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Projections of UK CO_2 emissions and assessment of the economic impacts of carbon budgets, Ref RMP/4973

A report for the Committee on Climate Change

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Contents

Executive Summary

Background to the study

- Cambridge Econometrics (CE) was commissioned by the Committee on Climate Change (CCC) for the project 'Consultancy services to project UK CO_2 emissions and assess the economic impacts of carbon budgets, RMP/4973'. This report presents projections from CE's integrated MDM-E3 model of energy demand, CO_2 emissions and economic (macro and sectoral) variables from reference scenarios[1] and under abatement scenarios specified by the CCC. The report also presents disaggregated energy demand and CO_2 emissions for England, Northern Ireland Scotland and Wales.

The MDM-E3 model

- MDM-E3 retains an essentially Keynesian logic for determining final expenditures, output and employment. The principal difference, compared with purely macroeconomic models, is the level of disaggregation and the complete specification of the accounting relationships in supply and use tables required to model output by disaggregated industry.

- MDM-E3 includes a detailed treatment of energy demand by 'fuel user' (for example, industries, households, transport) and by detailed fuel, measured in energy units. The model uses empirically-based estimates for its parameters governing the response of fuel users to changes in the price of fuels. The use of energy in power generation has its own treatment in which decisions to build and take supply from different kinds of power plant (using different fuels) are based on the projected cost of fuels and market-based policy instruments.

The scenarios

- A number of scenarios were developed. This report focuses on the comparison between an abatement scenario (ABATE1.1) which includes a range of carbon abatement measures, and a 'central reference' scenario (REF1), which excludes them. Both cases use the same central set of assumptions for fossil fuel prices.

- REF1 represents a state of the world in which only a minimal set of carbon abatement policies (those announced before the Energy White Paper) are in place; there is no EU ETS, and the ambitions of international agreements and overseas mitigation policies are no stronger than in recent history.

- In ABATE1.1 the following are assumed:
    - a revised profile for the capacity and electricity generated from renewables to achieve the UK's renewables target
    - carbon prices and caps on emissions from activities that are regulated by the EU ETS and caps on emissions that are not, so that overseas emissions credits can be used to reduce the net emissions of the UK

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[1] In this report, a 'reference' scenario is one that excludes the carbon abatement measures whose impact is assessed by comparison with the results of one or more 'abatement' scenarios. More than one 'reference' scenario was developed, reflecting different assumptions for world fossil fuel prices. These were developed to help inform comparisons with the projections from the BERR model.

- energy savings and fuel switching resulting from measures identified in the CCC's marginal abatement cost (MAC) curves
- auctioning of EU ETS allowances and mechanisms to recycle the revenue
- policies with similar impacts on output prices are pursued in the rest of the EU

Impact on energy and emissions

- Chart ES.1 shows the projections of CO_2 emissions under REF1 and ABATE1.1. The UK's net CO_2 emissions (including the net purchase of overseas emissions credits) in the abatement scenario in 2020 are projected to be 40% below the projected level in REF1, and also 40% below the 1990 level. Excluding net purchases of overseas emission credits, CO_2 emissions in the abatement scenario are projected to be 30% below the projected level in REF1 and the 1990 level. The contribution that the abatement policies make to curbing emissions is not significantly altered in a world with higher fuel price assumptions.

- Chart ES.2 shows the estimates of emissions reductions in ABATE1.1 (on the net carbon account basis) from various causes in 2020. More than three quarters of the emissions reduction projected in ABATE1.1 is due to reductions in final energy demand and the decarbonisation of the energy supply system and production processes. Of these, the reduction in final energy demand causes the greater reduction. The remainder is due to purchases of overseas credits.

- The projections of UK energy demand and CO_2 emissions were disaggregated to produce projections for England, Northern Ireland, Scotland and Wales. In ABATE1.1, emissions reductions in Northern Ireland and Wales are projected to exceed the UK average, while emission reductions in Scotland are projected to be lower than the UK average. These differences mainly reflect the scope for cuts in emissions from the power generation plants in each area.

Economic impact

- The abatement measures lead to a ¾% fall in GDP in 2020 compared with the level in the reference scenario. The projected reduction in GDP is caused by the carbon price from the EU ETS, the additional increase in electricity costs and prices caused by the adoption of more renewables generation technology, and the increase in the price of imports from EU member states. The consumer price index is projected to be raised by 3¾% in 2020. The scenario does not assume any change in monetary policy to curb higher inflation, but the increase of 3¾% in the level in 2020 implies only a modest increase in the annual rate of inflation.

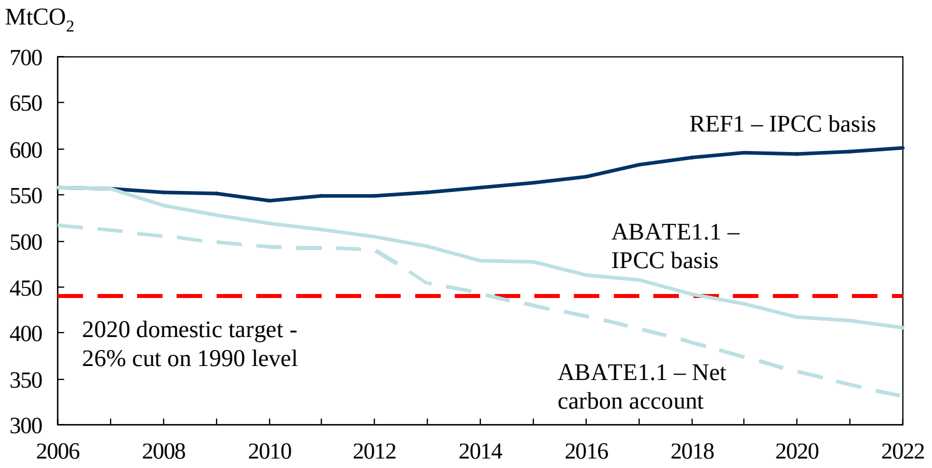
- Because part of the impact on GDP arises from the carbon price in the EU ETS, the way in which these revenues are treated affects the outcome for GDP. In the main abatement scenario, it was assumed that the EU ETS allowances are auctioned and that the revenues are recycled directly to household incomes.

- A policy of recycling revenues by reducing the rate of employers' national insurance contributions increases slightly the impact on GDP (because in this scenario the leakages are higher due to higher tax revenues from higher wages and industry profits).

- The economic impact of the abatement measures does not change much in a world of high fossil fuel prices. The higher carbon price results in a slightly larger boost to consumer prices, but the compensation effect of recycled revenues is also greater because the EU ETS auctioning revenues are larger.

- The sectors of the economy which see the largest impact on their output in the abatement scenario are, of course, the energy production sectors themselves, since the abatement measures reduce energy demand directly. Other sectors that see larger reductions include air transport, which faces higher costs due to its assumed inclusion in the EU ETS from 2013, and consumer-oriented sectors which are most exposed to the projected reduction in housing spending in the scenario. The smaller impacts on the remaining sectors of the economy reflect their smaller exposure to household spending and higher energy costs. Even, the EU ETS manufacturing sectors do not suffer particularly large reductions in value added because the impact on their competitiveness is partly shielded by the assumption of similar action in the rest of the EU.

CHART ES.1: PROJECTED UK CO_2 EMISSIONS

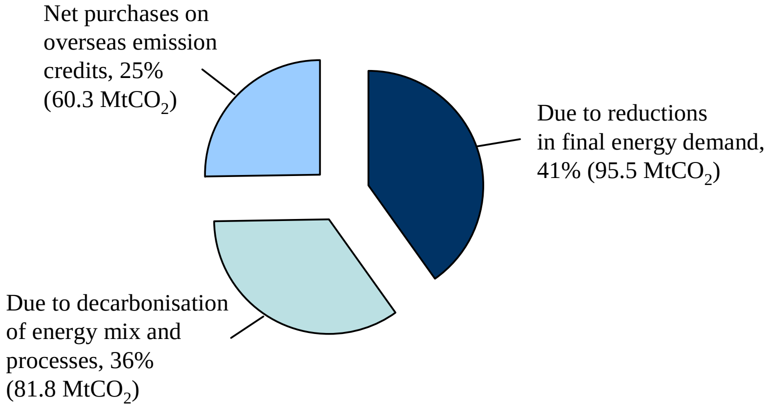


Note(s) : 1. Includes emissions from non-energy uses.
2. Excludes emissions from international travel and land use, land use change and forestry.

Source(s) : NAEI, DEFRA, BERR (DUKES 2007), Committee on Climate Change Secretariat and Cambridge Econometrics.

Ref : C82R1CCC, C82AB83MVAICCC.

CHART ES.2: BREAKDOWN OF CAUSES OF CO_2 EMISSION REDUCTIONS IN ABATE1.1, 2020



Note(s) : 1. Excludes emissions from international transport.
2. The estimate due to reduction in final energy demand was found by applying the average emission factor in REF1 to the difference in final energy demand in the scenarios. The estimate for the reduction due to decarbonisation was found by applying the difference in the average emission factor in the scenarios to final energy demand in ABATE1.1.

Source(s) : Cambridge Econometrics.

Ref : C82R1CCC, C82AB83MVAICCC.

1 Introduction and background

1.1 Introduction

1.1.1 Cambridge Econometrics (CE) was commissioned by the Committee on Climate Change (CCC) for the project 'Consultancy services to project UK CO_2 emissions and assess the economic impacts of carbon budgets, RMP/4973'.

1.1.2 This report presents projections from CE's integrated MDM-E3 model of

- energy demand and emissions
- economic (macro and sectoral) variables

from reference scenarios[2] and under abatement scenarios specified by the CCC.

1.1.3 A number of scenarios were developed. This report focuses on the comparison between the central reference (REF1) and abatement (ABATE1.1) scenarios, although we also discuss alternative projections and sensitivities, notably those based on high fossil fuel price assumptions and alternative mechanisms for recycling the revenues from auctioning allowances under the EU ETS.

Project background and objectives

1.1.4 Among other things, the CCC has been tasked to advise Government on the level of the carbon budgets consistent with meeting the (minimum) 26% CO_2 emission reductions target by 2020 stipulated in the Climate Change Bill. The CCC is also required to assess the macroeconomic and competitiveness impacts arising from the carbon budgets.

1.1.5 The CCC commissioned CE to produce projections from its MDM-E3 model in order to compare outcomes with those from other sources, eg energy projections from the DECC Energy Model[3] and macroeconomic and sectoral projections against a model housed in HMRC.

1.2 Authors and acknowledgements

1.2.1 The main authors of this report are Jamal Tarafdar (Project Manager), Phil Summerton and Richard Lewney (Project Director). Chris Thoung made a substantial contribution to the modelling and the study built upon work undertaken by other members of Cambridge Econometrics.

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[2] In this report, a 'reference' scenario is one that excludes the carbon abatement measures whose impact is assessed by comparison with the results of one or more 'abatement' scenarios. More than one 'reference' scenario was developed reflecting different assumptions for the context given by world fossil fuel prices in the range of low, central, high and high-high.

[3] Before the formation of DECC, this model was housed in BERR.

1.2.2 The authors wish to thank members of the CCC Secretariat for their contributions throughout the project, in particular Alice Barrs and Ajay Gambhir. We would also like to thank AEA Energy and Environment for the help it provided on the use of the national emissions inventory data and Carol Wilson of the Sustainable Consumption and Production Network (SCPNet) for allowing the use of its regional energy and emissions data for this study.

1.3 Contents

1.3.1 The main body of the report has the following structure:

- Chapter 2 discusses the main features of the MDM-E3 model, which has been used to produce the projections.
- Chapter 3 discusses the assumptions that underpin the central reference scenario (REF1).
- Chapter 4 discusses the assumptions that underpin the central abatement scenarios (ABATE1.1 and ABATE1.2).
- Chapter 5 reports the main outcomes from the energy and emissions projections for REF1 and ABATE1.1 including a summary of the projections disaggregated for each of the Devolved Administrations and England.
- Chapter 6 contains a summary of alternative energy and emissions projections to the central reference and abatement scenarios.
- Chapter 7 reports the main outcomes for economic (macro and sectoral) indicators for REF1 and ABATE1.1.
- Chapter 8 contains a summary of the economic impacts (macro and sectoral) from alternative projections to the central reference and abatement scenarios (the same as those referred to in Chapter 6).
- Chapter 9 lists all the references quoted in this report.

Appendices 1.3.2 The report has a number of appendices:

- Appendix A contains a more detailed discussion of the MDM-E3 model, which has been used to produce the projections. This supplements the discussion in Chapter 2.
- Appendix B contains a detailed discussion of the Electricity Technology Submodel.
- Appendix C contains a discussion of the relationship between certain microeconomic concepts relevant to the analysis of climate change mitigation policies and the macroeconomic outcomes, and presents an analysis of the breakdown of the macroeconomic effects arising from the implementation of different elements of the abatement measures.
- Appendix D describes the method used to derive the regional energy and emission projections discussed in Chapter 5.
- Appendix E contains projections of emissions from REF1 and ABATE1.1 of all the greenhouse gas emissions controlled by the Kyoto Protocol.

1.4 Further information

1.4.1 If you wish to discuss further the issues raised in this study, please contact Jamal Tarafdar (jt@camecon.com).

2 The MDM-E3 model of the UK economy

2.1 Introduction

2.1.1 The Cambridge Multisectoral Dynamic Model of the UK economy (MDM-E3) is the UK's most detailed integrated energy-environment-economy (E3) model, designed to analyse and forecast changes in economic structure, energy demand and resulting environmental emissions. The version of the model used in for this project is essentially the same as the one used to produce CE's latest Energy and Emissions forecasts (CE, August 2008). For this study the model has been extended to produce energy and emission projections for each of the devolved administrations and England, and the forecast horizon for the model was extended to 2030.

2.1.2 This chapter gives a brief summary of the principal features of MDM-E3. A fuller discussion is given in Appendix A and the references included there.

2.2 The treatment of the economy

2.2.1 The principal economic variables in MDM-E3 are

- the final expenditure macroeconomic aggregates, disaggregated by product, together with their prices
- intermediate demand for products by industries, disaggregated by product and industry, and their prices
- value added, disaggregated by industries, and distinguishing operating surplus and compensation of employees
- employment, disaggregated by industries, and the associated average earnings
- taxes on incomes and production, disaggregated by tax type
- flows of income and spending between institutions sectors in the economy (households, companies, government, the rest of the world)

2.2.2 Some variables are also disaggregated by government office region and devolved administrations. This applies particularly to value added, employment, wages, household incomes and final and intermediate expenditures. Prices are not typically disaggregated by region, because of data limitations.

2.2.3 MDM-E3 retains an essentially Keynesian logic for determining final expenditures, output and employment. The principal difference, compared with purely macroeconomic models, is the level of disaggregation and the complete specification of the accounting relationships in supply and use tables required to model output by disaggregated industry.

2.2.4 The parameters of the behavioural relationships in MDM-E3 are estimated econometrically over time, within limits suggested by theory, rather than imposed from theory. The economy is represented as being in a continual state of dynamic adjustment, and the speed of adjustment to changes (in, for example, world conditions or UK policies) is based on empirical evidence. There is therefore no assumption that the economy is in equilibrium in any given year, or that there is any automatic tendency for the economy to return to full employment of resources.

2.3 The treatment of energy

2.3.1 MDM-E3 includes detailed treatment of energy demand by 'fuel user' (for example, industries, households, transport) and by fuel, measured in energy units. The use of energy in power generation is given its own special treatment.

2.3.2 Except for power generation, final energy demand by fuel user and fuel is modelled by econometric equations in which the key influences (from the point of view of this study) are the level of activity of the fuel user (for example, the level of output in an industry, or the level of household income) and relative prices (the price of energy relative to the general price level, and the relative prices of the various fuels). A higher level of activity leads to higher energy demand, while higher energy prices discourage energy demand and a change in relative fuel prices induces substitution towards cheaper fuels.

2.3.3 MDM-E3 models the stock of power generation capacity and the annual generation of power from this stock in response to changes to demand for electricity, fossil fuel prices, carbon prices and incentives to increase the use of renewables. Essentially, new power generation capacity is built when the expected demand exceeds projected capacity (taking account of the retirement of plant) plus a margin. The choice of technology for the new plant (and in particular the choice of fuel) depends on a comparison of the projected costs of the available alternatives, including the incentives provided by policy (for example, a carbon price or the renewables obligation). The choice of which existing plants supply electricity in a given year (and hence which fuels are used in power generation) is made on the basis of the fuel prices and policy incentives prevailing in that year. The model adjusts each plant's load factor up or down as more or less generation is required.

2.3.4 The policy measures modelled in this study increase the costs of power generation and increase the incentives to build low carbon plants and to take supply from those plants. The costs are passed on to the users of electricity in the price that they pay.

2.3.5 Allowances to emit CO_2 under the EU ETS are treated as a financial asset whose price is set by assumption. If allowances are distributed freely (for example, on the grandfather principle), the profits of the firms receiving the allowances are increased. If allowances are auctioned, the revenues accrue to government and may be recycled to firms or households by compensating reductions in taxation or increases in government spending. The price charged by firms covered by the EU ETS is not affected by the decision whether or not to auction allowances.

2.4 The treatment of emissions

2.4.1 MDM-E3 covers all the greenhouse gases (GHG) emissions controlled by the Kyoto Protocol, as well as various other air emissions (for example SO_2).

2.4.2 For most energy-related air emissions (including CO_2), emission factors for each fuel and fuel user are calculated using the last year of outturn data for emissions and energy demand. Unless an end-of-pipe technology is available to curb emissions, the emission factors are held constant for the remainder of the projection period and applied to the level of demand for each fuel and fuel user. Thus, CO_2 emissions from energy use depend on the use of each fossil fuel and its carbon content.

2.4.3 Non-energy CO_2 emissions are driven by changes in activity for each of the relevant fuel users. Emissions from land use and land use change are not currently covered in MDM-E3.

3 The central reference scenario (REF1)

3.1 Overview

3.1.1 This project estimated the impact of carbon abatement measures by comparing the results of scenarios that include the measures with a reference scenario that excludes them. This chapter discusses the content of the 'central' reference scenario (REF1) which is based on the CCC's central sets of assumptions for fossil fuel prices and energy savings from government policies. The economic projections for REF1 were calibrated to forecasts of broad macroeconomic activity presented in the 2008 Budget report (HM Treasury, 2008). REF1 does not include the EU ETS carbon price.

3.1.2 Therefore REF1 represents a state of the world in which a minimal set of government policies to promote abatement of CO_2 emissions are in place, there is no EU ETS, and ambitions of international agreements and overseas mitigation policies in the projection period match historical efforts.

Contents

3.1.3 This chapter discusses the assumptions that define the central reference (REF1) and the modelling treatment used to implement them.

- Section 3.2 discusses the economic assumptions used to define the central reference scenario, REF1.
- Section 3.3 discusses the assumptions on action undertaken overseas.
- Section 3.4 discusses the fossil fuel assumptions.
- Section 3.5 discusses the assumptions on power generation.
- Section 3.6 discusses the assumed impact of policy measures.

3.2 Economic assumptions

UK GDP and manufacturing GVA

Broadly, the UK economy is assumed to grow at its trend rate in REF1

3.2.1 The CCC requested that under REF1 the outcomes for growth in UK GDP and manufacturing GVA should be calibrated to forecasts based on those developed for the 2008 Budget report (HM Treasury, 2008) (see Chart 3.1). These forecasts were developed in March 2008, and therefore do not embody the markedly worse economic outlook now in prospect for the next few years. However, since the focus of the analysis here is (a) on the long term, and (b) on the *differences* from base that arise as a result of abatement measures, the fact that the short-term outlook has changed is unlikely to change the conclusions of this report substantively.

3.2.2 Under these assumptions, growth in UK GDP is assumed to slow over the period to 2025. Growth in GDP is assumed to average 2½% pa over 2008-12, just below 2½%pa over 2013-17 and 2¼% pa over 2018-22. By 2025, growth in GDP is below 2% pa. Manufacturing GVA is assumed to be growing at a lower rate than GDP, but with the same trend of slowing growth. Stronger growth is assumed from 2026, with GDP growing by 2¼% pa. In order to produce REF1, MDM-E3 was calibrated to these outcomes in such a way that its economic properties were maintained so as to allow implementation of the economic impacts in the abatement scenarios.

Exchange rate assumptions

3.2.3 The CCC also provided assumptions for the exchange rates that should be used in the scenarios; the $:£ rate was fixed to 2:1 from 2008 and the €:£ rate was fixed to 1.43:1 from 2007.

3.3 Assumptions for actions to reduce emissions outside of the UK

REF1 assumes that action overseas continues to match historical efforts

3.3.1 In REF1 it has been (implicitly) assumed that action overseas in the projection period is the same as that assumed by CE in its most recent Energy and Environment report (Cambridge Econometrics, August 2008). In other words, actions taken by these countries in the recent past are assumed to continue in the projection period, for example continuation of policies adopted by signatories to the Kyoto to meet emission targets for 2012 and/or domestic targets.

3.4 Assumptions for fuel prices

The (real) price of oil is assumed to reach $72 per barrel by 2020

3.4.1 REF1 uses the central set of assumptions published by BERR (2008a) (see Chart 3.2). Under these assumptions, the real wholesale price of oil is assumed to rise by more than 3½% in 2008 and then fall by more than 9¾% in 2009. Thereafter, the price rises throughout the remainder of the projection period, so that by 2020 it is just below $72 per barrel and just below $76.50 per barrel by 2030, both in 2007 prices. The growth in the (real) oil price slows over the projection period: it is rising by almost 1% pa over 2008-12; by below ¾% pa over 2013-17; and by just above ½% pa over 2018-22.

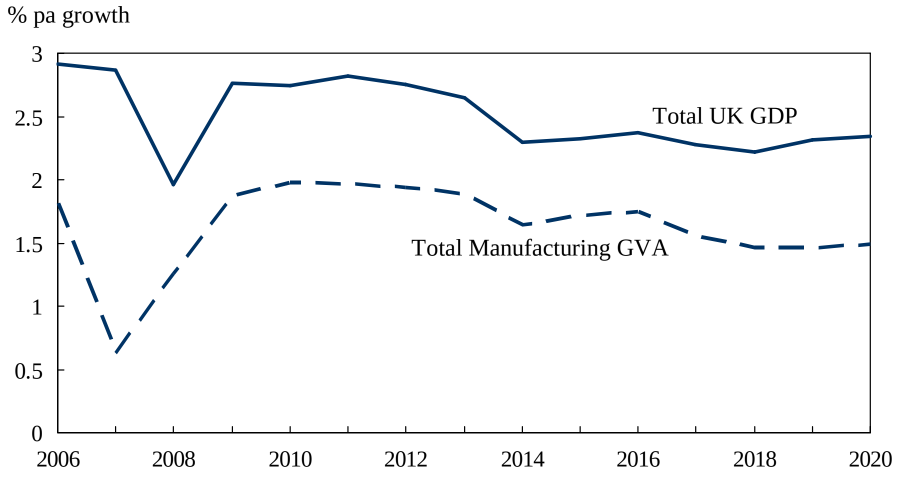
Coal is assumed to be much cheaper than gas

3.4.2 The real price of gas is assumed to rise over 2008-12, but more slowly than the oil price. Coal is assumed to become cheaper relative to gas. By 2015, the real price of gas is more than 3½ times that of coal. This is an important influence on the mix of fuels used for power generation.

3.5 Power generation assumptions

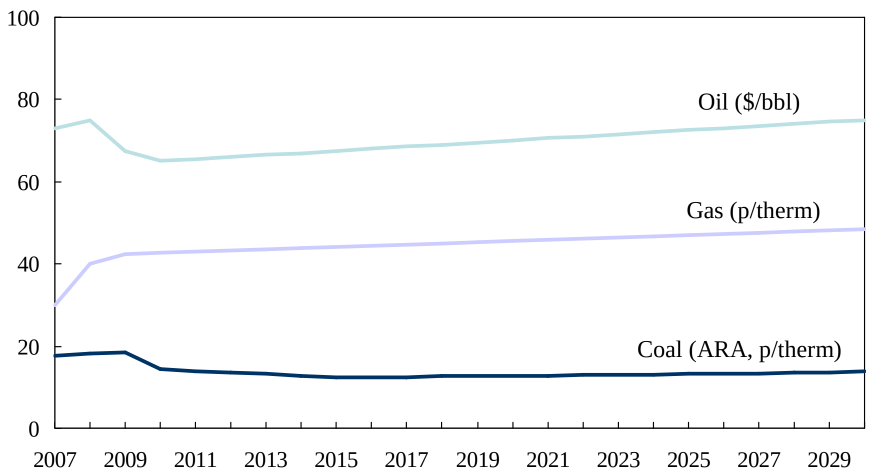
3.5.1 REF1 uses estimates of the (levelised) cost of new power generation capacity provided by the CCC. Chart 4.4 in Chapter 4 shows these cost assumptions. The estimates are based on the central fossil fuel price assumptions and show the cost of building new capacity in 2008, based on a discount rate of 10% pa. These costs do not include the learning curve effects that MDM-E3 normally applies, under which the cost of new technology declines as investment increases.

CHART 3.1: CCC ASSUMPTIONS FOR GROWTH IN BROAD UK MACROECONOMIC ACTIVITY (REF1)



Note(s) : Per annum growth on market (GDP) and basic price (GVA) bases are shown. Both are on chain-value measure.
Source(s) : ONS, Committee on Climate Change Secretariat and Cambridge Econometrics.

