: as low, or zero, carbon technologies reach scale, the cost of these technologies falls below the cost of fossil-fuel-intensive technologies. As a result of dynamic innovation, which has already substantially lowered the cost of renewable energy technologies, we expect electricity prices to be considerably lower at the end of the projection period.
- **Debt-financed investment**: we expect a significant amount of capacity in both labour and capital markets (unused capital on balance sheets and unemployed labour) that, brought into the economy through investment to bring about a low-carbon transition, results in increases in GDP and employment.
- **Reduced imports of oil and gas**: a particular feature of the UK economy is the high proportion of imports in the supply of oil and gas. As the economy transitions from ongoing spending on imported oil and gas in favour of low carbon domestic investments, leakage from the UK economy

[6] See: https://ec.europa.eu/energy/sites/ener/files/documents/case_study_2_capacity_constraints_and_macro_performance.pdf

[7] Even if the capital equipment is imported, it still must be installed locally.

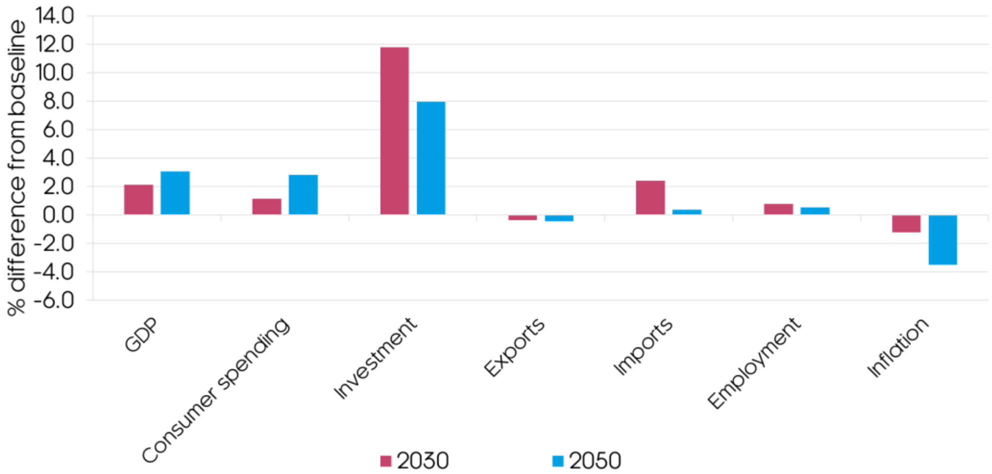
is reduced and the implied economic multiplier increases, leading to increases in GDP and employment (again, drawing on spare capacity).

The persistent effect on GDP out to 2050 arises because of the structural change in the UK economy away from imported oil and gas, which boosts domestic activity, which itself leads to an increase in imports of other goods and services. As a result, imports increase slightly in the long term but fall as a proportion of GDP.

A process of dynamic innovation, which lowers the overall price level relative to the baseline, also contributes to higher GDP through lower inflation.

GDP also remains higher because there are still additional investments being made through 2050 (see Figure 3.2) to bring about the transition.

Figure 3.2: Macroeconomic indicators



3.3 Broad sectoral impacts

The sectoral results show the considerable structural changes within the economy that are hidden by the relatively mild aggregate impacts. Manufacturing & Construction sees a large boost to demand brought about by investment in low and zero-carbon technologies. This effect is stronger initially and becomes more modest over the period to 2050. In contrast, Mining & Refining output falls considerably between scenarios (more than 40% lower by 2050), mostly brought about by the reduction in demand for refined oil in transport. Employment in this sector is relatively less affected because the Refining part of Mining & Refining is less labour-intensive than the wider sector. The remaining output in this sector is non-energy mining.

In Services, and Distribution, Retail, Hotels & Catering, output increases in response to the initial investment and the multiplier effect stimulated by that investment, directly leading to higher intermediate spending (businesses buying more intermediary services, such as consultancy, accountancy, legal services, etc) and then indirectly as a result of higher employment, incomes and consumer spending.