CHART 3.2: CENTRAL FOSSIL FUEL PRICE ASSUMPTIONS



Note(s) : 1. The prices are in 2007 terms, adjusted for general inflation thereafter.
2. It is assumed that 1 tonne of coal is equivalent to 250 therms of energy.
Source(s) : Committee on Climate Change Secretariat.

Without the carbon price, the fossil fuel prices imply that new coal plant is the cheapest

3.5.2 As there is no carbon price from the EU ETS in REF1, the assumptions imply that the cost of electricity from a new coal power station built in 2008 (without CCS) is almost 25% lower than from a new gas (CCGT) station. New nuclear plant is 10% cheaper. Coal and gas CCS are around 40% more expensive than gas. These assumptions also imply that on- and off-shore wind are almost double the cost of gas-based generation.

3.5.3 The relative costs (compared to gas CCGT) for technologies for which assumptions were not provided by the CCC (biomass, solar, marine/hydro and oil) were assumed to be the same as used in CE's most recent Energy and Environment report (Cambridge Econometrics, August 2008).

No new nuclear is allowed to be built in REF1 or the abatement scenario

3.5.4 As requested by the CCC, MDM-E3 was constrained so that new nuclear plant is not built either in REF1 or in the central abatement scenarios. The CCC rationale for constraining it in the reference scenario was unrelated to cost but rather that it was thought unlikely to be built in the absence of an appropriate policy framework consistent with concerted effort in reducing CO_2 emissions from power generation. The rationale for the exclusion of new nuclear power in the central abatement scenario was to avoid high penetration of both nuclear and intermittent forms of renewables generation in the period to 2022, since these are suitable only for servicing baseload demand for electricity which is a relatively low proportion of total electricity demand.

The Renewables Obligation (RO) is modelled without banding

3.5.5 As requested by the CCC, MDM-E3 was allowed to calculate the amount of new renewables power generation capacity built in response to the Renewables Obligation (RO). REF1 includes the impact of the non-banded RO so that a uniform level of support is provided to all eligible renewable technologies.

Assumptions made for post 2030

3.5.6 Because the choice of new power generation plant is modelled by forward-looking in MDM-E3, projections for the power sector to 2030 require assumptions for the wholesale electricity price and fossil prices to 2041. For this project, it was assumed that fossil fuel prices remain at the level (in real terms) achieved in 2030 and that the electricity price will broadly follow an extrapolation of the prices projected up to 2030.

3.6 Policy assumptions

Only policies announced in the UK Climate Change Programme Review (2006) are considered

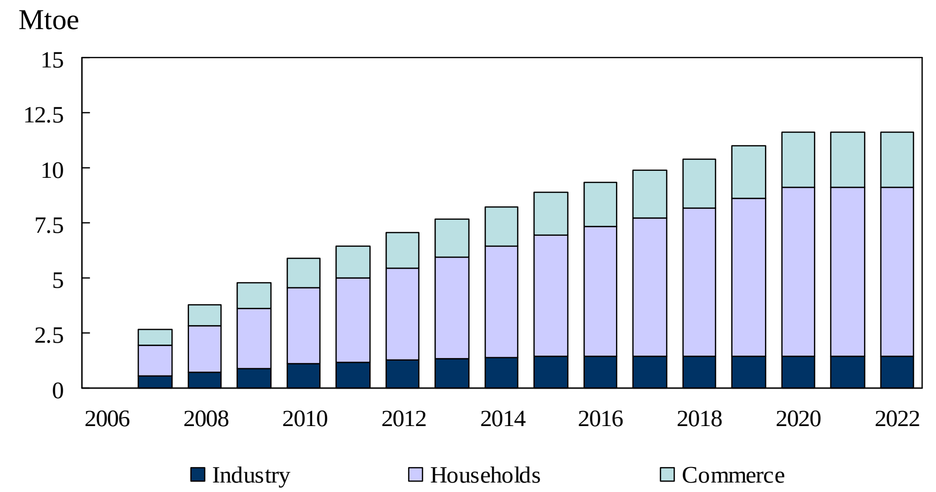
3.6.1 The CCC requested that REF1 use the central assumption for the energy savings and fuel switching expected to follow in response to the policies announced in the UK Climate Change Programme Review (DEFRA, 2006), (see Chart 3.3). These policies and their estimated impact on CO_2 emissions are listed in Table D1 of the May 2007 emissions projections from BERR[4] (BERR 2008b). To introduce these in a manner consistent with MDM-E3's baseline energy use levels, the BERR assumptions were converted to percentage reductions (or increase, in the case of fuel switching) in fuel demand (by each fuel user) using energy use and saving levels provided by the CCC.

[4] These projections are now conducted by DECC.

These policies are assumed to reduce energy demand from households by almost 20% by 2020

3.6.2 Most of the energy savings from the UK Climate Change Programme Review 2006 are assumed to come from households. By 2020, these policies are assumed to reduce household demand for energy by almost 20% (compared to the case when these policies are not in place). For the economy as a whole, more than 75% of the total savings are assumed to be due to a reduction in the demand for gas, and this figure rises to 90% of household energy savings. The policies are assumed to reduce energy demand from commerce (the public sector and the service industries) by just over 10% in 2020 compared with a no-policy case; energy demand from industry is assumed to be 4% lower.

CHART 3.3: CENTRAL ASSUMPTIONS OF ENERGY SAVINGS FROM GOVERNMENT BY FUEL USER (CUMULATIVE)



Note(s) : 1. Energy savings in 2006 assumed to be already captured in the 2006 outturn data.
2. Energy savings after 2020 are held at the level assumed for 2020.

Source(s) : Committee on Climate Change Secretariat and Cambridge Econometrics.

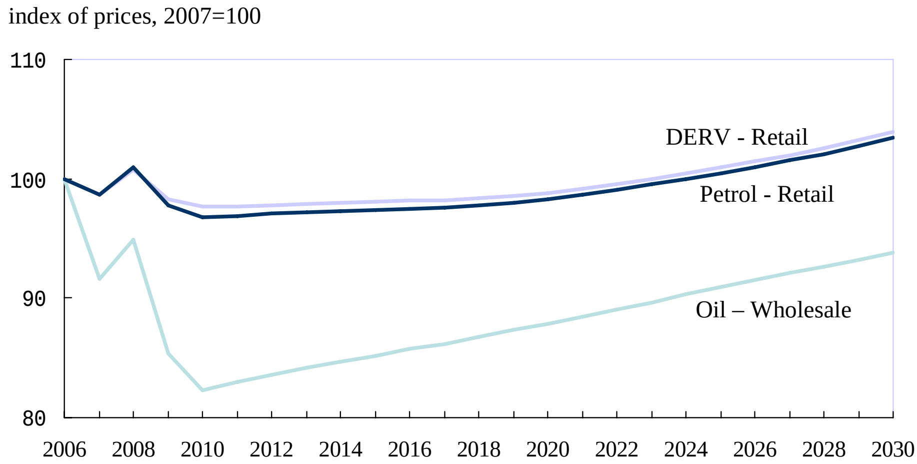
REF1 uses the model's treatment for the Climate Change Levy and fuel duty

3.6.3 As agreed with the CCC, the assumptions for the Climate Change Levy (CCL) and fuel duty are the same as those used in CE's most recent Energy and Environment report (Cambridge Econometrics, August 2008). The CCL is increased by the general level of inflation to maintain its real value in the projection period.

3.6.4 Increases in the level of the fuel duty announced in the Budget 2008 (HMT, 2008) are assumed to occur, including the increase that was due to take place in October 2008 although the government subsequently announced that this would be postponed. Thereafter fuel duties are increased in line with the RPI. Taken together with the assumptions for the world oil price, the effect is that the retail price of petrol and DERV (diesel) rises, but at a rate lower than the that of the wholesale oil price (see Chart 3.4), as this constitutes less than half the retail price.

3.6.5 Biofuels are assumed to supply 5% of road transport fuel by 2011, and it is assumed that this market share is maintained in the remainder of the projection period. Demand for motor spirit and DERV (diesel) is reduced to accommodate the use of biofuels.

CHART 3.4: PROJECTED PRICE OF ROAD FUELS



Note(s) : 1. Prices are deflated to 2007 terms using UK GDP deflator (home unit cost).
2. Retail prices include a 2p rise in fuel duty scheduled for October 2008, which the government has announced it will now postpone.

Source(s) : Committee on Climate Change Secretariat and Cambridge Econometrics.

4 The abatement scenarios (ABATE1.1 and ABATE1.2)

4.1 Overview

4.1.1 Projections for the central abatement (ABATE1.1 and ABATE1.2) scenarios were developed from the central reference scenario, REF1. A number of additional assumptions and measures were adopted in the abatement scenarios. In summary, these were:

- the level of mitigation action undertaken by the remainder of the EU and other countries
- a revised profile for the capacity and electricity generated from renewables to achieve the UK's renewables target
- the level of the carbon price and caps on emissions from activities that are regulated by the EU ETS and caps on emissions that are not
- the scale of energy savings and fuel switching resulting from measures identified in the CCC's marginal abatement cost (MAC) curves.
- the extent of auctioning of EU ETS allowances and mechanisms to recycle the revenue.

4.1.2 The only difference between the two central abatement scenarios is the choice of recycling mechanism for EU ETS auction revenues.

Contents

4.1.3 This chapter discusses the assumptions that define the two central abatement scenarios and the modelling treatment adopted to implement them.

- Section 4.2 discusses the assumptions and modelling treatment for the capacity and generation from renewables that have been imposed in the abatement scenarios.
- Section 4.3 discusses the assumptions and modelling treatment of mitigation action taken overseas.
- Section 4.4 discusses the assumptions for the caps and carbon price of the EU ETS. This section also presents the assumptions for the limits on the volume and prices of Clean Development Mechanism (CDM) credits used to offset emissions from the non-EU ETS sector.
- Section 4.5 discusses the MAC curve measures that have been modelled.
- Section 4.6 discusses the extent of auctioning of EU ETS allowances and the choice of recycling mechanism for the associated revenues.

4.2 Assumptions on action taken overseas

The EU is assumed to achieve a 30% reduction in emissions by 2020

4.2.1 It is assumed that the EU member states achieve their target of a 30% reduction in emissions for total EU CO_2 emissions by 2020. It was (implicitly) assumed that action outside the EU in the projection period matches historical action (which is the same as REF1).

The impact of EU action was modelled through changes in the price of imports

4.2.2 Since MDM-E3 is a UK model, the way in which this assumption for effort in the other member states of the EU has been modelled is to raise the price of imports from these countries to reflect the cost increases that mitigation policies are assumed to bring about. It was assumed that the prices of imports from the EU rise by the same extent that prices rise in the UK due to the carbon price from the EU ETS.

4.2.3 While MDM-E3 distinguishes import prices by product, it does not distinguish import prices by origin. In agreement with the CCC, the weight of the higher price of imports from the EU is taken to be 60%, which reflects the share of imports from the EU. In the modelling, import prices are adjusted to rise by 60% of the rise in domestic prices by 2020.

TABLE 4.1: KEY FEATURES OF THE CENTRAL REFERENCE (REF1) AND ABATEMENT SCENARIOS (ABATE1.1 AND ABATE1.2)

	Reference	Abatement
Broad UK macro economic activity	Budget 2008 forecast	Model determined
Global emission reductions	Historical action assumed to continue	EU meets 30% emission reduction target by 2020 Historical action assumed to continue elsewhere
Fossil Fuels	Central	Central
Impact of government policies [1]	Only those mentioned in Climate Change Policy Review (2006)	Only those mentioned in Climate Change Policy Review (2006)
MACC measures considered	✗	✓
Power generation	Deployment of renewables determined by the model. No new nuclear	Assumed renewables meets government aspiration of 30-35% by 2020. No new nuclear
EU ETS	✗	✓
Caps on non-EU ETS sectors	✗	✓
Auctioning of EU ETS mechanism (recycling mechanism)	✗	✓(ABATE1.1 - reduction in employers' NIC rate ABATE1.2 – lump sum transfer to households)
Use of CDM credits to offset emissions from the non-EU ETS sector	✗	✓

Note(s) : 1. Energy savings from non-price policies are taken from estimates from BERR (May 2008). The impact of price policies is determined by MDM-E3.
Source(s) : Cambridge Econometrics.

4.3 Power generation

The scale of renewable power generation is consistent with the UK's 15% renewable energy target

4.3.1 In the abatement scenarios we adopted assumptions provided by the CCC for the development of renewables capacity (see Chart 4.1) and generation. These assumptions reflect a generation mix consistent the government's stated goal that renewables account for 30-35% of power generation by 2020, which in turn is consistent with the UK's target that 15% of final energy demand is sourced from renewable fuels by 2020. The latter target was proposed by the European Commission to meet the 20% target for the EU as a whole (which was agreed European Council in May 2007).

The abatement scenarios have a rapid expansion in the use of renewables by 2020

4.3.2 Under these assumptions, the UK's total renewable capacity is projected to be just below 39 GW by 2020. This represents almost a ten-fold increase in capacity compared with that in 2006 (4 GW). Generation from renewables is projected be just over 112 TWh by 2020, which is around six times the level generated in 2006. As a result, renewables are responsible for more than 30% of UK power generation by 2020 in the abatement scenarios.

Wind is projected to be the dominant form of renewables capacity by 2020

4.3.3 By 2020, the capacity of off-shore wind in the abatement scenarios is projected to be just below 14½ GW. This is almost 50 times greater than the capacity in place in 2006. The capacity of on-shore wind is projected to reach 13¾ GW by 2020, which is more than eight times the capacity in place in 2006. Taken together, on- and off-shore wind are assumed to make up just under 75% (28 GW) of the total renewables power capacity in 2020 and almost 70% of total generation from renewables.

4.3.4 The renewables profile was introduced into MDM-E3 by using an existing mechanism that is used to model new generation capacity announced by the generators. This means that the usual consideration of build and lag times that the model adopts when determining the mix of capacity was overridden for renewables to ensure that the renewables target is met. No attempt was made to model a policy instrument that would bring this outcome about, but the consequence (in terms of the higher cost of electricity) is incorporated in the modelling.

4.3.5 Finally, a demonstration coal carbon capture and sequestration (CCS) power generation station of 0.3GW capacity is assumed to be operating from 2014.

4.4 Assumptions for the EU ETS and non-EU ETS caps and carbon prices

Emission caps

UK CO_2 emissions are capped to be 40% below the 1990 level by 2020

4.4.1 The CCC provided assumptions for the caps on emissions from EU ETS and non-EU ETS activities (see Chart 4.2). Under these assumptions, the UK's CO_2 emissions (excluding international aviation) are capped to just over 355 $MtCO_2$ by 2020. This is a reduction of almost 40% from the 1990 level. The total cap is assumed to be reduced at a rate of 3½-4% pa over 2013-20.

The EU ETS cap in 2020 is assumed to be cut by more than a third cf 2005 level

4.4.2 The assumptions for the EU ETS cap assume that emissions from all domestic flights from the UK are regulated under the EU ETS from 2013[5]. The caps are assumed to be reduced thereafter at rates between 2½-4¼% pa. By 2020, emissions from EU ETS activities are capped to just below 160 $MtCO_2$ (including domestic aviation). This represents a fall of almost 35% from the level of emissions regulated by the EU ETS in 2005.

The cap on non-EU ETS activities in 2020 is about 75% of the level in 2005

4.4.3 The cap on emissions not regulated by the EU ETS (non-EU ETS) is assumed to fall by some 3% pa from 2013, accelerating to almost 4% pa by 2020. By 2020, emissions from non-EU ETS activities are capped to below 200 $MtCO_2$. This represents a fall of more than 27% from the level of emissions from the non-EU ETS activities in 2005.

A limited amount of CDM credits can be used to offset emission from non-EU ETS activities

4.4.4 If emissions from non-EU ETS activities are higher than its cap, then the excess is assumed to be offset by purchasing certified emission reduction credits from Clean Development Mechanism (CDM) projects located overseas. However, limits on the use of CDM credits for this purpose have been assumed from 2012. By 2020, a maximum of 23 $MtCO_2e$[6] of CDM credits can be bought to offset the emissions from non-EU ETS activities.

Assumptions for coverage of the EU ETS

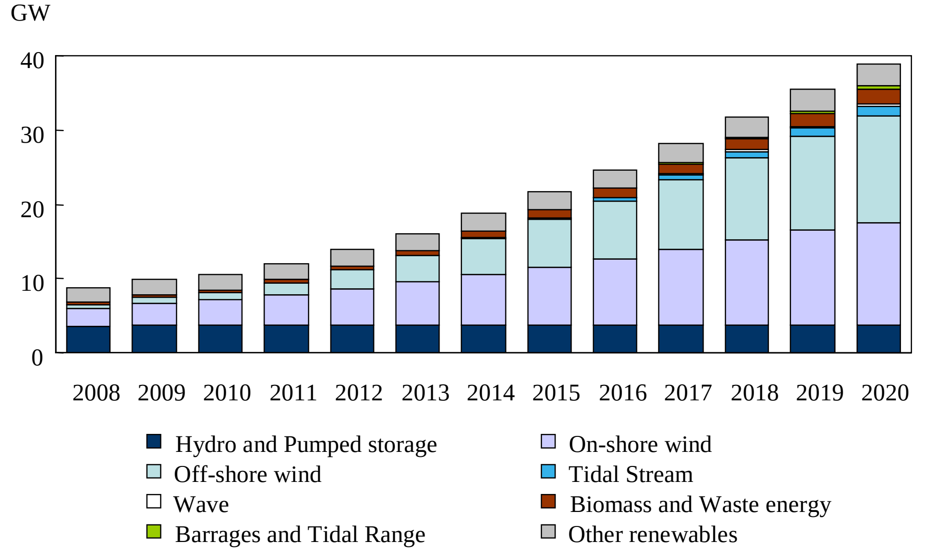
4.4.5 The CCC provided assumptions for the proportion of direct (ie excluding emissions attributed to the use of electricity) CO_2 emissions from each fuel user that were to be regarded as regulated by the EU ETS in the abatement scenarios (see Table 4.2). All direct CO_2 emissions from major power producers and the energy sector's own use are included. All direct CO_2 emissions from domestic air transport are assumed to be included from 2013. Some 76% of all direct CO_2 emissions from MDM-E3's industrial fuel users and autogenerators are assumed to be regulated by the EU ETS, while the remaining fuel users are assumed not to be covered.

4.4.6 As directed by CCC it is assumed that the proportion of emissions regulated by EU ETS remains constant throughout the projection period. This assumption could cause overstatements of the estimates of the volume of emissions regulated by the EU ETS over time from fuel users that are assumed to be partially regulated, eg industrial fuel users. In theory, those emissions regulated by the EU ETS should fall at a faster rate than those emissions that are not. Therefore, the assumption that the proportion of emissions from these fuel users that are regulated by the scheme remains constant may be overstating the amount of emissions covered by the EU ETS in the projections from the abatement scenarios.

[5] This assumption was made at the time when the modelling was being conducted. At the time of writing this report, it is planned to regulate emissions from domestic air transport from 2012.

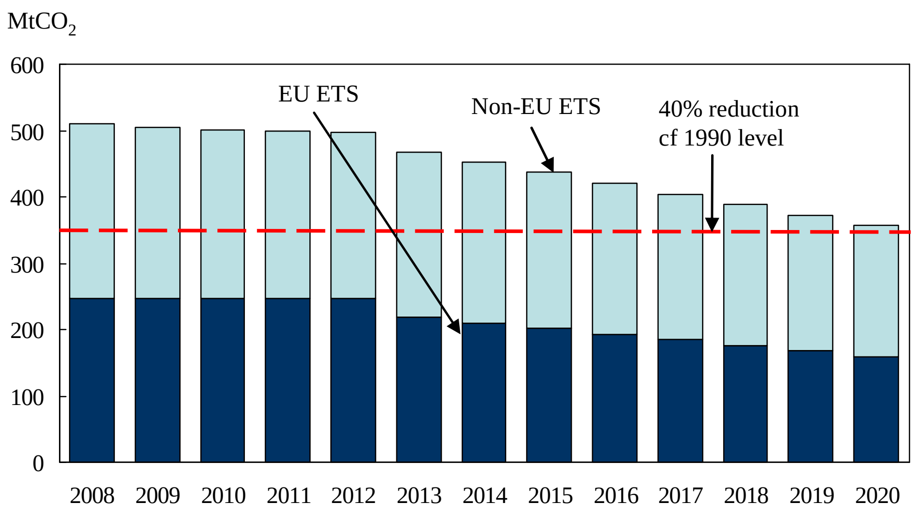
[6] CDM credits can be issued for the reduction of any of the six greenhouse gas emissions covered by the Kyoto protocol. Consequently CDM credits are denominated in CO_2 equivalent (CO_2e), which takes into account the global warming potential of each non-CO_2 greenhouse gas compared to CO_2.

CHART 4.1: PROJECTED RENEWABLE POWER GENERATION CAPACITY, UK



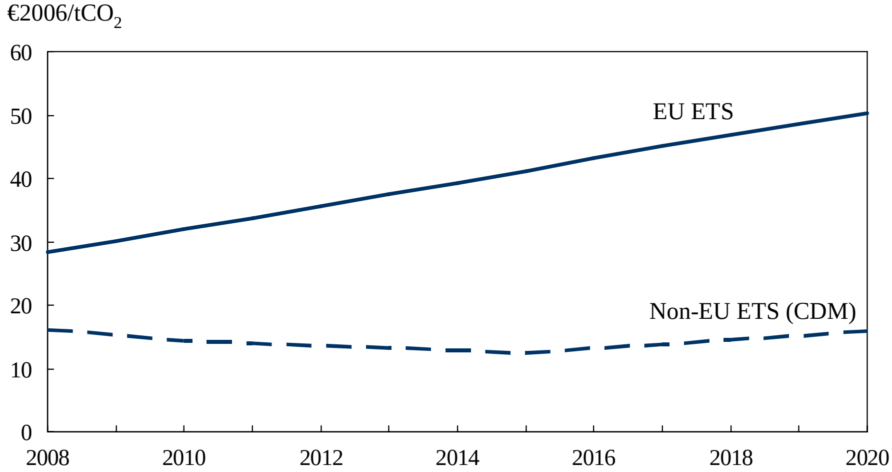
Note(s) : Used in the abatement scenarios only.
Source(s) : Committee on Climate Change Secretariat.

CHART 4.2: UK EMISSION CAPS, EU ETS AND NON-EU ETS



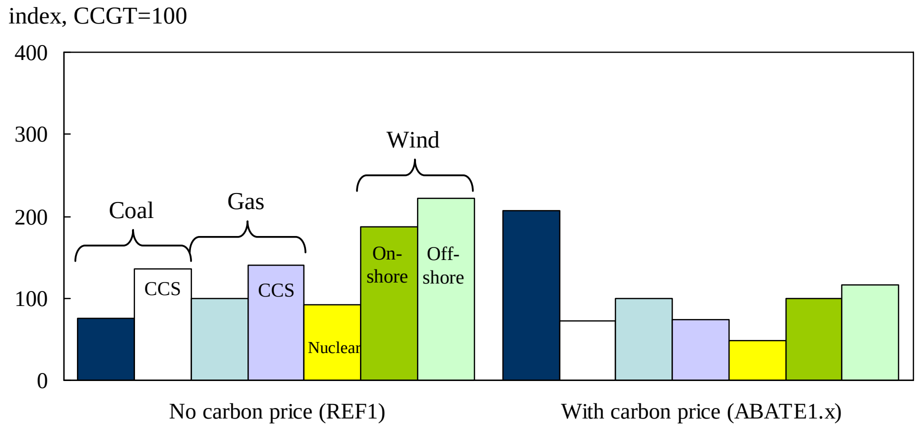
Note(s) : 1. Caps presented include emissions from domestic water and air transport, but not international.
Source(s) : Committee on Climate Change Secretariat.

CHART 4.3: ASSUMED CARBON PRICES FOR EU ETS AND NON-EU ETS ACTIVITIES



Note(s) : 1. Prices presented held at exchange rate in 2006.
2. Price in CO_2(e) for Non-EUETS.
Source(s) : Committee on Climate Change Secretariat

CHART 4.4: RELATIVE COST OF NEW POWER GENERATION PLANTS, LEVELISED COST, £2008



Note(s) : 1. These costs are predicated on the central set of fossil fuel prices in Figure 3.2.
2. Relative costs for technologies not provided by the CCC (biomass, solar, marine/hydro and oil) are assumed to be same as in original set of parameters in MDM-E3.
3. IGCC is not modelled by MDM-E3.
4. Costs with the carbon price are approximate. These use the EU ETS carbon price as shown in Chart 4.3. The carbon price after 2030 is assumed to be an extrapolation of the assumed prices up to 2030.
5. The cost of renewables excludes payments from the renewables obligation.
6. Learning curve effects are not included.
Source(s) : Committee on Climate Change Secretariat and Cambridge Econometrics.

Carbon prices

The EU ETS carbon price is assumed to rise by 5% pa, but CDM credits are assumed to be cheaper

4.4.7 The (real) carbon prices used in the central abatement scenarios are presented in Chart 4.3. In these assumptions, the (real) carbon price from the EU ETS is assumed to rise by 5% pa throughout the entire projection period.

4.4.8 The (real) price of CDM credits is assumed to fall by 5-6% pa over 2008-10, after which the fall in the price averages 3% pa to 2015. In the longer term, 2015-20, it is expected to rise by 5% pa. The consequence is that the price of CDM credits is assumed to become cheaper relative to the EU ETS carbon price over the projection period. In 2010, the (real) price of EU ETS allowances is assumed to be twice of that of CDM credits; by 2020, the EU ETS price is assumed to be more than three times the price of CDM credits.

The EU ETS carbon price is applied to the fuel price for regulated users

4.4.9 The carbon price from the EU ETS is treated in MDM-E3 as an increase in the price of fuels (weighted by the carbon content of the fuel) used by fuel users regulated by the EU ETS. The impact of the carbon price on fuel demand is determined by the econometric equations described in Appendix A.

There is a special treatment for carbon capture and storage (CCS)

4.4.10 The carbon price is also adjusted to reflect the scale of emissions emitted into the atmosphere. Consequently, carbon capture and storage (CCS) plant has only 10% of the carbon price applied to the carbon content of its fuels as it is assumed that only 10% of the emissions from power generated by such a plant are emitted into the atmosphere.

Impact on power generation

'Zero-carbon' generation becomes very competitive

4.4.11 When the central assumption for the EU ETS carbon price is applied, the relative costs of power generation technologies are changed radically in favour of those with no/low emissions (see Chart 4.4). New nuclear (if it were allowed) is now less than half the cost of gas-based generation. Generation from CCS is 25-30% lower. On-shore wind is on a par with gas-based generation, and off-shore wind is only 15% more expensive. New coal without CCS is now the most expensive form of generation as it is more than twice as expensive as gas-based generation.

4.5 Marginal abatement cost curve measures

4.5.1 The CCC requested that the modelling include the impact of specific abatement measures from its marginal abatement cost (MAC) curves. The measures covered all final fuel users in the economy and typically result in a reduction in final energy and fuel demand, although some measures involve fuel switching to renewables (see Table 4.3). The CCC also provided the associated technology cost of taking up the measures. No attempt was made to specify a policy instrument that would stimulate take-up of these are measures (most of which are assumed to be cost-effective).

4.5.2 In order to avoid double counting, the estimates of energy savings and fuel switching due to MAC curve measures are adjusted to account for measures assumed to be taken up by fuel users who are subject to the carbon price from the EU ETS.

Energy savings and fuel switching

Most of the energy demand reduction MAC measures are from using less direct fuels

4.5.3 In total, the MAC curve measures used in the abatement scenario reduced final energy demand by almost 190 TWh by 2020. Around 70% of this is due to reductions in demand for non-electric fuels (ie gas, petrol and diesel). Around 40% of the reduction in final energy demand is assumed to come from households. Some 50% of the reduction is assumed to come from commerce and road transport together. The remainder of the reductions come from industry.

4.5.4 The MACC measures are assumed to cause households to reduce energy demand by around 75 TWh in 2020. Around two-thirds of this is assumed to come from reducing non-electric fuels (mostly gas), with the remainder of the savings coming from reduced demand for electricity. More than 80% of the energy savings from industry is from reducing electricity demand. Less than a quarter of the energy savings from commerce is due to lower use of electricity.

TABLE 4.2: ASSUMED COVERAGE OF EU ETS ON FUEL USERS' (DIRECT) CO_2 EMISSIONS[1]

Assumed % of emissions regulated by the EU ETS	Fuel users
100%	Major power producers, Energy sectors' own use, Domestic air transport (from 2013)
76%	Autogeneration, all industries
0%	Households, Commerce, Road, Rail and Water Transport

Note(s) : 1. Includes direct non-energy as well as direct energy emissions.

Source(s) : Committee on Climate Change Secretariat.

TABLE 4.3: IMPACT FROM MACC MEASURES ASSUMED IN CENTRAL ABATEMENT SCENARIOS (2020)

Fuel User	Reduction in final energy demand (TWh)			Increase use of renewables (TWh)
	Total	Electricity	Other fuels	
Households	74.50	26.44	48.06	32.93
Commerce	43.68	9.91	33.77	11.88
Industry[1]	14.89	12.33	2.55	-
Road Transport[2]	53.29	4.25	49.04	-
Total[3]	186.36	52.94	133.43	44.80

Note(s) : 1. Includes energy saving and fuel switching from using CHP.

2. Represents an increased use of mains electricity by road transport. Use of biofuels is expressed as percentages of petrol and diesel used.

3. Total increase in the use of renewables excludes use of biofuels in road transport.

Source(s) : Committee on Climate Change Secretariat.

4.5.5 The MAC curve measures are assumed to reduce the use of conventional fuels in road transport. Also, they are assumed to lead to an increase in the use of electricity in road transport, although the reduction in fuel demand is almost 20 times more than the assumed level of electricity projected to be used by this fuel user. MAC curve measures assume that the biofuels content in road transport fuel in 2020 would be

- 7.3% in petrol
- 8.8% in diesel

Technological costs

The MAC measures have a technology cost of £6.2bn by 2020

4.5.6 The CCC also provided technology costs associated with the take-up of the MAC curve measures. These represent the costs borne by industries and households to pay for the MAC curve measures. It has been assumed that MAC curve measures taken up by 2020 would have a total technology cost around £6.2bn. Nearly 55% of this cost is incurred directly by households for domestic energy savings, and a further 40% of the technology cost falls on both industry and households in order to implement transport MAC measures

Modelling MAC curve measures in MDM-E3

4.5.7 The technology costs have been modelled by adjusting the pattern of expenditure of households and industries in MDM-E3 so that spending on a relevant product is increased.

4.5.8 For example, most of the costs associated with MAC curve measures for households required additional household expenditure on the consumption category 'Maintenance of housing'. The energy saving and fuel switching assumptions were modelled by adjusting fuel demand by each fuel user by the assumed amount.

4.5.9 Consequently, the economic impact of the MAC curve measures is captured by

1. savings from less spending on energy
2. increased expenditure on MAC curve measures such as the additional demand for construction and other sectors resulting from the increased expenditure by households on measures to improve energy efficiency in the home.

4.6 Assumptions for the extent of auctioning of EU ETS emission allowances and for the recycling of revenues

By 2020, 100% of EU ETS allowances are auctioned

4.6.1 In the abatement scenarios, power generators regulated by the EU ETS face full auctioning of EU ETS allowances after 2013. Other activities regulated by the EU ETS are assumed to face auctioning of 20% of their cap in 2013, after which the share of auctioning rises to 100% by 2020.

Revenues from EU ETS auctioning are used to purchase CDM credits

4.6.2 The revenues from the auctioning of EU ETS allowances are used to purchase CDM credits in the first instance to offset emissions above the cap for non-EU ETS activities. However, the CCC placed limits on the volume of the CDM credits that could be used for this purpose after 2012.

Recycling mechanisms

In ABATE1.1, households receive a (tax-free) payment

4.6.3 The excess revenues from the auctioning of EU ETS allowances, after the purchase of CDM credits, are recycled back into the economy in different ways in the central abatement scenarios. In ABATE1.1, revenues are passed on as a tax-free transfer directly to households. This was modelled as an increase in household disposable income.

In ABATE1.2, the rate of employers' NICs is cut

4.6.4 In ABATE1.2, revenues are recycled by cutting the rate of employers' National Insurance Contributions (NICs).

The recycling mechanisms are revenue neutral

4.6.5 The recycling is designed to be revenue neutral, in that cuts in the revenue from employers' NICs or the direct transfer to households match the (remaining) revenues from auctioning the EU ETS allowances. There are, however, different implications for government revenue arising from second-round effects on tax receipts.

5 Energy and emission projections for the central reference (REF1) and abatement scenario (ABATE1.1)

5.1 Overview

5.1.1 This chapter discusses the key features of the energy and emission projections from the central reference and abatement scenarios (REF1 and ABATE1.1). The economic projections for these scenarios are discussed in Chapter 7. This chapter focuses on projections for the UK as a whole, but there is also a summary of the implications for each of the Devolved Administrations (DAs) and England. In comparing the reference and abatement scenarios we focus on the differences between them in 2020.

5.1.2 All the projections presented in this chapter exclude energy demand and emissions from international air and water transport and emissions from land use, land use change and forestry[7]. We consider only emissions of CO_2 in this chapter. Projections for emissions of all six greenhouses regulated by the Kyoto Protocol can be found in Appendix E.

5.1.3 This chapter is organised as follows:

- Section 5.2 discusses the CO_2 emissions projections for the UK in REF1 and ABATE1.1.
- Section 5.3 discusses energy prices and demand projections for the UK in REF1 and ABATE1.1, with some analysis of energy demand by fuel user.
- Section 5.4 discusses projections of the power generation mix for the UK in REF1 and ABATE1.1.
- Section 5.5 contains a summary of projections made for each of the DAs and England.

Summary

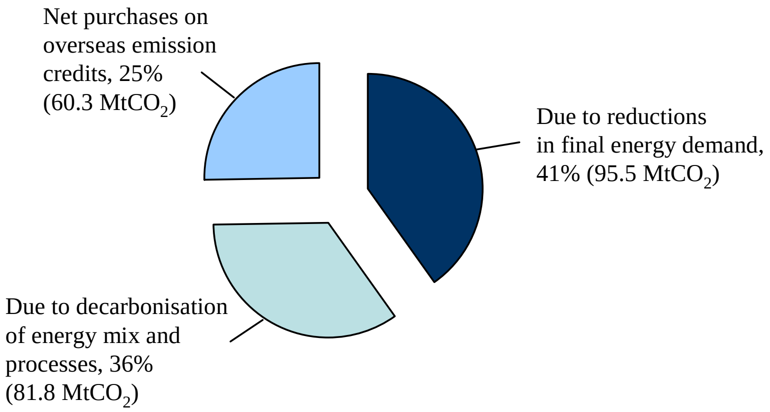
The 2020 emissions target is met in the abatement scenario

5.1.4 CO_2 emissions (on the net carbon account basis) in the abatement scenarios in 2020 are projected to be 40% below the projected level in REF1 and the 1990 level. On the IPCC basis, CO_2 emissions in the abatement scenarios are projected to be 30% below the projected level in REF1 and the 1990 level.

5.1.5 Chart 5.1 shows the estimates of emissions reductions in ABATE1.1 (on the net carbon account basis) from various causes. More than three quarters of the reduction in emissions projected in ABATE1.1 is due to reductions in final energy demand and the decarbonisation of the energy supply and processes. Of the two, the reduction in final energy demand has the greater impact on emissions. The remainder is due to purchases of overseas credits.

[7] Although these emissions are covered by the Climate Change Bill, their exclusion does not significantly alter the key messages from this study as they are unlikely to be affected much by the measures modelled here.

CHART 5.1: BREAKDOWN OF CAUSES OF CO_2 EMISSION REDUCTIONS IN ABATE1.1, 2020

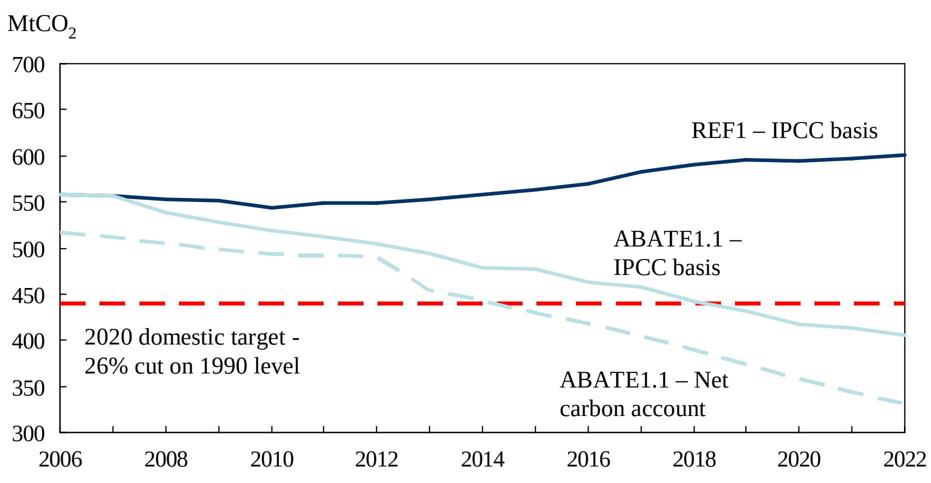


Note(s) : 1. Excludes emissions from international transport.
2. The estimate due to reduction in final energy demand was found by applying the average emission factor in REF1 to the difference in final energy demand in the scenarios. The estimate for the reduction due to decarbonisation was found by applying the difference in the average emission factor in the scenarios to final energy demand in ABATE1.1.

Source(s) : Cambridge Econometrics.

Ref : C82R1CCC, C82AB83MVAICCC.

CHART 5.2: PROJECTED UK CO_2 EMISSIONS



Note(s) : 1. Includes emissions from non-energy uses.
2. Excludes emissions from international travel and land use, land use change and forestry.

Source(s) : NAEI, DEFRA, BERR (DUKES 2007), Committee on Climate Change Secretariat and Cambridge Econometrics.

Ref : C82R1CCC, C82AB83MVAICCC.

5.2 CO_2 emissions

IPCC basis versus Net Carbon Account

5.2.1 We present emissions on the both the IPCC and net carbon account bases (see Chart 5.2). The IPCC basis attributes all the emissions emitted from sources within the UK (except those from international transport) to the UK. The net carbon account accepts 'emissions reductions' purchased in the form of allowances and credits from certified mechanisms such as the EU ETS and the CDM. In the case of the EU ETS, the emissions cap represents the emissions from these activities on the net carbon account measure. Emissions for REF1 are only available on the IPCC basis, as this scenario does not include caps on emissions.

5.2.2 CO_2 emissions in REF1 (on the IPCC basis) are projected to rise so that by 2020 (595 $MtCO_2$), they are 15¾% higher than the 2006 level (558 $MtCO_2$), or almost the same as the 1990 level, compared with the minimum 26% reduction from the 1990 level required by the Climate Change Bill (437 $MtCO_2$)[8].

Even without the use of purchased overseas emission credits, emissions in ABATE1.1 meet the Bill's 2020 emission target

5.2.3 CO_2 emissions in ABATE1.1 on an IPCC basis in 2020 are projected to be 30% lower than in REF1 and hence also some 30% lower than the 1990 level. They therefore meet the Climate Change Bill's 2020 emissions target. On the net carbon basis, which includes net purchases of overseas emission reduction credits from recognised schemes, emissions from ABATE1.1 in 2020 are almost 40% lower than in REF1 and the 1990 level.

Sources of CO_2 emissions

Power generation is projected to be responsible for less than a third of the UK's CO_2 emissions in 2020

5.2.4 Chart 5.3 shows the sources of CO_2 emissions by primary energy users in REF1 and ABATE1.1 in 2020. The share of emissions from power generators in ABATE1.1 in 2020 is projected to be almost 10pp lower than in REF1. This is due to increased use of renewables and the switch to other forms of less CO_2-intensive power generation. These factors also boost the price of electricity and cause a reduction in demand and hence the amount supplied (see Section 5.3).

Road transport is projected to account for third of the UK's CO_2 emissions in 2020

5.2.5 The share of emissions from road transport, other industry and energy sector own use in 2020 in ABATE1.1 are higher than in REF1 (especially that of road transport which is 5pp higher). This is not because emissions from these sectors are higher in ABATE1.1 than in REF1; rather the decrease in emissions from these fuel users is less, and so their share (in a smaller total) rises.

Impact of emission caps and carbon prices

5.2.6 Chart 5.4 presents the breakdown of projected emissions from those activities regulated by the EU ETS and those that are not. Although REF1 does not include emissions caps, to produce the chart, the assumptions of the coverage of the EU ETS in ABATE1.1 have been applied to the projections from REF1. This is to allow the estimation of the impact of emission caps and carbon prices on these activities.

[8] See footnote 7.

Emissions regulated by the EU ETS are 25% lower in 2020

5.2.7 In REF1, CO_2 emissions from EU ETS activities in 2020 are projected to be more than 35% higher than net emissions from EU ETS activities in 2005 (net emissions are equal to the cap, which in turn is equal to emissions from these sectors minus net purchases of overseas allowances). In ABATE1.1, caps have been imposed so that net emissions from EU ETS activities in 2020 are 35% lower than the net emissions in 2005. Excluding net purchases of overseas emission credits, emissions from EU ETS activities in ABATE1.1 in 2020 are 25% lower than in 2005. Therefore, the projected reductions in emissions from activities regulated by the EU ETS are greater than the 21% reduction target proposed the European Commission[9].

Emissions from non-EU ETS activities are below the proposed 2020 target

5.2.8 In REF1, CO_2 emissions from activities not regulated by the EU ETS are projected to be 4% lower in 2020 than in 2005. In ABATE1.1, emissions (excluding net purchases of overseas credits) are 25% lower in 2020 than in 2005. This means that the reduction in emissions from these activities is greater than the 16% reduction target for 2020 (from the 2005 level) proposed for the UK by the European Commission. Including overseas credits, projected net CO_2 emissions from these activities in ABATE1.1 are around 27% below the 2005 level.

Net purchases of overseas credits amount to more than 10% of UK net emissions by 2020

5.2.9 In ABATE1.1, net purchases of overseas credits in 2020 are equivalent in scale to 12½% of the projected UK net emissions. The vast majority of these are purchased under the EU ETS: net purchases of overseas credits amount to 20% of the projected net emissions from EU ETS regulated activities in 2020. Outside the EU ETS activities, the scale of net purchases of overseas credits is much lower, at 4% of net emissions. This is largely due to assumptions applied in ABATE1.1 on the limits to the use of such credits to offset emissions.

5.3 Energy prices and demand

Energy prices

5.3.1 Because we use a common set of fossil price assumptions in the central reference and abatement scenarios, the nominal prices of non-electricity fuels for fuel users not covered by the EU ETS do not change between the scenarios. In contrast, activities covered by the EU ETS experience an increase in the effective energy prices that they face in ABATE1.1.

5.3.2 The prices that see the largest increase in the abatement scenario are those relating to electricity. Chart 5.5 shows the wholesale[10] and retail[11] electricity prices in both scenarios. The changes between the scenarios assume that the higher cost of generation from renewables and the carbon price from the EU ETS are passed through to prices by the generators.

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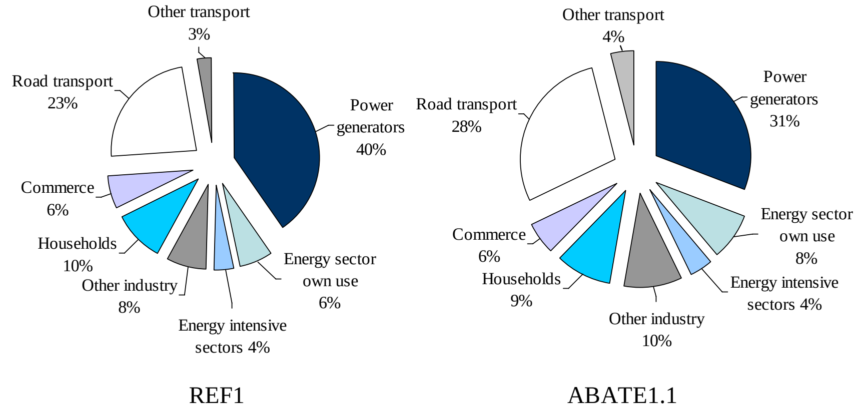
[9] The proposed 21% reduction by 2020 is for all emissions regulated by the EU ETS across all member states.

[10] The definition of wholesale price used in this report and in MDM-E3 is the weighted average of costs incurred by generators, such as the price of fuel and the carbon price from the EU ETS. It also includes the RO levy which is used to subsidise eligible renewable power generation technologies. It is not the same as the definition of the wholesale price used by the electricity markets, where the wholesale price is the single price charged by all supplying generators in a single half-hour period.

[11] The retail price is the wholesale price plus taxes and levies that are applied by MDM-E3. In MDM-E3, retail prices can vary by fuel user; the weighted average (by amount of electricity consumed) is the concept discussed here.

CHART 5.3: SOURCES OF UK CO_2 EMISSIONS, PRIMARY FUEL USERS, 2020

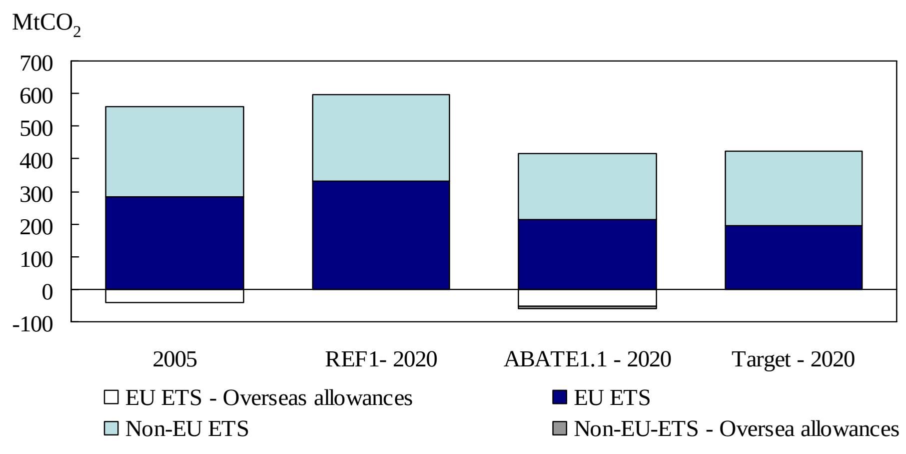


Note(s) : 1. Presented on the IPCC basis and therefore excludes emissions from net purchases of overseas emissions credits.
2. Excludes emissions from international transport and from non-energy uses.
3. Power generation comprises major power producers and autogeneration.
4. Other transport comprises rail transport, domestic air and water transport.

Source(s) : Cambridge Econometrics.

Ref : C82R1CCC, C82AB83MVAICCC.

CHART 5.4: CO_2 EMISSIONS FROM EU ETS AND NON-EU ETS ACTIVITIES



Note(s) : 1. The target shown for EU ETS activities is assumed to be 21% below the 2005 level, which is proposed by the European Commission as the target for the EU as a whole. Domestic air transport is regulated by the EU ETS from 2013.
2. The target shown for Non-EU ETS activities is assumed to be 16% below the 2005 level, which has been proposed by the European Commission.

Source(s) : NAEI, DEFRA, BERR (DUKES 2007), Committee on Climate Change Secretariat and Cambridge Econometrics.

Ref : C82R1CCC, C82AB83MVAICCC.

Electricity prices in ABATE1.1 are more than 80% higher by 2020

5.3.3 By 2020 the (real) wholesale price in ABATE1.1 in 2020 (9.8 p/kWh) is projected to be more than 85% higher than in REF1 (5.3 p/kWh). In ABATE1.1, the (real) retail price in 2020 (14.6 p/kWh) is more than 80% higher than that in REF1 (8.0 p/kWh). In both cases, the (real) retail price is some 50% higher than the wholesale price.

Final energy demand

Falls in the demand for electricity drives falls in total final energy demand

5.3.4 In response to higher energy (especially electricity) prices and the MAC curve measures, final energy demand in ABATE1.1 in 2020 (119 Mtoe) is 13½% lower than in REF1 (137 Mtoe). Electricity demand is 16½% lower (25 Mtoe compared with 30 Mtoe). In ABATE1.1 final energy demand is projected to be 18% lower in 2020 than in 2006 (145 Mtoe), compared with a fall of just over 5% in REF1 over the same period. Demand for electricity in ABATE1.1 in 2020 is projected to be 15% below the 2006 level (29.5 Mtoe), whereas it is projected to be 2% higher in REF1.

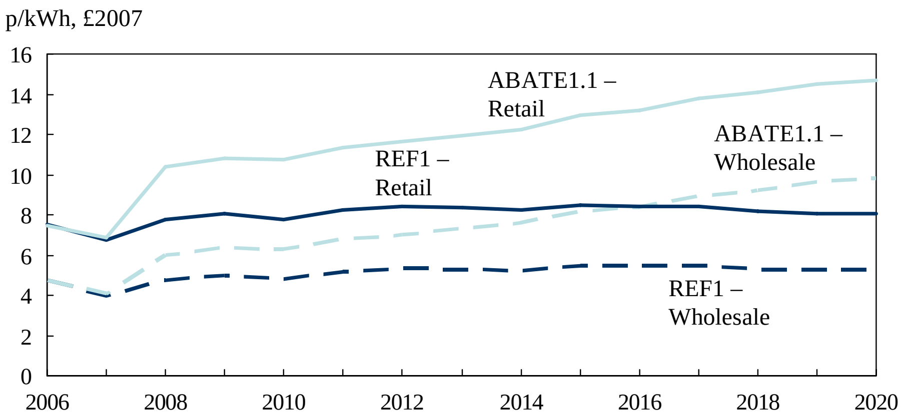
Industry's demand is projected to be particularly affected by measures in the abatement scenario

5.3.5 Chart 5.7 shows the reduction in final energy demand and electricity demand by fuel users in ABATE1.1 in 2020 compared with REF1. It shows that industry is projected to reduce demand for electricity by the largest proportion. The two fuel users 'energy-intensive industry' and 'other industry' reduce electricity demand by 24% and 20% respectively in 2020 in ABATE1.1; final energy demand (for all fuels) for these groups are 18% and 11% lower respectively.

5.3.6 These effects reflect the measures faced by the different categories of fuel user in the abatement scenario. The reduction in final energy demand is mainly driven by the rise in the EU ETS carbon price, since more than 75% of the emissions from the two industry fuel users are regulated under the EU ETS. The larger percentage reduction in demand for electricity than for all fuels in final energy demand is explained by the MAC curve measures applied to these fuel users in ABATE1.1; more than 80% of energy savings for these fuel users from the MAC curve measures relate to lower electricity use. A modest part of the reduction in energy demand is also due to lower economic activity in the abatement scenario.