For Agriculture, Transport & Communications, and Utilities the results are more complicated to interpret. Initially output is lower in the Utilities sector because of considerable investment in energy efficiency measures. By 2050, however, the increased demand for electricity (and, by 2050, hydrogen) to service the energy needs of the whole economy (heating, power and transport) leads to a considerable increase in output. The large increase in employment reflects a switch towards slightly more labour-intensive (renewable) technologies in the sector, relative to the baseline, as well as the increase in output.

Transport & Communications initially follows the overall story for the economy, again driven by direct business demand indirect increases in consumer demand. In the long term, however, the impact on logistics from lower demand for freight transport means that there is no overall impact on output in this sector.

Agriculture has a higher output over the period, partly because efficiency savings drive prices lower and partly because of the increased demand for food brought about by higher incomes. In the UK, Agriculture is a relatively small sector and therefore this has a relatively small effect on the overall GDP story.

Table 3.1: Sectoral impacts

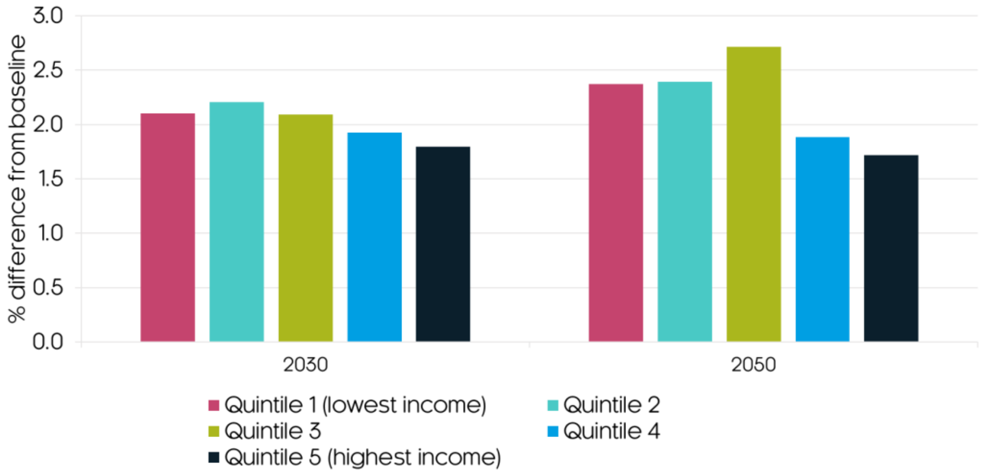
	Output		Employment	
(% difference from baseline)	**2030**	**2050**	**2030**	**2050**
Agriculture, etc	4.5	4.3	4.2	2.9
Mining & Refinery	-19.0	-42.9	-7.8	-11.0
Utilities	20.5	34.6	4.5	35.5
Manufacturing & Construction	7.7	5.5	1.1	0.5
Distribution, Retail, Hotel & Catering	1.3	1.0	1.8	0.9
Transport & Communications	2.4	0.3	2.0	0.1
Services	1.8	1.7	0.2	0.0

3.4 Social indicators

Since economic output is higher in the 6CB scenario than the baseline, it follows that there is an increase in demand for labour. The sectoral composition of the higher level of employment is explained in the section above. Overall, the increase in employment of around 1% means that more than 300,000 people are employed each year over the period 2030 to 2050 than would have been the case in the baseline. The increase in employment is one of the main drivers of the increase in real disposable income, at least in the period to 2030. The subsequent pick up in real income arises from (relatively) lower consumer prices, primarily driven by lower electricity prices.

Taken as a package of measures, the transition to a net-zero economy will not worsen real income inequality (see Figure 3.4). By 2030, all income quintiles see a relative increase in real disposable income of between 1.2% and 1.5%. In 2050, real disposable income is 2.5%-3.0% higher for the three lowest income quintiles, but only around 2.0% higher for the highest two income quintiles, suggesting that the package of measures is slightly progressive.