5.3.7 Household demand for energy is 20% lower in ABATE1.1 in 2020 than in REF1, whereas electricity demand is only 12% lower. This is because the assumptions for MAC curve measures implemented by households have a greater impact on the use of gas than electricity. Another influence is the fact that the price elasticity of household demand for electricity is less than for industrial fuel users, reflecting fewer substitution opportunities in households. Finally, the retail price of electricity faced by households in the abatement scenario rises by a smaller percentage compared with other fuel users as the household retail price is less dependent on the wholesale price (the retail price faced by households includes taxes and levies, which are kept the same in reference and abatement scenarios, and which other fuel users do not face).

CHART 5.5: PROJECTED UK ELECTRICITY PRICES

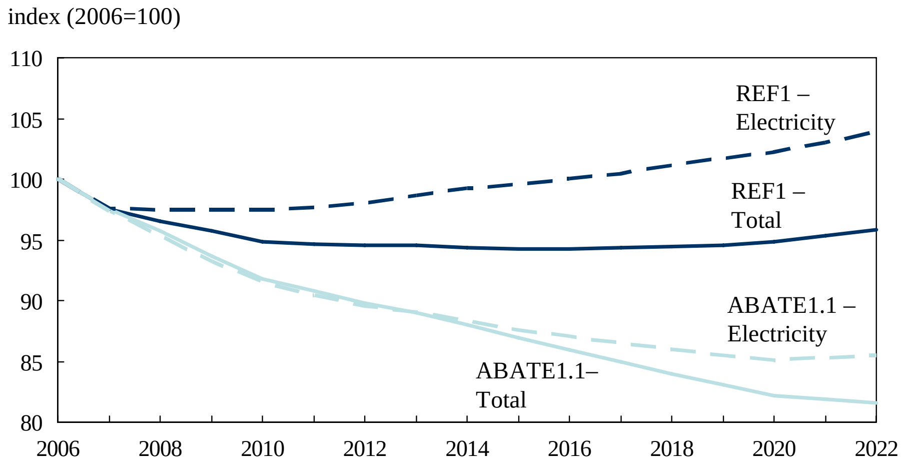


Note(s) : 1. The wholesale price presented is the weighted average of costs incurred by generators, such as the price of fuel and the carbon price from the EU ETS. It also includes the RO levy which is used to subsidise eligible renewable power generation technologies.
2. The retail price presented is the weighted average (by amount of power consumed) of retail prices faced by fuel users in MDM-E3.
3. Prices deflated by home unit costs.

Source(s) : NAEI, DEFRA, BERR (DUKES 2007), Committee on Climate Change Secretariat and Cambridge Econometrics.

Ref : C82R1CCC, C82AB83MVAICCC.

CHART 5.6: PROJECTED FINAL ENERGY DEMAND



Note(s) : The chart shows demand from final users shown (ie not including demand from power generation and energy sector own use).

Source(s) : NAEI, DEFRA, BERR (DUKES 2007), Committee on Climate Change Secretariat and Cambridge Econometrics.

Ref : C82R1CCC, C82AB83MVAICCC.

5.4 Power generation

Capacity and generation

Measures in the abatement scenario cause less use of coal and more use of renewables by 2020

5.4.1 Charts 5.8 and 5.9 show the projected power station capacity and power generation in the two scenarios. Capacity is shown by station types and generation is shown by the fuels modelled by MDM-E3. The main difference in the abatement scenario is the lower use of coal stations and the greater use of renewables.

5.4.2 In REF1, coal power stations (both with and without FGD[12]) are projected to make up 36% of the UK's power generation capacity by 2020 (39 GW). This is due to the large difference in the gas and coal price assumed in this case (see Section 3.4). In ABATE1.1, the amount of coal capacity (22 GW) is projected to be cut by almost half, so that by 2020 coal stations make up 19% of capacity. In ABATE1.1, renewables capacity (37.5 GW) in 2020 is projected to be more than twice the level in REF1 (17 GW). In ABATE1.1, renewables are projected to make up 33% of power generation capacity in 2020.

5.4.3 The same pattern of changes is also present in the projections of generation from the two scenarios, although the magnitude of the changes is greater reflecting the ease with which the mix of generation can be changed (and the loads factors varied accordingly). Generation from coal stations in ABATE1.1 in 2020 (101 TWh) is projected to be almost 60% lower than in REF1 (237 TWh).

5.4.4 Generation from coal stations in REF1 by 2020 (237 TWh) is projected to be 75% higher than the 2006 level (135 TWh). This is because the capacity is projected to grow by 50% in REF1 (38 GW) by 2020 compared with the 2006 level (26 GW), and the load factor for coal plants is projected to be 20% higher in REF1 by 2020 compared to the 2006 level. The greater use of coal in REF1 is caused by the use of the central set of fossil fuel price assumptions (see Section 3.4) where coal is assumed to be (much) cheaper than gas.

The projected use of renewables is consistent with government renewables targets

5.4.5 Generation from renewables in ABATE1.1 in 2020 (120 TWh) is projected to be more than double the amount in REF1 (49 TWh). Renewables are projected to be responsible for 33% of the power generated in 2020 in ABATE1.1[13].

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[12] Flue gas desulfurisation (FGD) is the technology used for removing sulphur dioxide (SO_2) from the exhaust flue gases in power plants that burn coal or oil to produce steam for the steam turbines that drive their electricity generators. Its use in the UK has been accelerated by the Large Combustion Plant Directive (LCPD), which is modelled in both scenarios.

[13] This figure is derived by divided total projected generation from renewables by total projected generation for all power generators. This percentage rises to 37% on the renewables obligation basis, which does not count all generation from renewables in the numerator and uses UK sales of power generation as the denominator which excludes generation from autogeneration.

5.4.6 The EU ETS carbon price penalises coal particularly, and the installation of more renewables capacity effectively crowds out the need to build additional power station capacity based on other fuels.

Emissions

Emissions from power generation in the reference scenario rise by 20% over 2006-20

5.4.7 Chart 5.10 shows the CO_2 emissions from power generation. In REF1 CO_2 emissions are 20% higher in 2020 (230 $MtCO_2$) than in 2006 (190 $MtCO_2$). This reflects higher electricity demand, but more especially the projected build of coal-fired power stations in this scenario; CO_2 emissions from coal used in power generation are projected to be 45% higher in REF1 in 2020 (190 $MtCO_2$) compared to the 2006 level (132$MtCO_2$). Emissions from gas are projected to be 35% lower.

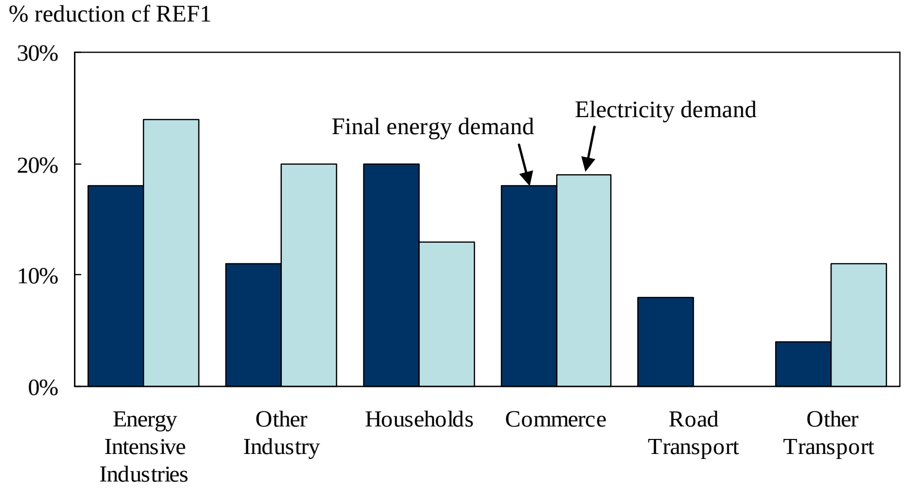
Emissions from power generation in the abatement scenario fall by 50% by 2020

5.4.8 In ABATE1.1, CO_2 emissions are almost 50% lower in 2020 (120 $MtCO_2$) than in REF1, reflecting the substitution of renewables for coal and lower electricity demand. Emissions from coal used in power generation in ABATE1.1 in 2020 (83 $MtCO_2$) are almost 60% lower than in REF1. Overall, the projected CO_2-intensity of electricity in ABATE1.1 (337 gCO_2/kWh) in 2020 is 37% lower than in REF1 (541 gCO_2/kWh). The remainder of the fall in emissions is due to projected lower demand for electricity (see Section 5.3).

MDM-E3 may be overstating the increased use of coal in the reference scenario

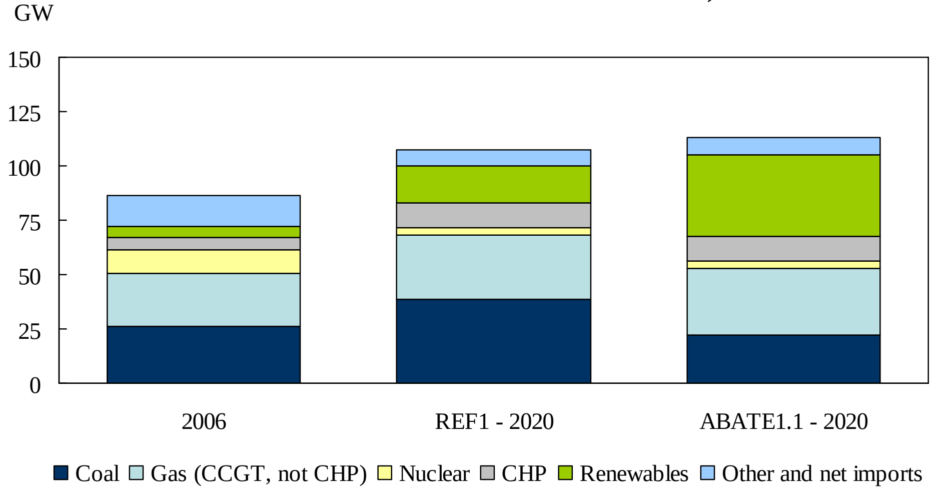
5.4.9 Simplifying assumptions, notably the priority given to cost minimisation, have been made in the design of MDM-E3 to make the projection of the optimal generation mix tractable. Such assumptions could overstate the use of coal in the reference scenario compared with what would happen in reality. For example, generators may wish to maintain a variety of generation technologies in order to hedge against uncertainties of the price of fuels, breakdowns and sudden changes in demand. If so, the scale of reduction in CO_2 emissions from power generation caused by the substitution of renewables for coal in the abatement scenario may be somewhat overstated, if, for example, some of displaced capacity from the reference case were gas.

CHART 5.7: PROJECTED REDUCTIONS IN ENERGY DEMAND IN ABATE1.1, 2020



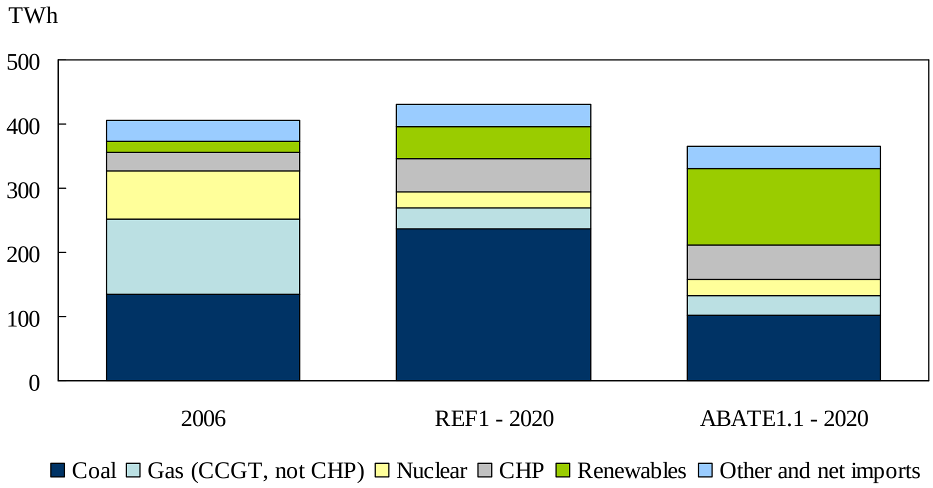
Note(s) : 1. Use of electricity by road transport (due to MAC curve measures) in ABATE1.1 is not shown as it was zero in REF1.
Source(s) : NAEI, DEFRA, BERR (DUKES 2007), Committee on Climate Change Secretariat and Cambridge Econometrics.
Ref : C82R1CCC, C82AB83MVAICCC.

CHART 5.8: PROJECTED CAPACITY OF POWER GENERATION BY STATION TYPE, UK



Note(s) : 1. Power generation includes major power producers and autogeneration.
2. Coal includes both FGD and non-FGD installations.
3. Coal CCS is included in coal and gas CCS is include in gas.
Source(s) : BERR (DUKES 2007), National Grid, Committee on Climate Change Secretariat and Cambridge Econometrics.
Ref : C82R1CCC, C82AB83MVAICCC.

CHART 5.9: PROJECTED POWER GENERATION BY STATION TYPE, UK

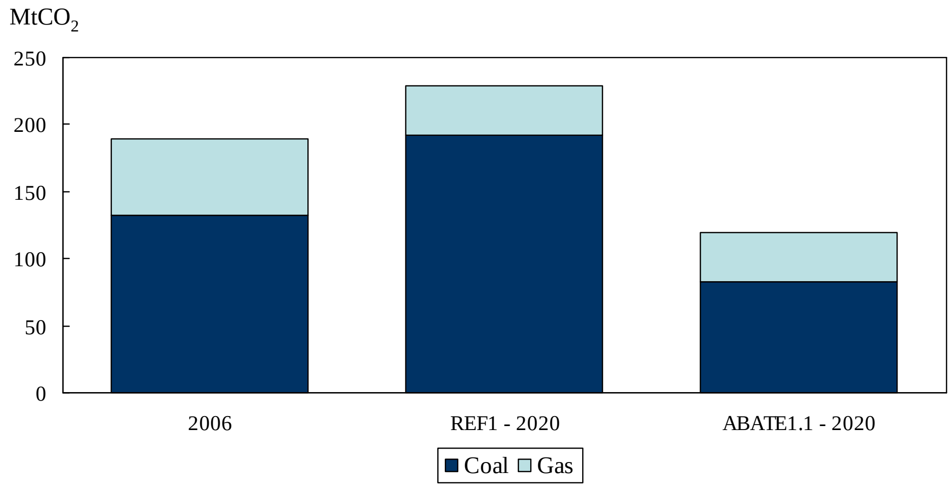


Note(s) : 1. Power generation from major power producers and autogeneration.
2. Coal includes both FGD and non-FGD installations.
3. Coal CCS is included in coal and gas CCS is include in gas.

Source(s) : BERR (DUKES 2007), National Grid, Committee on Climate Change Secretariat and Cambridge Econometrics.

Ref : C82R1CCC, C82AB83MVAICCC.

CHART 5.10: PROJECTED CO_2 EMISSIONS FROM POWER GENERATION BY FUEL, UK



Note(s) : 1. Power generation includes major power producers and autogeneration.
2. Nuclear and renewables are assumed to be zero-carbon.
3. Coal includes both FGD and non-FGD installations.
4. Emissions from oil are not shown, but are very small amount.

Source(s) : BERR (DUKES 2007), National Grid, Committee on Climate Change Secretariat and Cambridge Econometrics.

Ref : C82R1CCC, C82AB83MVAICCC.

5.5 Regional energy and emissions projections

5.5.1 The CCC secretariat requested disaggregation of the UK energy and emissions projections for each of the Devolved Administrations (DAs) in Northern Ireland, Scotland and Wales, and England. A summary of the methodology used to derive these estimates can be found in Appendix D.

5.5.2 This section contains a summary of the regional energy and emissions projections from central reference scenario, REF1, and the abatement scenario, ABATE1.1. The base data used for these projections is the 2007 update of data collected for the Sustainable Consumption and Production Network (SCPNet). The latest year of outturn in this data set is 2005. It should be noted that the data are not fully consistent with the GHG inventories.

5.5.3 Energy and emissions presented in this section exclude energy demand and emissions from air, rail and water transport. Offshore emissions (eg from platforms in the North Sea) have also been excluded, but its energy demand is included. The emission projections presented here are on the IPCC basis (ie they exclude emissions reductions from purchases of overseas credits).

5.5.4 The energy savings and fuel switching from abatement scenarios (and the consequent changes in emissions) have been apportioned to fuel users in each of the DAs and England by the share of total UK energy demand from that fuel user in each area. For example, if 75% of energy demand from industry is from sites located in England, then 75% of the impact of energy savings from the MAC curve measures applied to industry is allocated to those based in England.

CO_2 emissions

Projected emissions in REF1 rise due to power generation

5.5.5 Table 5.1 shows the percentage changes in the projected level of CO_2 emissions in 2020 for each of the DAs, England and the UK, compared to the 2005 levels. The changes for the central reference and abatement scenarios are shown. Changes in emissions including and excluding emissions from power generation are shown separately.

5.5.6 Generally, CO_2 emissions in REF1 are projected to be higher in 2020 than the 2005 levels. However, emissions excluding those from power generation are projected to be lower. The difference is most striking for Northern Ireland where emissions are projected to rise by 80% when emissions from power generation are included, but to be 20% lower when they are excluded. This is due to the projected increase in power generation in Northern Ireland in this period in REF1. It should be noted that large percentage changes typically represent small changes in the levels of emissions (projected emissions from Northern Ireland in 2020 in REF1 are less than 5% of the projected UK total).

5.5.7 The exception to this trend is Scotland, where emissions in 2020 are projected to fall regardless of whether power generation is included. This is because a large coal power station located in Scotland is assumed to close by 2015 in the reference scenario.

The projected abatement measures are projected to cut emissions in Northern Ireland and Wales by more than the UK average

5.5.8 CO_2 emissions in the UK (on the IPCC basis and excluding emissions from air, rail and water transport and offshore emissions) in the abatement scenario in 2020 are projected to be 31% lower than that in REF1 (see Chart 5.11). The reductions in emissions from Northern Ireland (51%) and Wales (45%) are projected to be greater than the UK average. The reduction in emissions from Scotland (16%) is projected to be lower than the UK average. Unsurprisingly, given its size in relation to the UK, England's reduction (30%) is close to the UK average.

5.5.9 The percentage reduction in emissions is particularly large in Northern Ireland and Wales due to the greater influence of power generation on emissions in these regions. Power generation is projected to account for more than 70% of total emissions in Northern Ireland in 2020 in REF1 and more than 50% in Wales. The UK average is projected to be 40%. Therefore emissions from these regions are affected more by the fuel switching and reduction in electricity generation caused by the measures in the abatement scenario.

5.5.10 The smaller reduction projected in Scotland is due to the limited scope for fuel switching in the power generation plant based there, since a large coal power station located in Scotland is assumed to close by 2015 in any case.

Energy demand

5.5.11 Chart 5.11 also shows the percentage reduction in primary and final energy demand in each of the DAs, England and the UK. It shows that measures in the abatement scenario are projected to affect primary energy demand more than final energy demand in the most regions, except for Scotland. This is because these measures affect energy demand from power generators (whose energy demand is included in the primary energy demand measure but not in final energy demand) much more than final energy demand by final end users.

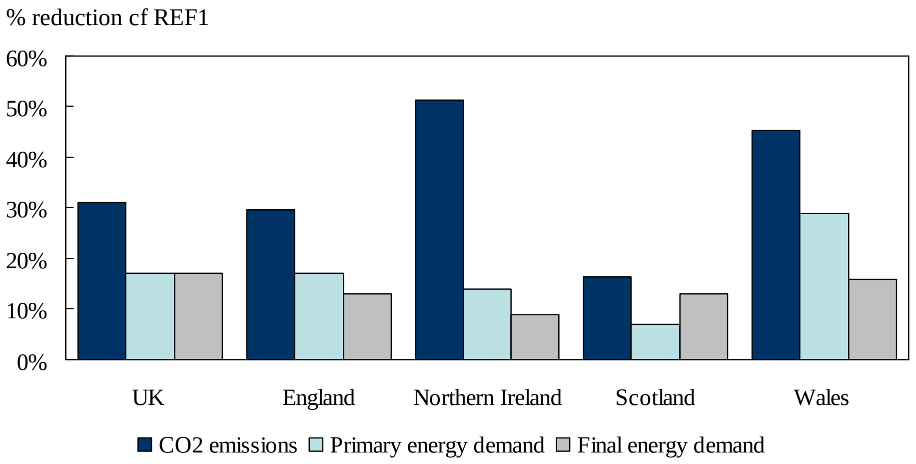
5.5.12 The exception to this is Scotland, where the reduction in final energy demand in the abatement scenario in 2020 (13%) is almost double the reduction in primary energy demand (7%). This is because the scope for fuel switching in the power sector there is limited, since a large coal power station located in Scotland is assumed to close by 2015 in both scenarios.

TABLE 5.1: CHANGE IN CO_2 EMISSIONS[1] IN 2020 (% CHANGE FROM 2005)

	Including power generation		Excluding power generation	
Country	REF1	ABATE1.1	REF1	ABATE1.1
England	6.9	-24.7	-1.2	-20.9
Northern Ireland	80.2	-1.5	-18.8	-34.0
Scotland	-22.2	-34.9	-16.9	-31.6
Wales	4.2	-49.4	-15.8	-34.2
UK	6.1	-26.9	-4.2	-23.2

Note(s) : 1 IPCC basis. Includes direct non-energy as well as direct energy emissions.
2. Excludes emissions from air, rail and water transport and from offshore
Source(s) :NAEI, BERRS (DUKES 2007), SCPNet(2007), Cambridge Econometrics
Ref : C82R1CCC, C82AB83MVAICCC.

CHART 5.11: PROJECTED REDUCTIONS IN CO_2 EMISSIONS AND ENERGY DEMAND IN ABATE1.1, 2020



Note(s) : 1. Excludes energy demand and emissions from air, rail and water transport and emissions from offshore.
2. Emissions are on the IPCC basis. Emissions from power generation are included.

Source(s) : NAEI, DEFRA, BERR (DUKES 2007), SCPNet (2007) Committee on Climate Change Secretariat and Cambridge Econometrics.

Ref : C82R1CCC, C82AB83MVAICCC.

6 Sensitivity tests on energy and emission projections

6.1 Overview

6.1.1 This chapter discusses the key features of the energy and emission projections under abatement scenarios undertaken in the context of higher fossil fuel prices assumptions (see Section 6.2). The economic projections for these scenarios are discussed in Chapter 8. As in the discussion in Chapter 5 comparing the reference and abatement scenarios in the central fossil fuel prices, we focus here on the differences between them in 2020 as a result of the abatement measures.

6.1.2 We also conducted a sensitivity test which focused on the way in which the revenues from the auctioning of EU ETS allowances are recycled into the economy. Since the alternative method of recycling that was modelled was not associated with energy or emission specific measures, the only differences of interest are their macroeconomic impact, not their impact on energy and emissions. The macroeconomic differences are discussed in Chapter 8.

6.1.3 Finally, we conducted further sensitivity tests on the reference projection under low and 'high-high' fuel prices[14]. These were developed to inform a comparison with the DECC model. These projections are not discussed in this report.

6.2 The impact of abatement measures in the context of high fossil fuel prices

6.2.1 Given the uncertainty about the future level of fossil fuel prices, the reference (REF2) and abatement (ABATE2.1) scenarios were repeated to implement abatement policies in a context of high fossil fuel prices, to test whether the impact of the polices was substantially different. The results reported here do not represent the impact on the energy demand and emissions from higher fossil fuel prices, but rather the impact of carbon abatement measures in a world of high fossil fuel prices.

The price differential between gas and coal is smaller in the high fuel price assumptions

6.2.2 The high fuel price assumptions are consistent with those published by BERR (2008a). In these assumptions, the (real) oil price rises to \$95 per barrel by 2020. This is about a third higher compared than in central case. The real price of gas is assumed to rise to 60p/therm by 2020, which is about a third higher than in the central case. In the high set of assumptions, the price differential between gas and coal is assumed to be less in 2020 (3.3 times more expensive) than in the central set (almost 3½ times more expensive).

[14] These also matched the assumptions published by BERR (2008a)

6.2.3 The assumptions for abatement measures provided by the CCC were adjusted to reflect the context of high fossil fuel prices, so that the carbon price was higher[15] and the technological abatement measures that become economically attractive are located higher in the schedule of MAC curves.

High fuel prices do not change the impact of the abatement measures significantly

6.2.4 Table 6.1 show the impact of the abatement measures on key energy and emission variables in the context of central and the high fossil fuel prices. The impacts under the two cases are very similar. In both cases, abatement measures are projected to curb CO_2 emissions (on the IPCC basis) by some 30% in 2020 compared with what happens without the measures.

6.2.5 The biggest difference between the two is the impact on the retail electricity price. In a world of high fossil fuel prices, the abatement measures are projected to cause the retail price of electricity rise by 86% in 2020, compared with 80% under the central set of fuel price assumptions. This entirely reflects the higher assumptions of EU ETS carbon prices which MDM-E3 assumes is passed through wholly onto the wholesale electricity price.

The limited differences are due to the fuel price and other scenario assumptions

6.2.6 There are a number of reasons why the two sets of results are similar. Firstly, the difference in the gas and coal price assumptions was already so large in the central fossil fuel price case that the further widening had very little impact on the power generation mix. Secondly, about a third of the generation mix is dictated by the assumptions on the rapid deployment of renewable power in the abatement scenarios.

TABLE 6.1: IMPACT OF ABATEMENT MEASURES IN 2020
(% REDUCTION COMPARED WITH REFERENCE SCENARIOS)

	Central fuel price assumptions	High fuel price assumptions
UK CO_2 emissions (IPCC basis)	-30	-31
UK CO_2 emissions (Net carbon account)	-40	-38
Final energy demand	-14	-13
Average retail electricity price[1]	+80	+86
Demand for electricity	-15	-19
Average CO_2-intensity of electricity	-37	-40

Note(s) : 1 The retail price is the wholesale price plus taxes and levies that are applied by MDM-E3. In MDM-E3, retail prices can vary by fuel user; the weighted average (by amount of electricity consumed) is the concept discussed here.
Source(s) : Cambridge Econometrics.
Ref : C82R1CCC, C82AB83MVANCCC

[15] Although the price differential between gas and coal under the high fossil fuel price assumptions is less in proportionate terms, it is greater in absolute terms, and a higher carbon price is needed to offset this. The take-up of renewables in the abatement scenarios is mainly by assumption (see Section 4.3).

7 Macroeconomic and sectoral projections for central reference (REF1) and abatement (ABATE1.1) scenarios

7.1 Overview

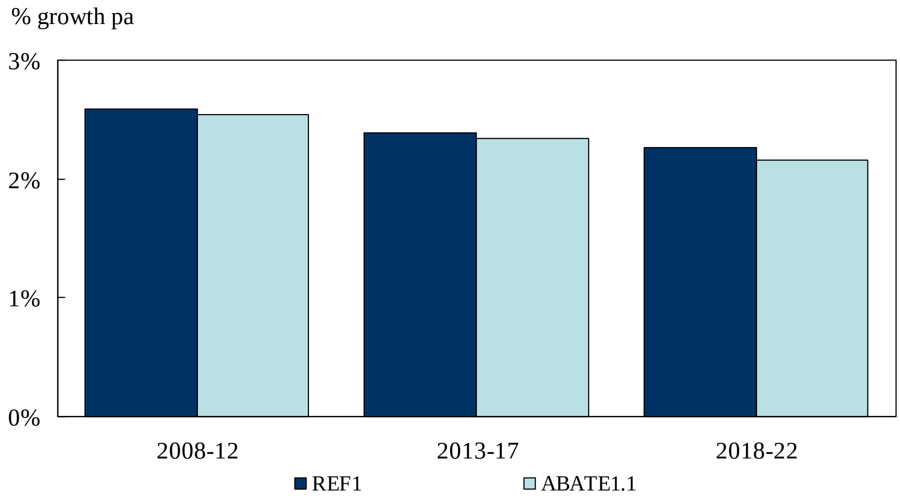
7.1.1 This chapter discusses the macroeconomic impacts which arise from the implementation of the carbon reduction measures, calculated here as the difference in outcomes between the central reference case and the abatement scenario. Chapter 5 discussed the energy and emissions savings resulting from the measures and it is important to consider these savings when looking at the macroeconomic impacts. The overall GDP impact is discussed in Section 7.2 and a decomposition of the contribution of the various stages in the modelling to the GDP impacts can be found in Appendix C. The carbon reduction measures also affect the UK's trade balance, the rate of price inflation and the level of employment, and these effects are discussed in Section 7.3.

7.2 The impact on UK GDP

The carbon abatement measures reduce GDP by 0.8% in 2020

7.2.1 Overall, the carbon abatement measures are estimated to lead to a 0.8% fall in GDP in 2020 compared with the level in the same year in the central reference scenario. In the central reference scenario GDP grows by 2.47% pa over the period 2006-20; this is reduced to 2.41% pa over the same period in the abatement scenario.

CHART 7.1: PROJECTED GROWTH IN UK GDP



Source(s) : NAEI, DEFRA, BERR (DUKES 2007), SCPnet (2007) Committee on Climate Change Secretariat and Cambridge Econometrics.
Ref : C82R1CCC, C82AB83MVAICCC.

7.2.2 In the budget periods 2008-12 and 2013-17 GDP growth is around 0.05 pp pa lower, rising to 0.1 pp pa lower over 2018-22, as shown in Chart 7.1.

7.2.3 The introduction of a carbon price alone, in the form of the EU ETS, accounts for much of the overall decrease in GDP as discussed in Appendix C. The implementation of the MAC curves has a mildly positive impact on GDP as the fuel savings marginally outweigh the technology cost. The additional GDP impact is largely due to the implementation of higher import prices to model the European-wide element of the EU ETS. The effect of auctioning and recycling directly to household incomes has only a modest overall GDP impact as it mainly changes the distribution of income in the economy.

Some potential effects have been excluded from the modelling

7.2.4 By assumption, import prices to the UK were increased by 60% of the change seen in domestic prices in the UK following the introduction of the allowance price. This is intended to simulate the higher costs for exporters in EU member states from the direct and indirect effects of higher allowance prices under the EU ETS, but this may impart a downward bias to the results. In reality all countries within the EU ETS will see increases in domestic prices which would make UK exports more competitive, and this effect is not included in the model scenario. However, the domestic price increase in the EU ETS countries is also likely to lead to a reduction in activity there, and so the net effect on exports is uncertain.

7.2.5 No attempt has been made in the modelling to reflect the potential benefits of higher rates of innovation arising from strong domestic demand for energy efficiency and carbon abatement technologies, which could improve the competitiveness of UK suppliers of these technologies.

7.3 Other macroeconomic impacts

Prices and wages

Consumer prices are 3¾% higher in 2020

7.3.1 The most significant impact of the carbon reduction measures is the impact on producer and consumer prices. The rate of consumer price inflation averages 2.4% pa over 2006-20 in the reference scenario compared with 2.64% in the abatement scenario. As a result, by 2020, consumer prices are 3.8% higher in the abatement scenario. This reflects the substantial carbon price which flows through the price of electricity and other EU ETS sectors both directly to households and also indirectly through the impact on production costs. The overall price increase is boosted further by the assumption of higher import prices, which affect consumer prices directly (because of the share of imports in household consumption) and indirectly through the impact on producer prices (through increased unit costs and as competitor prices). In MDM-E3 interest rates are exogenous and the results do not incorporate any tightening of monetary policy to restrain price inflation.

Real wages are lower

7.3.2 In MDM-E3, average earnings are modelled by industry and region. The net effect of the changes is that wages do not catch up fully to higher consumer prices. This contributes to a boost to employment, but the combined effect is that in 2020 real personal disposable income is some 1.6% lower in the abatement scenario. The consequent reduction in household spending leads the reduction in GDP.

7.3.3 The MACC measures were applied to current expenditure of industries and households. Depending on the scale of any individual scheme, it might be classified as current or capital spending in the national accounts. However, the treatment of the MACC technology costs here has been to use the CCC's annualised estimates of each scheme's installation and operating costs and benefits, and so current expenditure is the relevant concept to adjust. For household consumption we assume that overall spending is unchanged, so that spending on other products is adjusted for the net cost/benefit of MACC measures, although in practice the measures are essentially self-financing.

Expenditure

The fall in GDP is led by lower household spending

7.3.4 Household expenditure is 1.57% lower by 2020 in the abatement scenario, largely because the impact of the rise in consumer prices on real household incomes is less than fully offset by higher wages and employment. There is a slight reduction in the saving ratio. The fall in household expenditure explains most of the reduction in GDP and most of the reduction in import volumes.

Trade

Imports fall by a little more than exports

7.3.5 The balance of trade in goods and services improves marginally as a result of the abatement measures. In 2020 the balance is -£21.8bn in the abatement scenario compared to -£24.5bn in the central reference scenario.

7.3.6 Import volumes are 0.6% lower than in the central reference case by 2020. However, import volumes as a share of GDP are slightly higher as a result of the measures. There is some loss of competitiveness by UK producers to firms located outside of the EU. However, the effect on the level of imports of this loss of competitiveness is outweighed by the income effect of lower overall activity in the economy.

7.3.7 Export volumes are slightly lower in the abatement scenario. Although export prices have increased in response to higher unit costs, the effect is quite small and in most sectors UK exports are no longer highly price-elastic. By 2020, export volumes as a share of GDP are slightly higher in the abatement scenario because the reduction in GDP, led by reduced domestic spending, is greater than the reduction in exports. However, as noted earlier the modelling has not taken account of the effects of a strong carbon price on EU activity.

Employment

Employment is higher

7.3.8 As energy costs are considerably higher, this has the effect of making labour relatively cheaper. This substitution effect outweighs the activity effect of lower GDP, and employment[16] is about ¾% higher by 2020 in the abatement scenario. In the central reference scenario, employment grows at around 0.61% p.a. between 2006 and 2020 compared to 0.65% in the abatement scenario. In each of the three carbon budget periods employment in the abatement scenario is above the central reference scenario.

[16] Employment is measured as a headcount of jobs, not as full-time equivalent jobs or number of workers.

Investment

Investment is lower

7.3.9 In MDM-E3 investment in gross fixed capital formation is mainly determined by the level of activity in each investing sector. In our implementation, the boost to expenditure for the MACC measures is represented as current expenditure. Therefore, investment levels are lower in the abatement scenario by slightly more than the reduction in GDP in 2020 (1%).

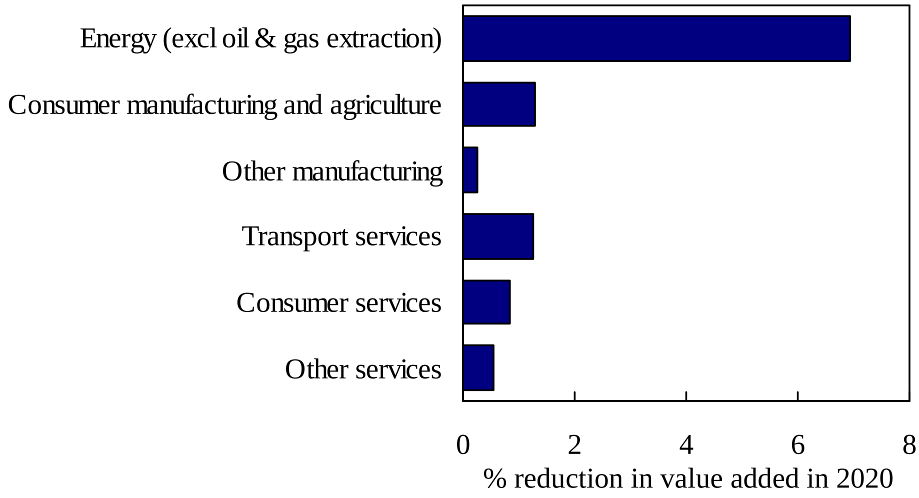
7.3.10 It is ambiguous what change occurs in the projected level of investment undertaken by power generators in the abatement scenario. In the abatement scenario, more power generation capacity is required per unit of generation than in REF1 due to the higher use of renewables assumed in this case (renewables are modelled to have a lower load factor than fossil-fuel based forms of generation). However, total capacity in REF1 and the abatement scenario are at similar a level as demand for electricity is lower in the abatement scenario. It is not possible to separately identify the change in the level the investment by power generators alone as this is contained in an investment category that also includes investment by gas and water supply industries.

7.4 Sectoral impacts

7.4.1 This section summarises the results for the impacts of carbon abatement at the sectoral level. Although the order of presentation in this report has shown the macroeconomic outcomes first, this should not be interpreted to mean that the macroeconomy is treated as an entity that is defined prior to the industry sectors. In MDM-E3, the macroeconomic results are calculated as the sum of its sectoral outcomes, not derived first with the sectoral disaggregation undertaken in some subsequent step.

7.4.2 For each of the 42 industries identified in MDM-E3, output depends upon the demand for products (broken down into the categories of final demand together with the intermediate demand arising from each other industry) and the share of that market taken by domestic producers as against imports. The sectoral results therefore reflect the extent to which each sector is exposed to the pattern of changes in the final expenditure components discussed above, and the extent to which its costs are affected by the carbon abatement policies. If the policy amounted to a simple tax on all carbon use in the economy, the impact on costs would be proportionate to the direct and indirect carbon intensity of each sector's production. In fact the policies actually implemented in the modelling are more specific than this, with a carbon price applied to the EU ETS sectors, a target for renewables in power generation, and some specific measures to promote take-up of largely no-regrets (taken as a whole package) technological abatement options. Much of the impact on costs therefore focuses on electricity use, since this is the product whose price is most boosted by the policies.

CHART 7.2: BROAD SECTORAL IMPACTS OF THE CARBON ABATEMENT POLICIES



Note(s) : Differences between ABATE1.1 and REF1 scenarios.
Source(s) : Cambridge Econometrics.
Ref : C82R1CCC, C82AB83MVAICCC.

Value added 7.4.3 A summary of the impacts on value added by sector is shown in Chart 7.2. In the chart, MDM-E3's 42 sectors have been aggregated into broad groups to help to highlight differences according to the characteristics of the sectors. The chart shows the difference in value added in 2020 between the abatement scenario and the central reference scenario; the context for this is the reduction of 0.8%% in GDP as a whole noted in Section 7.2 above. Changes in value added, measured in real terms, mainly reflect the reductions in purchases of the products of each industry in response to higher prices.

Energy production 7.4.4 The biggest impact, of course, is on energy production itself, since reductions in energy use and the energy intensity of the economy are one of the principal consequences of the abatement measures. Within energy, the largest reduction in value added is in gas supply (about 11% lower in 2020), partly because this is the main fuel against which substitution of renewables in power generation occurs, and partly because some of the specific abatement measures introduced for firms and households result particularly in savings in the use of gas. Value added in electricity supply is 5½% lower in 2020, and value added in manufactured fuels (which includes oil refining) is 2½% lower. In MDM-E3, extraction of oil and gas is set by assumption (because it depends greatly on the physical characteristics of the fields in question) and so this does not change in the scenario; changes in demand are reflected entirely in imports.

Transport services

7.4.5 The next most-affected industry is air transport, in which value added is 2% lower in 2020. This arises from the impact on its costs of the inclusion of domestic and international aviation in the EU ETS from 2013. Also, household spending on air transport is income-elastic and so affected to a greater degree by the reduction in real household income. Air transport is included in the Chart 7.3 in the category ‘transport services’. Rail, road and water transport services are less affected, seeing reductions in value added of about 1%, reflecting a reduction in household demand and the lower demand for freight transport throughout the economy.

Consumer-oriented sectors

7.4.6 The next most-affected industries are those which supply a greater proportion of their output to consumers, since household spending is the category of final demand that is most reduced in the abatement scenario. In Chart 7.3, the group ‘consumer manufacturing and agriculture’ includes food, drink, tobacco, textiles, clothing, furniture, recreational goods and agriculture. It should be remembered, however, that consumer demand for these products is also met in part by imports, and so the impact of reduced UK spending is borne partly by foreign suppliers. On average this group sees a reduction in value added of 1¼%, with reductions closer to 1½% for food, drink & tobacco and agriculture.

7.4.7 Consumer services see a reduction in value added of just under 1% in 2020. Among the sectors included here, hotels & catering, retailing and personal services are more affected than wholesale distribution.

Sectors that are less affected

7.4.8 The smaller reductions in the remaining sectors of the economy reflect their smaller exposure to household spending and higher energy costs. The EU ETS manufacturing sectors do not suffer particularly large reductions in value added because the impact on their competitiveness is partly shielded by the assumption of similar action in the rest of the EU. However, MDM-E3 does not distinguish imports by country of origin, and so the impact on sub-sectors that are more exposed to competition from outside of the EU would be larger than the results shown here.

8 Sensitivity tests on macroeconomic and sectoral projections

8.1 Overview

8.1.1 The purpose of this section is to assess the robustness of the results against different sensitivities. In the abatement scenario discussed in Chapter 7 the revenue gained from auctioning EU ETS permits is recycled directly to household incomes. In Section 8.2 we assess the impacts of recycling the revenue by reducing employers' national insurance contributions (NICs). We have also assessed the impact of the abatement scenarios in a world in which fossil fuel prices are higher than was assumed for the central reference scenario and the abatement scenario discussed in Chapter 7. We consider a second abatement scenario with high fossil fuel prices and compare this with a high fossil fuel price reference scenario, the results of which are discussed in Section 8.3. The implications of these sensitivities for energy use and CO_2 emissions are discussed in Chapter 6.

8.2 Recycling EU ETS auction revenues as cuts in employers' NICs

8.2.1 In the main abatement scenario described in Chapter 4 the revenues gained from auctioning EU ETS permits were recycled directly to household incomes. In this sensitivity the revenues from auctioning EU ETS permits are used to reduce the rate of employers' NICs.

GDP is lower when revenues used to cut NICs rather than recycled directly to households, because there are more leakages to taxation

8.2.2 The two recycling scenarios both have the effect of mitigating the impact on GDP, compared with a case in which the revenues accrue to government and are not spent. The positive effect on GDP in 2020 of recycling revenues is about 0.4pp when revenues are recycled directly to household incomes, but about 0.2pp when NIC rates are cut. In principle we might have expected the effect of cutting NIC rates to be more positive, because this policy provides a benefit to the economy's productive potential from cutting a distortionary tax. However, there are some leakages to taxation as a result of the reduction in NIC rates (higher pre-tax profits and wages) which reduce the income that reaches households whereas in the abatement scenario discussed in Chapter 7 the revenues are recycled directly to post-tax household incomes. When income is recycled directly to household incomes, there is little effect on consumer prices but a considerable boost to incomes. When income is recycled as a cut in employers' NICs, more of the benefit to household incomes and spending comes through lower prices.

8.2.3 However, the policy of cutting NICs is slightly more beneficial to employment, even though GDP is lower, because of the reduction in labour costs faced by employers.

8.2.4 The other differences in macroeconomic indicators are very small. In 2020, imports are 0.1% lower in the scenario where revenues are recycled by cutting NICs rather than directly to incomes, reflecting weaker household spending. Also in 2020, exports are very slightly higher as a result of recycling to NICs rather than directly to incomes, because unit costs are slightly lower in the NIC recycling scenario. Consumer prices are lower when revenues are recycled as cuts in NICs because this scenario does cuts production costs.

8.3 High fossil fuel prices

8.3.1 Given the uncertainty about the future level of fossil fuel prices, we repeated the full set of scenarios to implement abatement policies in a context of high fossil fuel prices, to test whether the impact of the polices was substantially different. The results reported here do not represent the impact on the economy of higher fossil fuel prices, but rather the impact of carbon abatement measures in a world of high fossil fuel prices.

8.3.2 This sensitivity test was carried out under very particular circumstances. At the CCC's request, in order to try to isolate the effect of fossil fuel prices, as distinct from wider structural change in the economy that might occur in response to such prices, MDM-E3 was calibrated so that the main features of the economy in the high fossil fuel reference scenario were kept the same as in the central reference scenario. The assumptions for abatement measures provided by the CCC were adjusted to reflect the context of high fossil fuel prices, so that the carbon price was higher and the technological abatement measures that become economically attractive are located higher in the schedule of MAC curves.

The GDP impact is robust to different fossil fuel price assumptions

8.3.3 The GDP impact of moving from the high fossil fuel price reference scenario to the high fossil fuel price abatement scenario with recycling to household incomes is slightly lower than under central fuel prices, at 0.75%. The higher carbon price results in a slightly larger boost to consumer prices: consumer prices are 4.0% higher in 2020 as a result of abatement policies compared to 3.75% in 2020 in the central fossil fuel price comparison. On the other hand, the compensation effect of recycled revenues is also greater because the EU ETS auctioning revenues are larger with a higher carbon price. Consequently, the impact of the abatement measures on household spending is only slightly less when fossil fuel prices are at high levels.

8.3.4 As the impact on prices and household spending are broadly similar, the other macroeconomic impacts are similar between the two cases.

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Appendix A The MDM-E3 Model

A.1 Introduction

Background and history

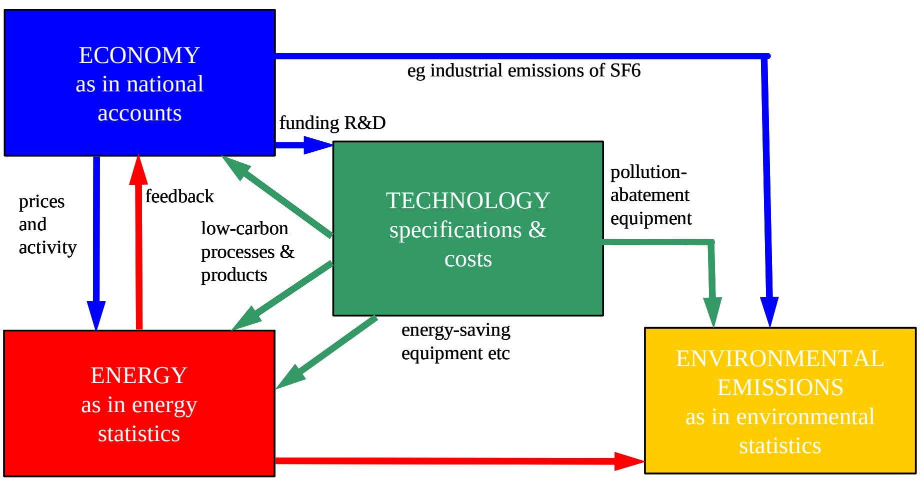
A.1.1 The Cambridge Multisectoral Dynamic Model of the UK economy (MDM-E3) is the UK's most detailed integrated energy-environment-economy (E3) model, designed to analyse and forecast changes in economic structure, energy demand and resulting environmental emissions. The current version of MDM-E3 is based on the 2003 Standard Industrial Classification (SIC03). The model has a pedigree that goes back to the combined static input-output and linear-expenditure system of the Cambridge Growth Project (Stone and Brown, 1962 and 1965), one of the first large-scale econometric models to be solved on a mainframe computer (Refro, 2003). The model became dynamic in the late 1970s (Barker, 1975). A comprehensive account of an earlier version of the economic model is given in Barker and Peterson (1987).

A.1.2 The version of the model used in for this project is essentially the same as the one used to produce CE's Energy and Emissions forecasts published in August 2008. For this study the model has been extended to produce energy and emission projections for each of the devolved administrations and England.

Contents

A.1.3 This chapter gives most detail to the way in which MDM-E3 determines energy demand, the power generation supply mix and emissions. Section 2.2 gives an overview of the integration of energy use and emissions in MDM-E3. Section A.3 focuses on the methodology used in the model to project energy and fuel demand. Section A.4 discusses the endogenous modelling of the UK power capacity and generation mix. Section A.5 discusses the method used to estimate greenhouse gas emissions. Section A.6 summarises how MDM-E3 determines economic variables.

FIGURE A.1: ENGINEERING-ENERGY-ENVIRONMENT-ECONOMY INTERACTIONS IN MDM-E3



Source(s) : Cambridge Econometrics.

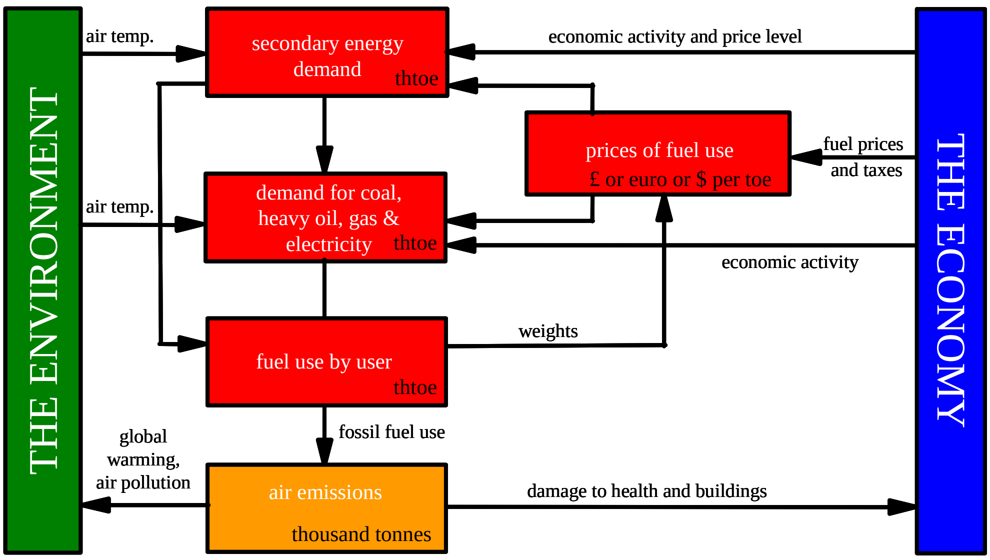
A.2 Modelling energy and emissions in MDM-E3

A.2.1 Flows in the economic model are generally in current and constant prices, prices are treated as unit-value indices, and the energy-environment modelling is done in physical units. This modelling is described in Barker et al (1995).

A.2.2 MDM-E3 includes a bottom-up (the ETM) submodel to model changes in the power generation sector's use of fuels in response to policy initiatives and prices. This modelling approach has been reviewed by McFarland (2004) and has the advantages that it avoids the typical optimistic bias often attributed to a bottom-up engineering approach, and the unduly pessimistic bias of typical macroeconomic approaches. It was the focus of a recent Tyndall Centre project (Koehler et al., 2005) and the current research under the Energy Systems and Modelling Theme (ESMT) for the UKERC (Barker et al., 2005a).

A.2.3 Energy-environment characteristics are represented by submodels within MDM-E3, and at present the coverage includes energy demand (primary and final), environmental emissions, and electricity supply. Energy demand by industries is then translated into expenditure flows for inclusion within the input-output structure to determine economic variables, so that MDM-E3 is a fully-integrated single model, allowing extensive economy-energy-environment interaction (see Figures A.1 and A.2).