Figure 3.3: Real disposable income, by quintile



3.5 Public finance

Public finance is likely to play an important role in the transition to a zero-carbon economy: it can stimulate investment and crowd-in private sector investment. For the purposes of this modelling exercise, we ensured that there was government budget neutrality ***between*** the scenarios by offsetting any spending increases with increases in tax receipts. In other words, the increase in GDP between scenarios is not a result of a fiscal stimulus since the net fiscal position is the same in both scenarios. However, during times of higher unemployment and low interest rates, as we are seeing now, there is a strong economic rationale for the government to invest heavily to bring about the transition directly. This would lead to an even faster transition and stronger economic performance at the expense of an increase in government debt.

4 Limitations and conclusions

4.1 Limitations

Uncertainty in the analysis

There is inherent uncertainty in any research that considers the future and because of the limited scope we have not attempted to address this uncertainty.

The scope of the modelling analysis was limited:

- Only one low carbon pathway was assessed and, for the purposes of assessing the macroeconomics, we assume that the measures to reduce carbon emissions are implemented effectively.
- No attempt is made to deal with major uncertainties, such as:

- fossil fuel prices
- action in other countries
-radical uncertainties (pandemics, financial crisis, etc)

- The distributional analysis is relatively simple, looking only at real income distribution by quintile.

Ignoring these factors means that the detailed results should be interpreted as indicative only; we can only draw broad conclusions from the analysis. For example, we do not know from this analysis whether a more market-based transition or a publicly-financed transition would be better for economic prosperity or equality. We also do not know if the results would be robust in a world of ultra-low oil and gas prices.

Moreover, the research scope could be expanded to supplement the modelling analysis. One factor would be to look at the local economic implications of a transition in the various regions and cities of the UK. Can we identify local areas that are vulnerable to the transition, can they be supported and at what cost? A second factor would be to look in more detail at the structural changes in the economy and the implications for the jobs market. The quantitative modelling analysis assumes that people can easily move across the UK and between sectors. This is a reasonable assumption over the 30-year time horizon being assessed, but there could be skills gaps that prevent the transition from happening. Sharp economic declines in certain sectors, occupations, or entire regions, if not managed, could dent public confidence in the transition even if there are net economic benefits.

4.2 Conclusions

Despite the limitations of the research, the implications of this modelling analysis are clear: economic prosperity in the UK would be increased by meeting the sixth carbon budget, in the manner set out by the CCC and in pursuing a longer-term transition to a net-zero economy by 2050. Based on our wider research on this topic, we expect that this finding would be robust to many of the key uncertainties (such as future fossil fuel prices and the costs of low carbon technologies) but this has not been tested specifically here.

The net benefit of action accrues evenly across different income quintiles, with a slightly more progressive outcome in the long term because of lower electricity prices than in the baseline.

Moreover, given a likely continued slowdown in the UK economy because of Covid-19 and Brexit, there is more scope than ever for a green economic stimulus. During times of higher unemployment and low interest rates, as we are seeing now, there is a strong economic rationale for the government to invest heavily to bring about the transition directly. This could lead to a faster transition and stronger economic performance at a time when there will be substantial downward pressure on employment[8].

In summary, although the assessment period for the 6th Carbon Budget remains some way off, current economic conditions provide a unique opportunity to accelerate the transition to a low-carbon economy and meet the specified budget. Ahead of the 2021 Conference of the Parties (COP), due to be held in Glasgow, the UK government has the chance to show global leadership, while simultaneously protecting jobs and livelihoods as we emerge from the Covid-19 pandemic.

[8] https://www.wemeanbusinesscoalition.org/wp-content/uploads/2020/10/Green-Recovery-Assessment-v2.pdf

Appendices

Appendix A Broad policy parameters for CCC 6CB scenario

Introduction

The CCC will advise on the level of the sixth carbon budget in December 2020 and set out potential pathways to meet it. The advice is not intended to be prescriptive either over the exact mix of technologies and behaviours or the best policy options to bring those forward. However, for the sake of modelling it can be necessary to characterise certain policy choices.