FIGURE A.2: THE ENERGY SUBMODEL IN MDM-E3



Source(s) : Cambridge Econometrics.

A.2.4 The ability to look at interactions and feedback effects between different sectors - industries, consumers, government - and the overall macroeconomy is essential for assessing the impact of government policy on energy inputs and environmental emissions. The alternative, multi-model approach, in which macroeconomic models are operated in tandem with detailed industry or energy models, cannot adequately tackle the simulation of 'bottom-up' policies. Normally such multi-model systems are first solved at the macroeconomic level, and then the results for the macroeconomic variables are disaggregated by an industry model. However, if the policy is directed at the level of industrial variables, it is very difficult (without substantial intervention by the model operator) to ensure that the implicit results for macroeconomic variables from the industry model are consistent with the explicit results from the macro model. As an example, it is very difficult to use a macro-industry, two-model system to simulate the effect of exempting selected energy-intensive industries from a carbon or energy tax.

Energy and emissions projections have been extended to 2030

A.2.5 Before undertaking this project, MDM-E3 projected UK economic, energy and emissions variables to up to 2020 as a matter of course. We have extended the model to project energy and emissions to 2030 by maintaining the econometric equations currently used to estimate energy and fuel demand. Because of the forward-looking nature of the way in which MDM-E3 models decisions to build power station plant, projections for the power sector to 2030 require assumptions for the wholesale electricity price and fossil prices to 2041. For this project, we have assumed that fossil fuel prices remain at level achieved in 2030 and that the electricity price will broadly follow an extrapolation of the modelled prices.

A.2.6 We also have maintained the equations that govern the macroeconomic responses. However, this report only focuses on emission and energy projections to 2022. Projections of macro and sectoral economic variables have only been made available to 2022.

A.3 Modelling energy demand (non power generation uses)

A.3.1 The energy submodel determines final energy demand, fuel use by user and fuel, the prices of each fuel faced by fuel users, and also provides the feedback to the main economic framework of MDM-E3. Fuel use for power generation is calculated in the electricity supply industry (ESI) submodel, which uses a 'bottom-up' engineering treatment. See Section A.4 for a further discussion on this. Section A.8 contains a full list of fuel users and fuels that MDM-E3 currently covers.

Aggregate energy demand for each fuel user is determined first

A.3.2 Final energy and fuel demand by fuel user is modelled by econometric equations, which are estimated using a standard cointegrating technique (see Tables A2 and A3 in section A.8 for the functional form of the equations). The estimation of energy demand occurs in a two-step method. Firstly, the aggregate (ie with no breakdown by fuel type) demand for energy for each end-user is determined. Typically, the key dependent variables are:

- the activity of the fuel user, usually taken to be gross output of the sector, but, in the case of road transport, gross domestic product plus imports is used and in the case of households, household expenditure is used

- technological progress in energy use, which reflects both energy-saving technical progress and the elimination of inefficient technologies
- the price of energy relative to general prices
- changes in temperature

Announcement and awareness effects are included for industrial fuel users

A.3.3 In addition, to account for the Climate Change Levy and Climate Change Agreements, we also include the 'announcement' effect of the CCL and the 'awareness' effects on participating industries of the CCAs. The estimates of these effects were derived from a study Cambridge Econometrics for HM Customs and Excise (Cambridge Econometrics, 2005).

Shares are estimated to derive fuel users' demand for each fuel

A.3.4 Fuel users' demand for each fuel is estimated by splitting the estimated aggregate energy demand. To reflect the fact that fuel switching is inhibited by the existing stock of appliances and machinery used in the economy and the available infrastructure, it is assumed that fuel users adopt a hierarchy in their choice of fuels;

- choosing first electricity for premium uses (light, electrical appliances motive power, special heating applications)
- then sharing out non-electricity demand for energy between three fossil fuels (coal and coal products, oil products and gas)

A.3.5 The specification of these equations is similar to that of the aggregate energy equations, except that the estimated variable is the fuel share, and the explanatory variables are:

- activity
- technology measure
- three price terms - the price of the fuel type in question, the price index of its nearest competitor, and the general price index within the economy
- temperature (where relevant)

A.3.6 This method is regarded to be the most suitable given the data available and the relative quality of data at different levels of disaggregation. The aggregate energy demand equations command a higher level of confidence than the fuel share equations. The estimated fuel share equations used to split aggregate demand to yield demand for individual fuels by fuel users fit the data better than equations which directly estimate the demand of a particular fuel by an individual fuel user. This is partly due to high level of volatility in the time series data at this level of detail.

Equations used for modelling demand are in co-integrating form

A.3.7 Both the aggregate energy/fuel demand equations and the disaggregated fuel share equations are specified as cointegrating equations. Appendix B contains a technical discussion of the equations. In summary,

- the dynamic part of the equation provides short-term responses of energy demand,
- the long-term response is captured in the long-term part of the equation, adjusted for the speed of adjustment term (or error correction mechanism)

A.3.8 The equations for final energy demand are estimated on the latest data from the Digest of UK Energy Statistics (BERR 2007), where outturn data is provided up to 2006.

A.3.9 The wholesale prices of fossil fuels such as coal, oil and gas are assumptions in MDM-E3. For this project, we have used assumptions on fossil fuel prices provided by the CCC. Wholesale prices are converted to consumer/retailer prices for each fuel user by applying appropriate levies and taxes.

A.4 Modelling power generation

A.4.1 MDM-E3 models the stock of power generation capacity and the annual generation of power from this stock in response to changes to demand for electricity, fossil fuel prices, carbon prices and incentives to increase the use of renewables. For this project, we have made the distinction between major power producers (MPPs) and autogeneration. Changes to the power capacity stock is modelled by the electricity technology submodel (ETM). Estimation of generation from the capacity stock is modelled by the electricity supply industry (ESI) submodel. More details on the ETM can be found in Appendix B.

Modelling capacity

In MDM-E3, changes to the power capacity stock is modelled by the Electricity Technology submodel (ETM)

A.4.2 The ETM builds on earlier work by Anderson and Winne (2004). The ETM assumes the role of the national social planner whose objective is to derive a schedule of build of new capacity to meet expected demand. It chooses to build capacity from a range of generation technologies.

A.4.3 In CE's regular forecasts, the demand for electricity expected by the planner when making decisions to build new capacity is derived by extrapolating recent historical trends. This treatment means that the ETM adopts 'adaptive' expectations of demand. It is our belief that this is appropriate method to mimic the actual behaviour of generators in this respect. This is not suitable in scenario analysis, as price variations would lead to different demand expectations. For this project expected demand is therefore equal to realised demand, ie perfect foresight.

A.4.4 The key drivers in determining the capacity build are contemporaneous and future values of

- the required supply margin, usually expressed as a percentage on top of winter peak demand (currently this is around 18%)
- the prices of generation fuels (largely fossil fuels)
- the carbon prices of generation fuels
- the capital costs of new build
- the maintenance costs of new plant
- the payments to generators from the Renewable Obligation (RO); only eligible renewable power generation technologies attract the payment
- learning curve effects
- the build time of new plant

Learning effects

A.4.5 The ETM considers learning effects, where the cost of building a particular type of new capacity falls as more of that capacity gets built. These learning effects were maintained in the scenarios conducted for the CCC project. This reduces the cost, and hence the impact on electricity prices, of new power capacity built in the scenarios. This is especially pertinent for the abatement scenarios since they assume a substantial increase in the use of renewables in the projection period. However, the impact from learning effects is limited as cost reductions are assumed to diminish with greater scale.

The objective of the ETM is cost minimisation

A.4.6 The ETM uses cost minimisation of net present value (NPV) in order to determine the type of new capacity that is built. Coupled with the learning effects, this can cause the schedule of new build generated by the ETM to be dominated by one particular type of technology. This effect is tempered by constraints on the amount of new build that is permitted to occur and assumptions for the technology chosen for any existing announced new build. Usually, the discount rate used by the ETM is the government's recommended rate of 3½% pa. However, since the costs have been calibrated to assumptions provided by the CCC, the discount rate used for this project matches that used in the CCC estimates (10% pa).

The ETM can model the 'banding' of the Renewable Obligation

A.4.7 The ETM allows the model to project the impact of the Renewables Obligation (RO) including the proposed 'banding' of RO payments. The model considers the contemporaneous and expected future values of RO payments, which are entered as inputs. For the reference scenarios, RO without banding has been modelled.

The ETM also considers the impact of the Large Combustion Plants Directive (LCPD)

A.4.8 The ETM also models the impact of the Large Combustion Plants Directive (LCPD). The ETM assumes that around 8 GW of capacity will close by 2015/16 because of the LCPD. Restrictions on operating hours of the affected plants due to LCPD are incorporated in the ESI submodel.

Data

We have used information on cost of new generation provided by the CCC

A.4.9 The CCC provided information on costs for some types of new technologies; for other types, MDM-E3's existing information was used. Further details can be found in Chapter 3. The data for the parameters used in the ETM is from several sources. These include UKERC, DECC[17]. National Grid Seven Year statement and bespoke analysis of the investment made by generators.

Modelling generation

Power generation is estimated by the electricity supply industry (ESI) submodel

A.4.10 The ESI sub-model distinguishes the fuel burn and other characteristics of existing power stations and possible future stations, to allow for substitution on the basis of current fuel and carbon prices. The model adjusts these load factors up or down as more or less generation from these plants is required.

[17] Before the formation of DECC, this information was published by BERR.

The ESI takes account of environmental regulations

A.4.11 The ESI uses cost minimisation to decide the generation mix in any given year. In some cases, however, these load factors are constrained in accordance with non-economic factors such as regulations. For example, the Environment Agency's regulations on emissions from coal and oil-fired power stations require that the load factors of plants with or without FGD should be adjusted as follows: plants without FGD have their load factor restricted while plants retrofitted with FGD operate at a higher load factor (in the ratio 2:1) than plants without FGD owned by the same power companies. The ESI also takes into account the impact of the Large Combustion Plant Directive.

A.4.12 The ESI sub-model also includes a separate treatment of combined heat and power (CHP). In the CHP sub-model that has been developed, it is assumed that CHP schemes are operated before other electricity demand is taken from the grid. Hence, the demand for heat and power from CHP schemes is derived in the model before the overall demand for power. The generation from CHP schemes is then subtracted from the overall demand for electricity to be met by the generating stations attached to the grid. The use of electricity from the CHP plants shows up as increased energy efficiency in overall electricity generation (because, as the proportion of CHP-generated electricity increases, the efficiency rises).

Modelling the electricity price

A.4.13 Electricity prices are endogenously derived and depend on the relative share of each fuel used in generation of power in the year. The value of renewable certificates and any carbon price are also passed through to the wholesale price. It is assumed that 100% of the costs of generation are passed though to the wholesale price. This is consistent with evidence of the ability of power generators to pass on the cost of the Phase 1 EU ETS carbon price to the wholesale electricity price (Ekins, 2005). The retail price of electricity faced by end users is calculated by the model, based on historical evidence. Large industrial users can be insulated from variations in the retail price as they may have bilateral contracts with suppliers to fix the price for a number of years.

MDM-E3's modelling may be over-stating the role of nuclear and intermittent forms of generation such as wind

A.4.14 Due to their characteristics and the nature of the UK electricity market, there are real-world constraints on the extent to which nuclear and intermittent forms of generation such as wind (without back up) can service the power needs of the UK, especially the daily and seasonal peaks in UK's electricity demand. However, the electricity submodels in MDM-E3 do not incorporate these constraints; all available technologies are treated as perfect substitutes for each other. Coupled with the cost minimisation algorithm used to determine the capacity and generation mix for power generation, the effect can be that the proportion of capacity made up by intermittent forms of generation such as wind can be overstated. For these reasons, the build of new nuclear was prohibited in the scenarios conducted for the present study. This was to avoid high penetration of both nuclear and intermittent forms of renewables generation, since these are suitable only for servicing baseload demand for electricity which is a relatively low proportion of total electricity demand.

A.5 Emissions

We have incorporated draft inventory data for 2006 provided by the CCC

A.5.1 MDM-E3 covers all the greenhouse gases (GHG) emissions controlled by the Kyoto Protocol. Emissions of CO_2 and the wider basket of greenhouse gas gases have been calibrated to draft NAEI data for 2006 (NAEI, 2008) provided by the CCC. We have also updated the historical data in light of revisions made in the draft inventory.

For this project we have estimated emissions on both the IPCC and net carbon account bases

A.5.2 The IPCC includes estimated volumes of emissions emitted from sources in the UK (and Crown Territories). The IPCC excludes emissions from international aviation and shipping, The net carbon account takes the IPCC and subtracts net purchases of emissions credits bought from overseas in 'certified' schemes ('purchased effort'). These include EU ETS allowances purchased from other member states and overseas credits generated by the CDM. The carbon budgets and targets in the Climate Change Bill relate to the net carbon account.

CO_2 emissions from energy use

A.5.3 Emission factors for each fuel and fuel user are calculated using the last year of outturn data for emissions and energy demand, in this case the draft emissions data for 2006 with DUKES 2006 energy demand. Emission factors are held constant for the remainder of the projection period.

CO_2 emissions from non - energy use

Non-energy CO_2 emissions from industry

A.5.4 Non-energy CO_2 emissions are currently modelled in relation to fuel users but not to individual fuels. All non-energy CO_2 emissions are then linked to activity indicators and are subsequently driven by changes in activity for each of the fuel users. Emissions from land use and land use change are not covered.

Emissions from non-CO_2 greenhouse gases

A.5.5 MDM-E3 uses a number of treatments to model non-CO_2 greenhouse gases to reflect the different drivers of emissions, only some of which are related to energy use.

A.5.6 Emissions of methane and nitrous oxide (N2O) from energy use are modelled in MDM-E3 with a treatment similar to that used for CO_2, ie to apply the appropriate emissions factor to fuel use. The emissions factors for this project are derived from analysis of draft 2006 inventory data. Non-energy related non-CO_2 emissions are simply driven by population growth.

A.6 The treatment of the economy in MDM-E3

A.6.1 The purpose of MDM-E3 is to abstract the underlying patterns of behaviour from the detail of economic life in the UK and represent them in the form of a key set of identities and equations. In a complex system, such as the UK economic system, the abstraction is very great. In any economic model the initiatives, responses and behaviour of millions of individuals is aggregated over geographical areas, institutions, periods of time and millions of heterogeneous goods and services into just a few thousand statistics of varying reliability. The aim of MDM-E3, then, is to best explain movements in the data and to predict future movements under given sets of assumptions.

A.6.2 A key contribution of the approach to modelling the UK economy in MDM-E3 is the level of disaggregation. The macroeconomic aggregates for GDP, consumers' expenditures, fixed investment, exports, imports, etc are disaggregated as far as possible without compromising the available data.

A.6.3 One reason for disaggregation is simply that it is necessary to answer certain questions of economic interest. Some macroeconomic questions are intrinsically structural and if they are to be answered using a model then it must be disaggregated in some way. The disaggregation of agents and products is crucial in trying to understanding the behavioural responses of heterogeneous agents as it reduces the bias encountered in estimating aggregate relationships.

The National Accounts Structure of MDM-E3

A.6.4 A social accounting framework is essential in a large scale disaggregated economic model. The early versions of MDM were based on the definitions and estimation of a Social Accounting Matrix (SAM) for the UK and its associated input-output tables and time-series data. The principles of SAM have been extended and elaborated in detail in the UN's revised System of National Accounts (SNA). Accordingly we now use the SNA for the accounting framework for the data and the model.

A.6.5 The national accounts provide a central framework for the presentation and measurement of the stocks and flows within the economy. This framework contains many key economic statistics including Gross Domestic Product (GDP) and gross value added (GVA) as well as information on, for example, saving and disposable income.

A.6.6 The national accounts framework makes sense of the complex activity in the economy by focusing on two main groupings: the participants of the economy and their transactions with one another.

A.6.7 Units are the individual households or legal entities, such as companies, which participate in the economy. These units are grouped into sectors, for example the Financial Corporations sector, the Government sector and the Household sector. The economic transactions between these units are also defined and grouped within the accounts. Examples of transactions include government expenditure, interest payments, capital expenditure and a company issuing shares.

A.6.8 The national accounts framework brings these units and transactions together to provide a simple and understandable description of production, income, consumption, accumulation and wealth. These accounts are constructed for the UK economy as a whole, as well as for the individual sectors in the Sector Accounts.

A.6.9 Since 1998 the National Accounts have been consistent with the European System of National Accounts 1995 (ESA95). The ESA95 is the European implementation of the international System of National Accounts 1993 (SNA93) developed by the UN to ensure a common framework and standards for national accounts, including input-output analyses, sector accounts and constant-price analyses. The ESA95 was developed to reflect the changing role of government, the increased importance of service industries and the increased diversity of financial instruments. It recognises the wider scope of capital formation, by using concepts such as intangible assets.

The Determination of Output

A.6.10 The determination of output in MDM-E3, shown in Figure A.3 can be divided into three main flows of economic dependence;

- The output-investment loop
- The income loop
- The export loop

A.6.11 In the following paragraphs, the constituent variables which determine output are explained in terms of their econometric or identity relationships.

Consumers' Expenditure

A.6.12 Consumers' expenditure is estimated at an aggregated level for each of the 12 UK regions covered in MDM-E3 and then further disaggregated to the 52 expenditure categories which relate to the COICOP classification. At the aggregate level regional consumption in real terms is predominantly a function of regional real income.

A.6.13 This relationship is constrained to reflect the idea that expenditure cannot outgrow income levels in the long term, although it is possible in the short term. The other key drivers of regional consumption as defined in the equations are;

- the adjusted dwellings stock
- the OAP dependency ratio
- inflation

A.6.14 In the short run we also consider the effects of;

- unemployment - in the literature high levels of unemployment are linked to sharp falls in consumer spending beyond the fall in consumer spending which can be explained by an associated fall in real gross disposable income that the unemployment would cause; this is explained in the literature by the uncertainty that unemployment induces across a region

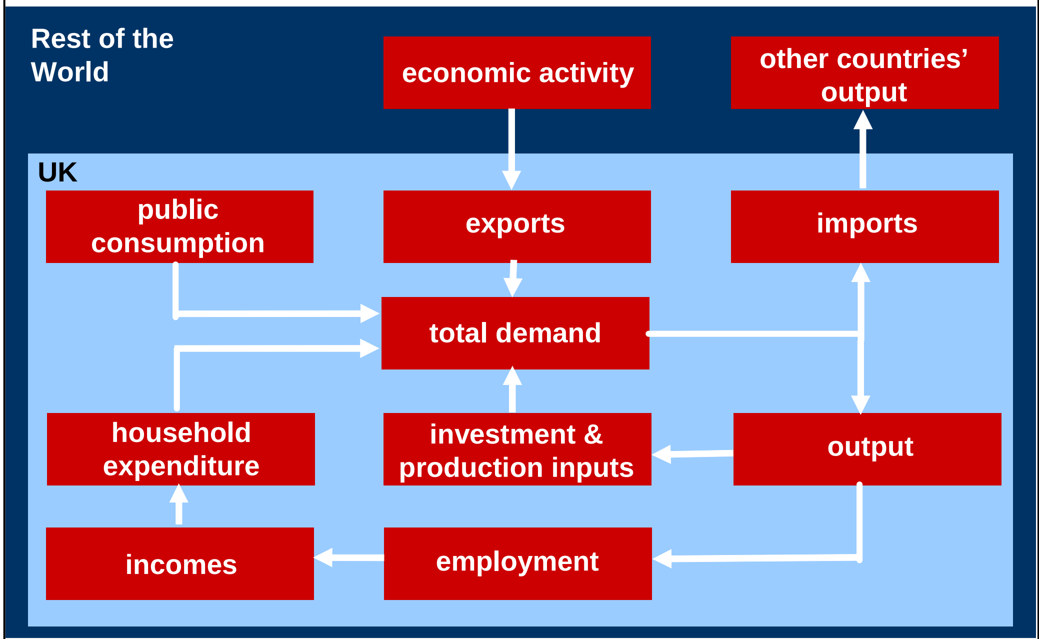
- real house prices - we assume here that there is a positive (negative) wealth effect caused by increasing (decreasing) real house prices which causes consumption to increase (decrease) in the short run.

A.6.15 Regional consumption is then disaggregated further in the disaggregated regional equations which take the main independent variable as regional consumption, which effectively reflects the income effect on consumption (the parameter is restricted to be positive). The other explanatory variables are relative prices in the form of the price of each consumer category compared to the overall price index for all consumer items, this captures the price effect (the parameter is restricted to be negative). The OAP and child dependency ratios are also considered so as to reflect differing consumption patterns arising from changing demographic structure in the different regions.

A.6.16 For the consumption categories that represent energy products, consumption in each region is determined by applying the growth rate in UK fuel consumption (in energy units) from the fuel user 'households' (or in the case of petrol - road transport) to the real consumption of gas, electricity, coal, petrol and manufactured fuels. The fuel used by households and road transport is derived in the energy demand equations discussed earlier. Disaggregated consumption is then scaled to match regional consumption at the aggregate level.

A.6.17 Household expenditure by expenditure category is then mapped to the 42 product categories to derive domestic consumer demand by product category.

FIGURE A.3: THE DETERMINATION OF OUTPUTS



Source(s): Cambridge Econometrics.

Investment

A.6.18 Among other elements such as social-capital formation, public and private sector dwellings and legal fees, the most important element of gross fixed capital formation is the acquisition of new buildings, plant and machinery and vehicles by industry.

A.6.19 Investment in MDM-E3 is treated quite differently to the neoclassical framework which relies on the production function of firms and net present welfare maximisation based on equating the user cost of capital with the marginal product of capital. However, the neoclassical treatment leads to an unresolved conflict between the implied costless switch between capital and employment and the observation that capital stock adjustments are subject to significant time lags.

A.6.20 In MDM-E3 investment data is divided into 27 investing sector categories at the national level. The national investment equations depend on industry output, which is converted from the 42 industry sectors to the 27 investing sectors. The equations yield the result that an increase in output will lead to an increase in investment. Typically, the investing sectors which are most responsive to changes in output are the capital-intensive manufacturing-based investment sectors such as Transport Equipment.

A.6.21 The investment equations are specified in the Engle Granger cointegrating form and therefore allow for the impact of the lagged investment and an error correction term allowing adjustment to the long-term trend.

Government spending

A.6.22 Assumptions for government capital spending are used to forecast gross fixed capital formation in the investing sectors relating to Health, Education and Public Administration. Government final consumption expenditure is treated exogenously in MDM-E3 and is based on the plans announced in the Comprehensive Spending Review and Budget statements.

A.6.23 Government revenues from taxes on income and production are inherently endogenous as they rely on consumption and incomes. This duality is an important consideration in scenario analysis. Increased tax revenues are not automatically recycled into the economy. Model operators must decide where additional revenue should be spent. If additional tax revenues are not spent they will, by definition, simply reduce the Public Sector Net Cash Requirement (PSNCR), but this has no further effects on behaviour (for example, it is not assumed that household spending responds to the prospect of higher or lower taxation in future as indicated by the extent of government borrowing in the present).

Import and export volumes

A.6.24 MDM-E3 has assumptions for 19 world regions, covering (among other factors) activity (GDP), price levels and exchange rates. The world activity indices are the key drivers of export demand, which is estimated across the 42 product categories. The result is that an assumed change in US GDP growth will affect the products that are most traded with the US, depending on the weighting of US demand in the world demand for UK exports and the responsiveness of UK export demand to the change in the world activity index. The price of exports also affects the level of export demand. To explain historical export volumes two dummy terms for integration with the EU internal market are significant for 1974 and 1978.

A.6.25 Import volumes are determined by domestic demand and import prices relative to domestic prices. A capacity utilisation constraint is also considered in the short term.

Intermediate demand

A.6.26 Input-output supply and use tables (SUTS) provide a framework to make consistent estimates of economic activity by amalgamating all the available information on inputs, outputs, gross value added, income and expenditure. This is shown in Figure A.4. For a given year, the input-output framework breaks the economy down to display transactions of all goods and services between industries and final consumers (eg households, government) in the UK. Since 1992, ONS has used the input-output process to set a single estimate of annual GDP and ONS has published the detailed analyses in the SUTS.

A.6.27 The information from the regular releases of SUTS are used in conjunction with the more detailed analytical tables (last published for 1995) to construct the inputs that are required for the MDM model. An input-output table has been estimated from official data to provide the detail needed to model inter-industry purchases and sales.

A.6.28 The input-output coefficients derived from the SUTS allow intermediate demand to be derived for each product given the final demand at the product level of disaggregation.

A.6.29 The employment equations for MDM-E3 are based on a headcount measure of employment rather than on a full-time equivalent basis. The employment equations are specified by region and industry, The two main drivers of employment are gross output and the relative wage costs as measured by industry wages relative to industry prices.

A.6.30 Labour productivity is defined on a net output per job basis.

The determination of prices

A.6.31 In MDM-E3 assumptions are made for world prices and exchange rates. These are then used to determine import prices, which are one element of the cost to the UK's industries of bought-in inputs. The other element is, of course, the cost of the UK's own production. Figure A.5 shows the determination of prices in MDM-E3. Unit material and labour costs determine industry output prices. Consumer prices, then, depend partly on import prices and partly on UK industry prices, together with taxes on products. Consumer prices have an influence on average wage rates, as do labour market factors. Average earnings and productivity are then used to determine unit labour costs. Export prices depend partly on unit labour costs in the UK and partly on world prices (reflecting the extent to which prices are set in world markets).

Exchange rates and interest rates

A.6.32 Previous versions of MDM have sought to include endogenous treatments for interest rates and exchange rates but the inclusion of these specifications often led to increased instability within the model. Recent versions of the model therefore rely on an exogenous treatment for both exchange rates and interest rates. This has important consequences for scenario analysis. For instance, unilateral UK action on carbon taxes might push domestic consumer price inflation to a position where the Bank of England might take deflationary action by increasing the repo rate. Similarly, exchange rates do not change in response to domestic prices, the balance of payments, world prices, Treasury bill rates and so on.

Industry prices

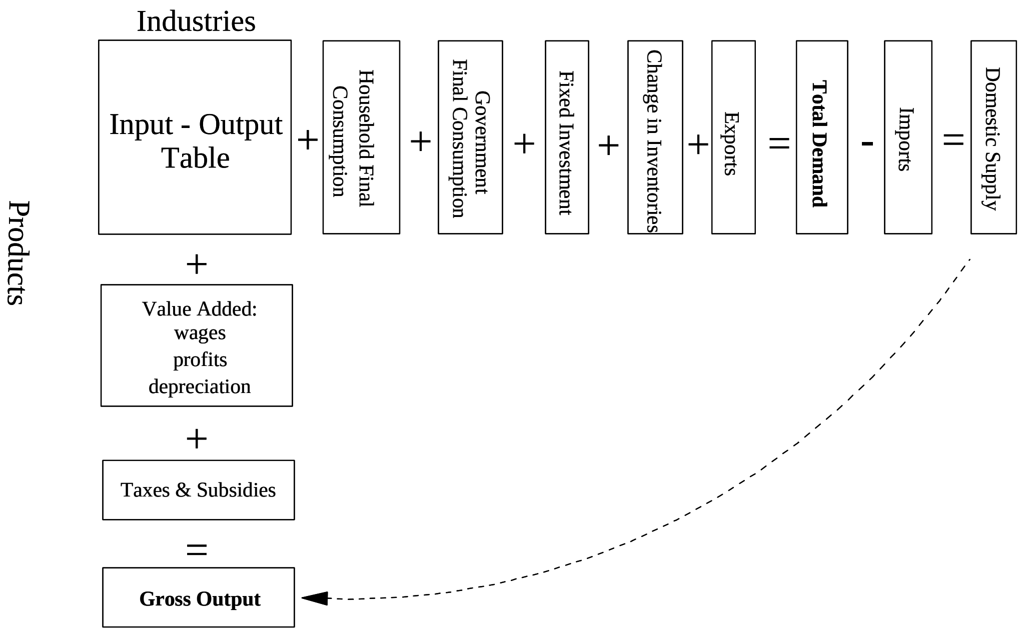
A.6.33 Industrial prices are formed as a mark up on unit costs with an allowance for the effect of the price of competitive imports, technological progress and, in the short run part of the equation, the effect of expected consumer price inflation. The supply side comes in through the utilisation of capacity as measured by the ratio of actual output to normal output.

A.6.34 For many of the industries the dominant effect is industrial unit costs. However, import prices can affect domestic prices in three different ways. First, by directly increasing industrial unit costs, to the extent that industry inputs are imported. Second, as competitor prices so that domestic prices tend to rise with import prices over and above any effect on costs. Third, as import prices directly affect consumer price inflation and therefore the expectation of future increases in import prices.

Import and export prices

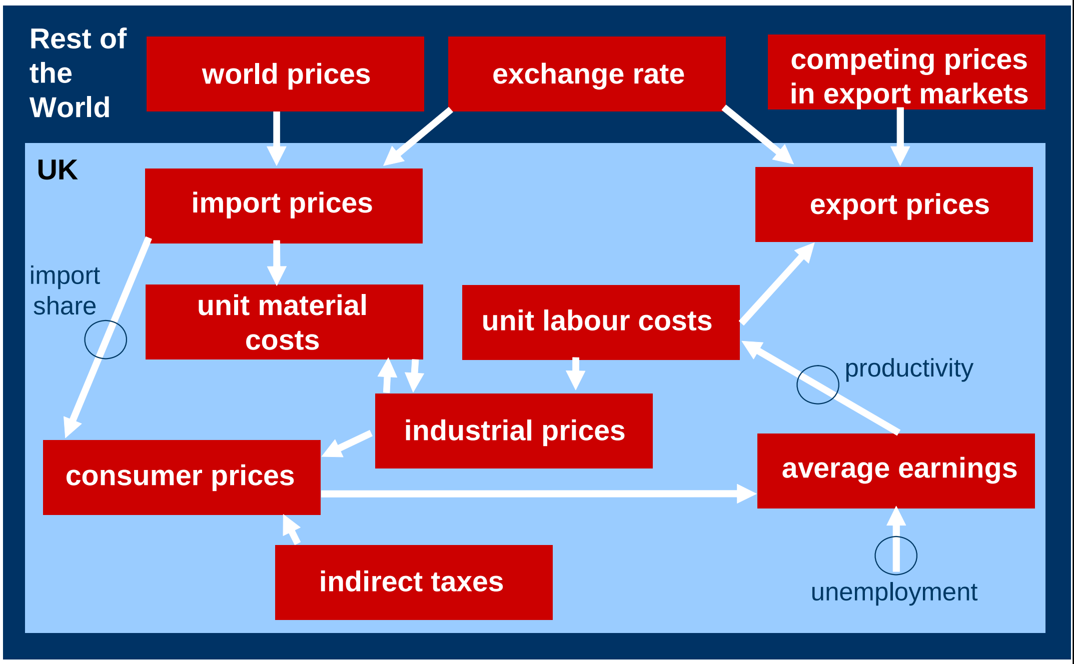
A.6.35 These equations play the role of transmitting world inflation to the UK economy through its effect on export and import prices. Import and export prices are determined by world product prices, the exchange rate, world commodity prices and unit cost. For export prices in the short term there is also a supply side effect which comes through the increases in the utilisation of capacity. A measure of technical progress is also included to cope with the quality effect on prices caused by increased levels of investment and R&D. Restrictions are imposed to force price homogeneity and exchange rate symmetry on the long-term equations.

FIGURE A.4: THE CORE INPUT-OUTPUT STRUCTURE



Source(s): Cambridge Econometrics.

FIGURE A.5: THE DETERMINATION OF PRICES



Source(s): Cambridge Econometrics.

Consumer prices

A.6.36 Consumer prices are determined by import prices and industry prices and the respective weighting of imports and domestic purchases in consumers' expenditure, together with the application of product taxes.

Wages

A.6.37 The aggregate consumer price index is assumed to have a positive relationship with wages, such that an increase in prices should lead to an increase in wages. Productivity also has a positive relationship with wages: if employees in an industry are able to increase value added by increasing output for the same input then they are able to command higher wage rates.

A.6.38 The treatment of wages in MDM partly follows the typical wage bargaining model. The opportunity from not working as expressed by unemployment benefit has a positive relationship with wages as the benefit rate will mean that workers will want to gain sufficiently more than the available benefit transfer to justify employment. In MDM-E3, again following the wage bargaining models, unemployment levels also have an impact on wages: if unemployment is high it follows that wages will be low as there is no incentive for employers to pay an individual more when there are a large number of unemployed willing to work for a lower salary.

A.6.39 The retention ratio term identifies the average real take home pay for any given salary level. The purpose of this is to simulate the characteristic of individuals operating in a way to make sure that their net pay means they are equally well off following a change in tax. If income tax increases, the retention ratio falls and wages rise to (fully or partially) compensate for the higher tax rate.

A.6.40 In an attempt to understand relationships between wages within one industry but across regions, or within one region but across industries, MDM-E3 also uses external industry wage rates and external regional wage rates to estimate wage rates as a system. The idea is that if wages in a region are increasing for all other industries that are not industry Y, then this should drive an increase in industry Y wages, within the specified region. This argument is then extended for one industry's wages across all the regions. If the oil and gas industry increases wage rates in all non X regions, this will have an impact on the oil and gas industry wages in region X.

A.6.41 Wage bills are calculated across region and industry by multiplying the average wage by the number of full time equivalent (FTE) employees. Further key variables, such as the total wage bill, average wage, average wage for a region and average wage for an industry are also calculated.

Financial stocks and returns

A.6.42 The treatment of financial stocks and returns in the model is currently quite limited and they have no important effects.

A.7 Definitions

Gross Domestic Product and Gross Value Added

A.7.1 GDP measures the total final expenditures on all goods and services produced within the economy (eg household expenditure, government expenditure).

A.7.2 Gross Value Added (GVA), measures the contribution to the economy of each individual producer, industry, sector or region in the UK. The GVA generated by any unit engaged in production activity can be calculated as the residual of the unit's total (gross) output less intermediate consumption (that is, goods and services used up in the process of producing the output); it is approximately the difference between turnover and expenditure on goods & services.

A.7.3 GDP (at market prices) provides a key indicator of the state of the whole economy and is used to analyse the expenditure measure of GDP. However, the contribution to the economy of each individual producer, industry or sector is measured using GVA (at basic prices).

A.7.4 Market prices (also known as purchasers' prices) are the prices paid by the purchaser and include transport costs, trade margins and taxes (unless the taxes are deductible by the purchaser). Basic prices are the preferred method of valuing output in the accounts. They reflect the amount received by the producer for a unit of goods or services, excluding any taxes payable, and including any subsidy receivable on that unit as a consequence of production or sale (that is, the cost of production including subsidies).

A.7.5 The link between GVA and GDP in both current prices and chained volume terms is: GVA at basic prices + taxes on products - subsidies on products = GDP at market prices.

Industry GVA and gross output

A.7.6 There are different indicators that can be used to measure the output of an industry. Two measures used in economic analysis presented in this publication are gross value added (GVA) and gross output. Both measures of output are typically expressed in £ million and can be measured in current prices or volume measures (ie when the impact of price inflation has been removed).

A.7.7 Gross value added (GVA), which is also referred to as net output, measures the net contribution to the economy of each individual industry. It represents the wealth created and is essentially the difference between turnover, on the one hand, and expenditure on goods and services, on the other. It comprises principally wages & salaries and profits.

A.7.8 The gross output of an industry includes its GVA plus its purchases of other goods and services. Gross output is comparable to turnover.

A.8 Energy classifications and equations

TABLE A1: FUEL USER GROUPS AND FUEL TYPES

MDM Fuel User		MDM Industry		MDM Fuel Type		MDM Commodity
Power generation	22	Electicity	1	Coal and coke	2	Coal
			2	Motor spirit	9	Manufactured Fuels
Own use	2	Coal	3	Derv		
	3	Oil & Gas etc	4	Gas oil		
	9	Manufactured Fuels	5	Fuel oil		
	23	Gas Supply	6	Other refined oils		
Basic Metals	14	Basic Metals	7	Gas[1]	23	Gas Supply
Minerals	4	Other Mining	8	Electicity[2]	22	Electicity
	16	Non-metallic Mineral Products	9	Nuclear fuels		
Chemicals	13	Pharmaceuticals	10	Steam		not classified
	14	Chemicals nes	11	Renewables		
Other industry	5	Food, Drink & Tobacco				
	6	Textiles, Clothing & Leather				
	7	Wood & Paper				
	8	Printing & Publishing				
	12	Rubber & Plastics				
	15	Metal Goods				
	16	Mechanical Engineering				
	17	Electronics				
	18	Electrical Engineering & Insruments				
	19	Motor Vehicles				
	20	Other Transport Equipment				
	21	Manufacturing nes				
Rail transport	34	Rail Transport etc Consumer demand				
Road transport	35	Other Land Transport, consumer demand				
Water transport	36	Water Transport				
Air transport	37	Air Transport				
Households		linked to consumers' expenditure				
Commerce etc	1	Agriculture etc				
	24	Water Supply				
	25	Construction				
	26	Distribution				
	27	Retailing				
	28	Hotels & Catering				
	32	Communications				
	33	Banking & Finance				
	34	Insurance				
	35	Computing Services				
	36	Professional Services				
	37	Other Business Services				
	38	Public Adminstration & Defence				
	39	Education				
	40	Health & Social Work				
	41	Miscellaneous Services				

Note(s) : 1 Natural gas, coke oven gas and town gas.
2 Secondary use, pumped storage and net trade.

TABLE A2: THE AGGREGATE ENERGY DEMAND EQUATION

Cointegrating long-term equation:

LN(FUE(.))			[total fuel used by fuel users]
	=	BFUE(.,11)	
	+	BFUE(.,12)*LN(FUY0)	[activity measure]
	+	BFUE(.,13)*LN(PFU)	[own price]
	+	BFUE(.,14)*LN(HUC)	[home unit costs]
	+	BFUE(.,15)*TIME	[time trend]
	+	BFUE(.,16)*LN(FYKE)	[technology index]
	+	BFUE(.,17)*AIRT	[temperature]
	+	BFUE(.,18)*CCLD	[CCL dummy]
	+	ECM	[error]

Cointegrating dynamic equation:

DLN(FUE(.))			[total fuel used by fuel users]
	=	BFUE(.,1)	
	+	BFUE(.,2)*DLN(FUY0)	[activity measure]
	+	BFUE(.,3)*DLN(PFU)	[own price]
	+	BFUE(.,4)*DLN(HUC)	[home unit costs]
	+	BFUE(.,6)*DLN(FYKE)	[technology index]
	+	BFUE(.,7)*AIRT	[temperature]
	+	BFUE(.,8)*CCLD	[CCL dummy]
	+	BFUE(.,9)*DLN (FUE(-1))	[lagged changes in fuel use]
	+	BFUE(.,10)*ECM(-1)	[lagged error correction]

Restrictions:

BFUE(.,13)+BFUE(.,14) = 0	[price homogeneity]
BFUE(.,3),BFUE(.,6),BFUE(.,13),BFUE(.,16) <= 0	['right' sign]
BFUE(.,2),BFUE(.,4),BFUE(.,7),BFUE(.,12),BFUE).,14 >= 0	['right' sign]
0 > BFUE(.,10) > -1	['right' sign]

Definitions:

BFUE	is a matrix of parameters.
FUE	is a vector of total fuel used by 13 fuel users, m therms.
PFU	is a vector of average price of fuels by fuel user, pence per therm.
FUY0	is a vector of activity for 13 fuel users, £m at 1995 constant prices.
FYKE	is a vector of technological progress for 13 fuel users, £m 1995 constant prices
HUC	is the index of home unit costs (the ONS deflator of GDP at factor cost).
AIRT	is the temperature variable (deviation of the average temperature from the 30-year mean 1961-90).
CCLD	dummy variable for CCL announcement effects 2001=0.5, 2002 onwards=1.0, all previous years=0.
(.)	indicates that the matrix is defined across fuel users.
LN	indicates natural logarithm.
DLN	indicates change in natural logarithm.
ECM	[error].

All variables (except HUC, TIME, AIRT and CCLD) are defined for the 13 fuel users.

TABLE A3: THE FUEL SHARE EQUATIONS

Cointegrating long-term equation:

LN(SHARE(.))			[total fuel used by fuel users]
	=	BFUJ(.,11)	
	+	BFUJ(.,12)*LN(FUY0)	[activity index]
	+	BFUJ(.,13)*LN(PFUJ(.))	[own price index]
	+	BFUJ(.,14)*LN(COMP(.))	[competitor price index]
	+	BFUJ(.,15)*LN(GENP)	[general price index]
	+	BFUJ(.,16)*DUM84	[dummy variable 1984=1]
	+	BFUJ(.,17)*LN(FYKE)	[technology index]
	+	ECM	[error]

Cointegrating dynamic equation:

DLN(SHARE(.))			[total fuel used by fuel users]
	=	BFUJ(.,1)	
	+	BFUJ(.,2)*DLN(FUY0)	[activity index]
	+	BFUJ(.,3)*DLN(PFUJ(.))	[own price index]
	+	BFUJ(.,4)*DLN(COMP(.))	[competitor price index]
	+	BFUJ(.,5)*DLN(GENP)	[general price index]
	+	BFUJ(.,6)*DIFF(DUM84)	[dummy variable 1984=1]
	+	BFUJ(.,7)*DLN(FYKE)	[technology index]
	+	BFUJ(.,8)*AIRT	[temperature]
	+	BFUJ(.,9)*DLN(SHARE(.))(-1)	[lagged changes in fuel shares]
	+	BFUJ(.,10)*ECM(-1)	[lagged error correction]

Identity:

for electricity: SHARE(.) = FUJT(.)/FUJ0

for fossil fuels: SHARE(.) = FUJT (.)/FUJ0 – FUJT(electricity))

Restrictions:

BFUE(.,13)+BFUE(.,14)+BFUE(.,15) = 0	[price homogeneity]
BFUJ(.,3),BFUJ(.,4),BFUJ(.,10),BFUJ(.,11) <= 0	['right' sign]
BFUJ(.,2),BFUJ(.,5),BFUJ(.,9),BFUJ(.,12) >= 0	['right' sign]
0 > BFUJ(.,7) > -1	['right' sign]

Definitions:

BFUJ	is a matrix of parameters.
FUJ	is a vector of fuel used by 13 fuel users for 11 fuel types, m therms.
FUY0	is a vector of activity for 13 fuel users, £m at 1995 constant prices.
PFUJ	is a vector of own prices for 13 fuel users and 11 fuel types, pence per therm.
COMP	is a vector of competitor fuel prices for 13 fuel users and 11 fuel types, pence per therm; these are defined specifically for each fuel type, eg prices of all fossil fuels is the competitor price in the case of electricity use.
GENP	is general price index for 13 fuel users, pence per therm, all fuel use (in the case of electricity users) or all fossil fuel use (in the case of non-electricity fuel users).
FYKE	is a vector of technological progress for 13 fuel users.
AIRT	is the temperature variable (deviation of the average temperature from the 30-year mean 1961-90).
(.)	indicates that a matrix is defined across fuel types.
LN	indicates natural logarithm.
DLN	indicates change in natural logarithm.
DIFF	indicates absolute difference.
ECM	[error].

All variables (except DUM84 and AIRT) are defined for the 13 fuel users.

Appendix B The Electricity Technology Submodel

B.1 Introduction

Background to the ETM

B.1.1 The Energy Technology Model (ETM) is a dynamic bottom-up technology simulation treatment which represents the take-up of a number of energy supply options, both conventional and non-carbon. The model was originally developed to generalise earlier work by Anderson and Winne (2004) to form the basis of a new energy technology component in the global model E3MG[18]. The submodel has now been incorporated into MDM-E3[19]. At present it covers technologies used in electricity supply, although it may be developed to cover other energy carriers in due course.

B.1.2 MDM-E3 thus includes the capacity to endogenously model an array of non-carbon energy options for electricity supply that could potentially emerge in the future, even though their costs are currently high relative to those of fossil fuels. The operational feature of the model is that these costs are largely declining, due to innovation, R&D investment, and learning-by-doing. The lower costs induce higher investment in non-carbon energy options. The process of substitution is also highly non-linear, involving threshold effects.

B.2 The mechanics of the ETM

The choice of technologies

B.2.1 The ETM models the process of substitution, allowing for non-carbon energy sources to meet a larger part of UK energy demand as the prices of these sources decrease with investment, learning-by-doing and innovation. Following the demand for various existing energy carriers (fuels), substitution will take place conditional on the possibility of supply of various energy sources. On the supply side the range of possibilities is very large, and there is considerable scope for substitution between them.

B.2.2 For each type of energy demanded there is usually a technology or fuel 'of choice' – what might be termed a marker technology – against which the alternatives will have to compete. In terms of electricity markets, UK assumes that the marker technology was dirty coal up to 1995 and gas CCGT thereafter.

B.2.3 In practice, the values of alternatives will vary widely relative to the costs of the marker technology. In the case of coal for electricity generation, costs differ between stations and to some extent across regions – due to proximity to the coal fields, the sulphur content of the coal, the availability of cooling water, site conditions etc. The costs of the marker technology may also vary greatly; if the marker technology is a gas-fired plant, its costs, like those of coal, will differ between sites and regions and, of course, with the price of gas.

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18 For more details, please see http://www.camecon.com/suite_economic_models/e3mg.htm. See also Barker et al (2006).

19 The online model manual is at http://www.camecon-mdm3emanual.com/cgi-bin/EPW_CGI.

The ETM in MDM-E3

B.2.4 Although MDM-E3 and E3MG are structurally consistent and share many of the same characteristics, there are many technical differences which imply that the exercise of implementing ETM into MDM-E3 necessitates making some structural changes to ETM. The first obvious difference between the two models is that MDM-E3 is not regional, and ETM thus has to be modified to only solve for one region, namely the UK. Although the electricity sector in MDM-E3 is technically split into three regions, England & Wales, Scotland and Northern Ireland, the electricity supply classification is by power station and technology rather than over regions.

B.2.5 In the MDM-E3, unlike the E3MG, there was already a submodel for the electricity supply industry in place prior to the implementation of ETM. The MDM-E3 ESI submodel is a treatment of the electricity systems in the three regions mentioned above. Its main purpose is to calculate the annual fuel use of the UK ESI, and as such it is a simulation model rather than an optimisation model, but it does include a treatment that models desired generation and a price-based generation mix. The submodel also models capacity new-build, as it aims to satisfy peak load plus plant margin by building the type of new capacity which is found to have the cheapest overall cost per unit. However, the inclusion of ETM replaces the capacity modelling in the ESI submodel, although the generation mix treatment is left unchanged.

B.2.6 The ETM in MDM-E3 has also been adjusted to the potential technologies in the UK. For instance, as wind power with storage is not likely to emerge as a possibility in the UK in the foreseeable future, it was removed while intermittent wind was disaggregated into onshore and offshore wind, with adjusted parameters. Also, as the MDM-E3 has a separate submodel for CHP, all CHP-specific technologies were removed.

B.2.7 The data input to the ESI submodel is based on the National Grid Transco's Seven Year Statement, which outlines all the power plants in England & Wales and Scotland currently in operation, and the respective lifetime of all these plants. The ETM is calibrated to this data, which implies that the decommissioning component of the original ETM is omitted as the SYS lists stations that are due for decommissioning.

B.2.8 The ETM in MDM-E3 makes use of certain policy restrictions specific to the UK. For instance, the new-build of nuclear is restricted as the UK does not yet have a firm policy on new-build of nuclear. The new-build of coal is also restricted post-2008 as we see it as unlikely that any new conventional coal-plant will get built after the start of the EU ETS Phase 2.

Frequency distribution

B.2.9 In ETM, the frequency distribution of feasible technologies could be represented by the ratio between the cost of all alternatives and the marker technology. Let P_{it} denote the price of he marker relative to that of the alternative i (Anderson and Winne, 2004, equation 1):

$$P_{it} = \frac{C_t^N (1+T_t)}{C_{it}(1+G_t)} \quad (1)$$

where C_t^n and C_{it} denote the present worth of the costs of using the technologies per unit of output, the superscript N in the former referring to the fuel of choice. T_t represents taxes (for instance carbon taxes) on the former and G_t taxes on the latter (either may be negative if the energy source is subsidised).

B.2.10 When the ratio C_t^N / C_{it} is greater than unity, the alternative technology costs less than the marker technology. The ratio may also show a wide frequency distribution, and it is likely that the mean value will fall below unity. This does not mean, however, that all alternative applications in all locations will be uneconomical.

B.2.11 Let C_t^N and C_{it} now denote the mean values of the costs of the marker and substitute technologies and P_{it} the mean value of the price ratio. An increase in the price ratio can be brought about in two ways. One is to increase taxes on the marker technology but not on the substitute (say through a carbon tax). The second is through an innovation which reduces the costs of the substitute relative to the marker. In both cases, the effect is to shift the distribution of costs, leading to a larger number of applications of the substitute technology through increased investments.

Investment in technologies

B.2.12 There are important features of electricity investment that relate to the electricity network:

- the problem of intermittency for some renewables, eg wind, means that there must be backup supplies to avoid occasional shortfalls
- the suitability of individual technologies to service ‘peak’ and ‘baseload’ demand for electricity
- optimal load factors vary across technologies, so that the mix of technologies in use will affect the overall generation available at any time at normal levels of prices
- new large-scale suppliers require new connections to the grid

B.2.13 These network characteristics have implications for efficiency and security of supply. The regulators of the grid have obligations for forward planning to match expected demand with planned capacity.

B.2.14 The implication is that electricity investment is not adequately modelled as that of a representative firm maximising profits in a fully competitive market under constant returns to scale. In the electricity industry, the firms are typically large and diverse; investment projects are diverse; and system changes can be significant in relation to the whole economy.

The ETM assumes the role of social planner

B.2.15 The ETM in MDM-E3 takes the network features into account by representing the investment decision as one taken institutionally by a social planner following rules promoting efficiency under social, economic and political restrictions. Some investment projects, eg nuclear stations have to be sanctioned explicitly by the government. In MDM-E3, therefore, the investment of nuclear stations can be restricted. Desired capacity will determine the size of the investment, and will depend on load factors, desired generation (modelled through the electricity supply industry submodel in MDM-E3) and the ratio between maximum generation (for peak loads) and average generation. Since there is a considerable lag between the decision to invest and the investment coming on stream (a lag of up to 10 years is allowed in MDM-E3), desired capacity and therefore desired generation has to be projected.

The key factor driving the investment decision is cost minimisation over the first 11 years of the project

B.2.16 It is assumed that decisions are decentralised, such that investors view their objective as minimising the costs of supplying a required amount of electricity. No assumptions are made about the overall objective of the firms involved. Economic instruments are included to provide incentives for different technologies. Functional forms and parameters are largely imposed, with testing and adjustment so that the historical data are explained by the model. The classifications adopted are as follows: there are 21 generic technologies; each technology has 25 characteristics; and the cost-benefit calculations are done by 9 categories.