This note sets out some possible policy choices that appear broadly sensible and are consistent with the CCC's previous advice to inform such modelling exercises. The note sets out the broad policy 'story' for each sector, with a focus on policies that determine where the costs will fall (rather than e.g. enabling policies to address barriers to take up). The note is intended as a supplementary note to accompany the CCC scenario outputs used directly in the CE modelling.

This note is not to be considered as CCC policy recommendations, but merely to provide guidance to modelling the macro-economic impacts of the CCC's scenarios, ahead of publication of more detailed policy recommendations alongside the CCC advice in December 2020.

Power generation

Scenario story

The CCC scenarios see investment continue to scale up in renewables and other low-carbon options, with gas increasingly pushed into a back-up role and then replaced by hydrogen or CCS (either new build or retrofitted).

Policy

- CfDs are signed at a volume in line with the deployment rates in the CCC scenarios, and the necessary prices to deliver those scenarios (which can be approximated by the assumed costs CCC use).
- Phase-out date: New build unabated gas stations are phased out from 2030, and from 2035 all existing gas stations must switch over to hydrogen or CCS – probably through a regulatory instrument comparable to LCPD or IED.
- Flexibility markets develop to ensure products are rewarded for the value they bring to the system.
- Ofgem approve the investment required in networks at a continuation of historic rates of return.
- A carbon price applies through the ETS and is expected to rise over time, though this is not expected to be a major driver of investments given the presence of the CfDs.

Buildings

Scenario story In the period to 2035 the efficiency of the housing stock is largely upgraded, while the low-carbon heat market scales to take over replacement installations from gas boilers. Initially hybrid systems with gas boilers backing up heat pumps are used, with pure heat pumps (effectively with electric back-up) taking over. New homes are genuinely zero-carbon from 2025. Non-residential buildings move over more quickly to low-carbon heating.

Policy

- Policy costs are spread more evenly across electricity and gas, resulting in lower retail electricity prices and higher gas prices. The Green Gas Levy is broadened to also pay for an increasing penetration of hydrogen initially regionally and ultimately nationally – it funds carbon contracts so that low-carbon hydrogen can be sold below the resulting retail price of gas.
- Grants are provided for heat pumps (e.g. at £4k per installation).
- Energy efficiency is delivered through a mix of grant funding and regulation, with
- Higher grants are available for fuel poor households for both efficiency and low-carbon heating, backed by a strong ECO as the delivery mechanism.
- Increases in network investment are approved by Ofgem, consistent with reinforcement/strengthening and spend levels in the CCC scenarios.
- Phase-out dates: regulation sets dates by when gas/oil boilers can no longer be installed in rented/private/social houses.
- Wider policy addresses barriers such as skills, awareness, compliance/performance.
- Small changes to behaviour (resulting in small reductions in energy use) occur in response to smart meters, which are paid for by suppliers.
- Non-residential buildings see taxation favour low-carbon heating (possibly with increases in CCL) and regulation to ensure a quick switchover.
- In areas with high levels of electrification, some local decommissioning of the gas grid is likely to occur.

Surface transport

Scenario story EV sales scale up to reach 100% of new cars/vans/motorcycles by 2032. HGVs follow soon after. Demand growth is moderated by improved logistics and a shift towards active travel and public transport.

Policy

- Better provision of infrastructure and services alongside changing public attitudes encourage a shift to active travel and public transport, knocking [10%] off baseline miles.
- Efficiency standards are applied in the UK and drive an improvement in the average efficiency of cars sold. A Zero Emissions Vehicle Mandate requires suppliers to increase their share of EVs in their sales to match the trajectory in the CCC scenarios (reaching 100% by 2032).
- Plug-in car grants are phased out as EVs drop in price (e.g. reaching zero around 2025).

- Road pricing replaces fuel duty in the long-term, maintaining HMT revenues from motoring. During the transition EVs continue to benefit from preferential tax treatment both in road pricing and VED.
- Charging infrastructure is largely privately funded, with some additional support from public funds and network spend roughly in line with existing plans.
- Publicly funded trials for low-carbon HGVs in the next decade, alongside international and technical developments inform choices in the longer-run, with conventional HGVs phased out by regulation by around 2040. During the transition, grant funding and preferential tax treatment support increasing uptake.

Industry

Scenario story CCS clusters are up and running from 2025, kicking off a hydrogen economy from then. Efficiency and electrification are taken up throughout the period from now to 2050.

Policy

- Initially, Exchequer funding pays for the added costs of decarbonisation in industry. The initial development of CCS infrastructure (i.e. pipes and stores) is publicly funded.
- Over time there is a transition towards ‘contracts for carbon’, with some capital support from the Exchequer. Product standards require increasing shares of low-carbon industrial products to be used in e.g. UK buildings and public procurement supports early market growth.
- Longer-term (from 2035), a rising carbon price and border adjustment take over as the main mechanisms driving change, supported by continued use of product standards.

Agriculture and land use

Scenario story Consumers shift diets away from the most carbon-intensive products (i.e. beef, lamb and dairy). Farmers increasingly take up low-carbon farming practices and use low-carbon machinery. Marginal land and some pasture freed up by changing diets is reallocated to afforestation and bioenergy production; peatlands are extensively restored.

Policy

- Better information (e.g. labelling), changing attitudes, nudges (e.g. wider provision of alternatives) and public procurement (e.g. in schools, hospitals and public premises) drive the change in diets.
- ELMS payments continue the funding level under CAP but are redirected to encouraging lower-carbon farming practices (and other public goods).
- Carbon sequestration through forestry and peat restoration is supported by carbon payments. These are paid for by a levy on either fossil fuel supply or aviation.

CO_2 Removal

Scenario story As well as land-based sequestration through forests and peatland, engineered removals scale up from the early 2030s, largely through bioenergy with carbon capture and storage (BECCS), potentially supplemented by direct air capture (DACCS).

Policy

- Engineered removals receive carbon payments.
- In early years, capital grants support CCS infrastructure development and early removals projects benefits from longer-term carbon contracts.
- Funding is provided by remaining fossil fuel use, by 2050 primarily in aviation.

Aviation

Scenario story Improvements to efficiency, both technical and operational, more than offset passenger demand growth, which is below BAU levels. Biofuels increase to a 10% share. Synthetic fuels are not expected to play a major role in the central CCC scenario, so emissions remain well above zero in 2050.

Policy

- Demand growth is moderated by changing attitudes and increased costs of flying driven by increased taxation. Any airport expansion is offset by fewer slots available elsewhere so that capacity is somewhat constrained overall.
- ICAO successfully introduces emissions trading internationally, with a cap that reaches net-zero by 2050 – requiring the aviation sector increasingly to purchase CO_2 removals. If ICAO does not succeed, the UK replicates its effect by increasing taxation and channelling revenues to CO_2 removal.

Shipping

Scenario story The industry improves efficiency (including some logistical gains) and switches over to ammonia fuel (based on low-carbon hydrogen).

Policy

- IMO strengthens its existing ambition to a 100% emissions reduction by 2050. If IMO progress is slow then a carbon price may be introduced.

Waste

Scenario story Behaviour changes reduce the amount of waste arisings, and disposal shifts away from landfill and incineration, with a major increase in recycling.

Policy

- Increases in landfill tax.
- Greater funds for waste collection, which is spent on universal collection of separated waste streams.
- Stronger producer responsibility rules drive the move towards a circular economy.
- Approvals are not issued for new waste incinerators and existing facilities are supported, then required, to fit CCS.

F-gases

Scenario story Use of F-gases is phased out over time.

Policy

- Regulation prevents use of F-gases in an increasing range of applications.

Hydrogen

Scenario story A market for low-carbon hydrogen emerges, reaching around 300 TWh/year by 2050.

Policy

- Government support incentivises the production of low-carbon hydrogen in the early stages, likely via a stylised CfD (or equivalent). This allows hydrogen to compete on an equal footing with other low-carbon options like electricity, bioenergy and CCS.
- As demand for hydrogen scales up (driven by industry, then later the power and shipping sectors) a traded low-carbon hydrogen market emerges, both in the UK and internationally.