B.2.17 There are four sets of data in the cost-benefit NPV classification for new electricity investment:

1 capital costs

2 non-fuel current costs

3 fuel costs

4 any GHG reduction benefits from the new electricity investment, valued at the emission allowance prices expected in the future

B.2.18 The overall net costs are calculated in £/MW. The capital and non-fuel current costs vary across the different electricity investment technologies and are calibrated to UK conditions. Usually, for example for CE's regular energy and emission forecasts, we would start with information provided by Anderson and Winne (2004). However, for the project for the CCC, we had use data provided by the CCC. The projected fuel costs in the NPV calculation are derived from the MDM-E3 projections and depend on which of the 11 energy carriers distinguished are used by the technologies.

The ETM almost takes account of the impact from 'learning by doing'

B.2.19 Specific technological progress has been included in the MDM-E3 ETM by a bottom-up representation of technologies using energy in the electricity industry, with learning curves and responses to real energy prices. As the real cost of carbon rises in the system, learning-by-doing reduces the unit costs of the technologies to respond to increase in the costs of carbon through costs of permits and taxes, the outcome is a wave of extra investment in the electricity industry.

B.2.20 Investment shares between the technologies in electricity generation technologies are based on the following equation (Anderson and Winne, 2004, equation 6):

$$S_{it} = S_{it-1} + a_i\, S_{it-1}\left(\hat{S}_{it-1}(1 + S_{it-1} - \sum_i S_{it-1}) - S_{it-1}\right)\left(P_{it} - P_{it-1}\right) \quad (2)$$

where S is market shares in new investment in technology i, is a maximum share attainable by any given technology and P is the price ratio of technology i to a marker technology or numeraire (typically CCGT). The equation is a modified logistic, with the responses dependent on the differences over time of the technology's price relative to the marker technology. If the price falls, the technology will be adopted at increasingly faster rates; eventually the rates diminish as saturation is approached. The learning rates estimates are taken from McDonald et al (2001).

The Renewables Obligation

B.2.21 The ETM model implemented in MDM-E3 has also been extended from the original ETM model in E3MG with the inclusion of a mechanism to cover the Renewables Obligation (RO). The RO is a requirement policy that induces electricity suppliers to ensure that a given percentage, or target percentage, of their electricity comes from renewable sources. If suppliers fall short of their percentage target, they pay a penalty. In the ETM MDM-E3 model, if actual renewable capacity is below the target in any given year, the social planner adjusts the proportion of investment in renewable capacity upward in accordance with the size of this gap. This implies that some renewable technologies will be politically favoured over the potentially more cost-effective conventional alternatives. The renewable technologies selected by the social planner have to be cost-effective, ie their NPV of benefits has to exceed that of costs, which typically means that onshore wind and biomass are favoured technologies.

Solving the model

B.2.22 The solution is iterative until a consistent converged set of results is achieved. Procedural rules are introduced for the system to respond to over- or under-utilisation of capacity and for fossil fuel capacity to be scrapped. The solution is tested on historical data to establish its properties and ensure that it simulates the main features in the data.

Parameters in the ETM

B.2.23 The investment decisions as well as the calculation of lifetime costs rest on a number of parameters. A list of the parameters used is outlined in Table B.1. For the project for the CCC, we used assumptions provided by the CCC. For technologies that the CCC were unable to provide information for, it was assumed that the relative cost of these technologies was as in the usual set of parameters used by MDM-E3 compared to cost of gas CCGT provided by the CCC.

TABLE B.1: PARAMETERS REQUIRED FOR THE ETM

Characteristic	**Units**
1. Unit capital costs	£/kW
2. Unit coal input	Mtoe or GJ/GWh
3. Unit gas input	Mtoe or GJ/GWh
4. Unit oil input	Mtoe or GJ/GWh
5. Unit CO_2 emissions	kg/kWh or GJ
6. Unit SO2 emissions	kg/kWh or GJ
7. Unit NOx emissions	kg/kWh or GJ
8. Unit PM10 emissions	kg/kWh or GJ
9. Load factor	ratio
10. Lifetime	years
11. Installation lag	years
12. Development lag	years
13. Learning rate	% of per unit rate
14. Substitution parameter	
15. Minimum cost	£/GJ
16. Technical limits	% of total supply
17. Infrastructure costs	£/GJ
18. Other unit costs (eg O&M)	£/GJ

Appendix C Identifying the Macroeconomic Effects of Climate Change Mitigation Policies

C.1 Introduction

C.1.1 This appendix presents a brief description of the relationship between certain microeconomic concepts relevant to the analysis of climate change mitigation policies and the macroeconomic outcomes. It also presents a way of disaggregating conceptually the various components of the macroeconomic changes arising from implementation of mitigation policies.

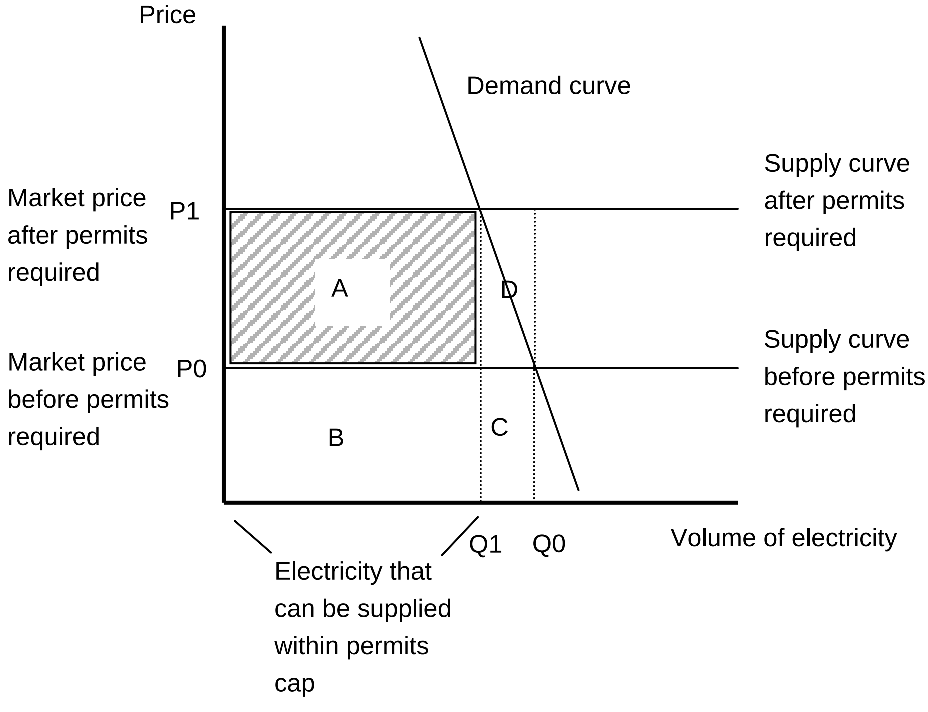
C.2 From micro to macro: an illustration of the case of tradable emissions allocations

Microeconomic, partial analysis

C.2.1 Consider, for simplicity, the case where allocations only apply to power generation, where there is no trade in allocations outside of the UK electricity sector, where the supply of electricity is completely elastic, and there is only one possible fuel which is carbon-based (and no sequestration is possible).

C.2.2 If the marginal cost of electricity production is constant, the conventional partial comparative statics approach yields the analysis shown in Figure C.1.

FIGURE C.1: IMPACT OF PERMIT ALLOCATIONS ON ELECTRICITY PRICE AND REVENUES



C.2.3 The allocation price will rise until the price faced by electricity users discourages consumption to the point where the carbon produced by electricity production matches the supply of allocations. In the diagram, this represents an increase in price from P0 to P1 which induces a reduction in consumption from Q0 to Q1. The allocation price per amount of carbon emitted by a TWh of electricity is (P1-P0), and the market value of the allocations is the area of the rectangle A. The revenue received by producers from the sale of electricity falls from (B+C) to B. The expenditure of electricity users changes from (B+C) to (A+B), and if demand is price inelastic (as shown in the diagram) then expenditure on electricity will increase (A is larger than C). The rectangle A+D represents the income that consumers would need to be given to allow them to purchase the same amount of electricity as before.

Macroeconomic consequences ignoring distribution of the proceeds of the sale of allocations

Prices and final expenditure

C.2.4 The price of electricity would rise. If the only users of electricity were households, then the only price of interest would be the electricity element of the consumer price index. The reduction in household spending on electricity would be the same as the reduction in the gross output of the electricity industry that is consistent with (in the same proportion as) the fall in TWh from Q0 to Q1. Household spending on other items would change, boosted by the relative price effect (substitution away from electricity) and depressed by the income effect of the higher price level. The aggregate effect is a reduction in household spending in constant prices, roughly in the same proportion as the increase in the consumer price index (depending on whether households respond by drawing on savings).

C.2.5 Since, in fact, electricity is also used as an intermediate input to production, the picture is somewhat more complicated. Both the wholesale price (faced by industries) and the consumer price of electricity rise. The reduction in household spending on electricity is less than the reduction in electricity gross output, because some of the demand reduction is in intermediate demand for electricity and so we need to consider where the rest of the reduction in final demand comes from. Suppose that the increased cost of electricity is passed on in industry prices in proportion to the weight of electricity in each industry's costs and assume for the moment that all output of UK industry is sold to UK households (and there are no imports). In that case, consumer prices of all products will rise according to their electricity-intensity. So this is analogous to the case in which all electricity is sold to households, except that some of those sales are embedded in other consumer products. The overall increase in the consumer price level is the same, except that less of it comes in the form of a direct increase in the electricity element of the consumer price index, and more of it comes in the form of (smaller) increases in other consumer prices. Once again, the aggregate effect is a reduction in household spending in constant prices, roughly in proportion to the increase in the consumer price index.

C.2.6 Now allow for the case where some sales by UK industries are to exports. To illustrate the effects, assume an extreme case that all UK production (except for electricity) is exported. Higher industry prices are (we assume here) passed on in higher export prices, with a resulting reduction in exports in constant prices. The scale of the effect on exports (and hence on GDP from the expenditure side) depends on the price elasticity of exports. Suppose that exports were not at all price-sensitive. The result of higher electricity prices would be a reduction in household spending on electricity, and no change in UK exports. In this case, some of the higher cost of UK electricity is borne by foreign consumers of UK exports (who now face higher prices). If, on the other hand, we assume that foreign consumers of UK products respond to higher prices in much the same way as UK consumers, the only difference that allowing for exports makes is that part of the reduction in final demand arising from higher electricity prices embodied in UK products is reflected in exports, whereas in the no-export case it is all borne by UK household consumption. The aggregate effect should be a reduction in household and export spending; the scale of the reduction in household spending in constant prices should be roughly in proportion to the increase in the consumer price index; the scale of the reduction in export spending in constant prices should reflect the price elasticity of exports and the increase in export prices.

Gross output, value added and imports

C.2.7 The effects of the reduction in electricity consumption are as follows. Electricity gross output in constant prices would fall by the same proportion as the fall in TWh from Q0 to Q1. If electricity production had no bought-in inputs, the reduction in gross output would all be felt as a reduction in its value added. Since it does have bought-in inputs (especially the fuel used), the reduction in gross output is reflected partly in a reduction in electricity value added and partly in a reduction in purchased inputs. Whether these two elements both fall in the same proportion depends on the extent to which they vary pro rata with production. If all the bought-in inputs were imported, this would cushion the effect of reduced electricity consumption on UK GDP (some of the reduction in value added would be borne by foreign producers). To the extent that some bought-in inputs are sourced in the UK, the supplying industries will themselves face reduced demand, with knock-on effects on their suppliers and on imported inputs, and so on. Ultimately, the reduction in (UK value added plus imports) should be equal to the reduction in electricity industry gross output reflected in the fall in TWh from Q0 to Q1.

C.2.8 We now need to account for the consequences for output of the income effects of the rise in the cost of electricity (the impact of the net loss of income shown as A-C in Figure C.1; remember that at the moment we are not allowing for redistribution of the allocation values represented by rectangle A). If the only users of electricity were households, this would come about in response to the changes (and, in aggregate, the reduction) in other categories of household spending resulting from price substitution and income effects. If the supply of these products were all imported, there would be no further effects on UK GDP, and the loss of output would be suffered by foreign producers. Since they are not all imported, the loss of output is shared between UK producers and imports.

C.2.9 Since there are other users of electricity apart from households, the position is more complicated. If all UK production were sold to households, the reduction in demand comes about in response to higher prices passed on to households and the resulting adjustments in the composition of household demand. Since some UK production is sold to exports, the reduction in demand also comes about from lower exports. Either way, the effect is a reduction in the gross output and value added of UK producers and in imports. The reduction in (UK value added plus imports) should be broadly of the same order of magnitude as the reduction in income (A-C).

Incomes and the income multiplier effect

C.2.10 Households suffer a reduction in real incomes because the consumer price index has been boosted (directly and indirectly) by the increase in electricity prices. The reduction in electricity gross output leads to a reduction in value added in the electricity industry and its suppliers (including imports) equal in magnitude to the rectangle C. That part of the reduction in value added which is borne by UK producers is reflected in reduced profits and wages, which produces expenditure multiplier effects throughout the economy.

Macroeconomic consequences when the proceeds of the sale of allocations are redistributed

C.2.11 Assume that allocations are allocated freely to electricity producers on the 'grandfather' principle, so that the proceeds of the sale of allocations enters into the electricity industry's profits. Assume also that the whole of this boost to profits is redistributed in dividends to UK households. Compared with the cases described above, households have now been partly compensated (in the amount A) for the reduction in real income that arises from higher electricity prices.

C.2.12 From the perspective of the welfare economics, the compensation is known to be insufficient to maintain the same standard of living, since households could have chosen to consume Q1 previously, and spend C on something else (which is the decision they are making now), but preferred Q0 for which the compensation A is not sufficient to attain. On the other hand, if they were compensated with (A+D), so that Q0 was within reach, this would be more than they require to stay on the same indifference curve (not shown in the diagram) because relative prices have changed. If we regard the reduction in real income as the additional compensation that would be required to keep households on the same indifference curve, it amounts to something between zero and D.

C.2.13 However, these welfare changes are not observable, and measured imperfectly in the national accounts. What is measured is the change in incomes and spending in nominal terms, and the change in consumer prices. In national accounts measurement, households will be no worse off if their real income and spending (ie deflated by the consumer price index) is the same after the change. Households have reduced their real (valued at pre-change prices) consumption of electricity by the rectangle C. Their nominal spending on electricity has increased by (A-C). Their nominal income has increased by A. If they spend all of this increase in income, they will spend an additional nominal amount equivalent to C on other products[20]. The extent of the reduction in real household spending caused by this shift in spending of C from electricity to other products depends on the choice of the price base year for measuring consumption.

C.2.14 If allocations are auctioned and the proceeds accrue to government and are used to cut taxes, welfare could be higher or lower depending on whether the welfare gain from cutting those taxes exceeds the welfare loss from raising the electricity price.

Low carbon technologies in power generation

C.2.15 The simple model described above serves to highlight many of the key issues involved in relating microeconomic effects to macroeconomic results. However, its assumption that there is only one possible fuel which is carbon-based needs to be relaxed when we want to consider the impact of policy on the choice of technology in power generation.

C.2.16 An extended model would have an upward sloping supply curve for electricity, and low carbon technologies would initially be present in the upper end of the curve, because their unit cost of production is higher. The introduction of allowances has the effect of shifting the low carbon part of the curve to the left, promoting these technologies ahead of some carbon-intensive alternatives for which allowances are now required. The required reduction in electricity consumption consistent with the allowances cap is now less, because some low carbon electricity can be consumed outside of the cap. Consequently, the price of allowances which has served to curb electricity consumption does not need to rise so far.

C.2.17 The macroeconomic consequences are not very different in character from those described above, but will now be smaller (lower increase in the price level, lower reduction in GDP) to the extent that the requirement to curb electricity consumption is mitigated by the availability of low carbon technology. Clearly the composition of demand for products in the economy will shift towards those associated with low carbon power generation; to the extent that these have a high import content, this will stimulate production outside of the UK.

[20] For simplicity, this ignores the income effect on the position of the demand curve.

TABLE C1: THE MACROECONOMIC IMPACT OF CARBON ABATEMENT MEASURES, CENTRAL FOSSIL FUEL AND CARBON PRICE CASE

		Differences from base (REF1) in 2020 (%)		
	Scenario reference	**GDP**	**CPI**	**Household expenditure**
With EU ETS carbon price, grandfathering of allowances	Ref1b	-0.70	2.49	-1.16
+ Additional generation from renewables	3P	-0.73	3.25	-1.48
+ Higher import prices	3M	-1.00	3.83	-1.93
+ MACC measures	3MV	-0.97	3.75	-1.82
+ Full auctioning of allowances, with no recycling	3MV_A	-1.21	3.76	-2.23
Alternative methods of recycling the value of auctioned allowances				
+ Recycling directly to household incomes	3MV_A_I	-0.82	3.75	-1.57
+ Recycling directly as cuts in employers' NICs	3MV_A_N	-0.99	3.36	-1.85

Note(s) : The scenarios build up the various measures. Each scenario in the list includes the measures in the preceding cases, except for the final recycling scenario which represents an alternative way of recycling the value of auctioned allowances (so that it builds on the 'full auctioning, no recycling' case).

C.2.18 The availability of low carbon technologies also allows the possibility of 'induced technological change'. To the extent that these technologies are currently immature, a substantial boost to global demand will stimulate R&D and the exploitation of economies of scale, reducing unit production costs and promoting the low carbon part of the supply curve further up the ranking of technology choices.

C.3 Disaggregating the components of the macroeconomic changes arising from mitigation policies

C.3.1 The analysis of macroeconomic impacts presented in the main report represents the accumulation of a set of changes introduced in the modelling. In this section we review the separate impact of each of these changes as they are built up to produce the final scenario, in order to aid understanding of the nature of the effects.

C.3.2 The results of the scenarios are all compared against a 'base' case, which represents the state of the economy, energy use and emissions in the absence of the carbon abatement measures to be modelled.

C.3.3 The measures introduced, cumulatively, are as follows:

- we introduce an escalating EU ETS carbon price for the price of allowances required by the industries covered by the scheme; we assume (initially) that the allocation of allowances follows the existing, largely grandfathered, principle; we also assume that the boost to profits associated with the value of the allowances is distributed to households after a deduction for corporation tax

- we force in a faster build of power generation renewables plant than the model would allow endogenously in response solely to the EU ETS carbon price to represent a policy to promote generation from renewables more vigorously so as to achieve the (separate) renewables target
- we raise the prices of imports to capture the impact of the adoption of similar carbon abatement measures elsewhere in the EU on the price of their exports
- we introduce specific reductions in energy use/changes in fuel use and increases in spending on other products by industries and households to represent the impact of a policy that promotes take-up of no-regrets abatement measures estimated by the CCC from its marginal abatement cost curves
- we withdraw grandfathering of allowances and require EU ETS users of carbon fuels to purchase allowances at auction; the revenues accrue to government and are not spent (implicitly they would be used to reduce government debt, but this has no impact in MDM-E3, and so auctioning without recycling represents a leakage of spending from the economy)
- we recycle the auction revenues by one of two methods: (i) a direct, untaxed transfer to households, and (ii) a reduction in employers' national insurance contributions

C.3.4 The cumulative impacts on selected economic indicators as the measures are introduced are shown in Table C1. These have been constructed by undertaking separate model runs and adding the measures incrementally. Since the model is not linear, the impacts are not strictly additive, and if the measures were implemented in a different order the change resulting from any particular measure would not necessarily be the same as implied in the table. Consequently the results shown in Table C1 should be taken as indicative rather than a definitive estimate of the contribution of each measure.

C.3.5 The introduction of the carbon price raises the cost of electricity (and other products covered by the EU ETS) through the economy, resulting in a boost to the consumer price index. The reduction in household expenditure is less because household incomes are boosted by the distribution out of profits of some of the value of the allowances. Apart from the leakage to corporation tax from profits, there are also leakages to product taxes (VAT and excise duties) and to imports as households substitute expenditure away from electricity and towards products with a higher tax and import content. There is also a loss of competitiveness of UK producers compared with imports because, thus far, import prices have not been adjusted to reflect the impact on the costs of competitors of policies implemented abroad.

C.3.6 When the take-up of renewables technology is accelerated, this raises the cost of electricity, raising the consumer price level and curbing household expenditure further.

C.3.7 When import prices are raised in response to the assumed implementation of similar policies in the rest of the EU, the loss of competitiveness of UK producers is mitigated, but this benefit is outweighed by the income effect of higher import prices. The consumer price level is pushed higher, household spending is cut further, and GDP is reduced further.

C.3.8 When allowances are auctioned, but the proceeds not recycled, there is little impact on consumer prices but a bigger effect on household spending because of the loss of income (profits previously associated with the value of allowances are no longer distributed).

C.3.9 The two recycling scenarios both have the effect of mitigating the impact on GDP. When income is recycled directly to household incomes, there is little effect on consumer prices but a considerable boost to incomes and GDP. When income is recycled as a cut in employers' NICs, the reduction in production costs is partly reflected in somewhat lower prices and partly in improved profitability. Most of the benefit to household incomes and spending comes through lower prices. Recycling via employers' NICs entails more leakages to taxation (on profits and wages), and the impact on GDP is virtually the same as under grandfathering (which also entails leakages to taxation on profits).

Appendix D Methodology for deriving regional energy and emission projections

D.1 Data

D.1.1 The data for the regional energy and emissions projections were based on the 2005 data prepared for SCPNet[21]. At a fuel user and fuel type level these data are no longer consistent with the DA energy and emissions data published as part of the National Air Emissions Inventory. For example, once the SCPNet data are collected they are not regularly updated, whereas data for previous years in the inventory can be updated in light of changes to methodology. The data are provided for 1990, 2000 and 2005 for emissions and 2000 and 2005 for energy.

D.2 Methodology

Power generation

D.2.1 All existing power generation sites in MDM-E3 have been attributed to a DA (or England) to calculate energy demand from power generation within a DA (or England). The existing 2005 regional data, collated for SCPnet, have then been scaled to match the regional DA view from MDM-E3 and the wider UK total. Emissions are also attributed to each DA (and England) in the same manner. As power stations are decommissioned in a particular DA (or England) there is a reduction in energy demand and any related emissions. New power station build is then split amongst the DAs (and England) depending on demand and interconnectors. Projected emissions and energy demand from power generation are therefore driven by new build of different plant types in each DA (or England).

Own use and other transformation

D.2.2 SCPnet data for energy demand and emissions by region for Own Use and Other Transformation have been scaled to match UK totals and grow in line with UK energy demand and consequent emissions for these two sectors. Emissions from offshore activities have been excluded from regional projections.

Final energy demand and emissions

D.2.3 For the remaining final users (except for transport sectors), SCPnet data have been scaled to match the NAEI UK totals for the year 2005. We then derive fuel user activity variables which are based upon gross output for each of our fuel user categories for each of the DAs (and England). For road transport, the activity indicator is based on total output for the DA (or England) plus imports and household spending in each DA or England. Household expenditure is used to determine households' energy demand.

[21] For further details, see http://www.wwflearning.org.uk/scpnet/news-archive,369,AR.html.

D.2.4 These activity indicators are then used to determine growth in energy demand for each fuel user and each fuel type for each DA (and England) across the projection period. For example, if regional activity for a fuel user is projected to grow in line with the UK average for that fuel user, fuel demand for that fuel user in that region will grow by the UK average. If the regional activity is growing faster (or slower) than the UK average, then fuel demand from the fuel user in that region will grow faster (or slower) than the UK average by a similar amount. Projections of regional output and household expenditure are produced by MDM-E3. Table D.1 below shows the projected average growth rates for total gross value added (GVA) and household expenditure in England, Northern Ireland, Scotland, Wales and the UK in REF1.

D.2.5 Levels of energy demand are calculated by applying the estimated growth rates to the 2005 base data. For consistency, energy demand has to be scaled to UK totals for each fuel user and type.

D.2.6 For emissions, implicit emissions factors are calculated over each DA (and England), for each fuel user and each type using the 2005 data. These emission factors are then applied to the projections of energy demand in each DA (and England), for each fuel user and fuel type, to give projections of emissions. Emissions are then scaled to the UK total for each fuel user and fuel type for consistency.

D.2.7 Estimated emissions from offshore have been excluded from the emissions projections. However, it has not been possible to exclude offshore's energy demand from the energy projections as the data do not allow this to be distinguished adequately.

D.2.8 All the regional energy and emissions projections exclude energy demand and emissions from rail, water and air transport (both domestic and international). Consequently, the emissions totals are less than the totals estimated in the UK projections.

D.2.9 Non-energy emissions are also determined by regional fuel user activity and then scaled to the UK total.

Emissions attributed to electricity consumption

D.2.10 Final users' electricity emissions are based on the electricity consumption and the average carbon intensity for electricity generation across the entire UK grid.

TABLE D.1: GROWTH IN ECONOMIC VARIABLES FOR DEVOLVED ADMINISTRATIONS AND ENGLAND IN REF1
(Average % pa growth over 2005-2020)

	England	Northern Ireland	Scotland	Wales	UK
Household expenditure	2.3	2.2	2.0	2.0	2.3
GVA[2]	2.6	2.4	2.1	2.4	2.5

Note(s) : 1. Growth of expenditure is in market prices and GVA in basic prices shown. Both are on a chain value measure (with 2003 as the reference year).
2. Excludes GVA for Extra-Regio (compensation of employees and gross operating surplus which cannot be assigned to regions) but includes ownership of dwellings and adjustment for financial services.

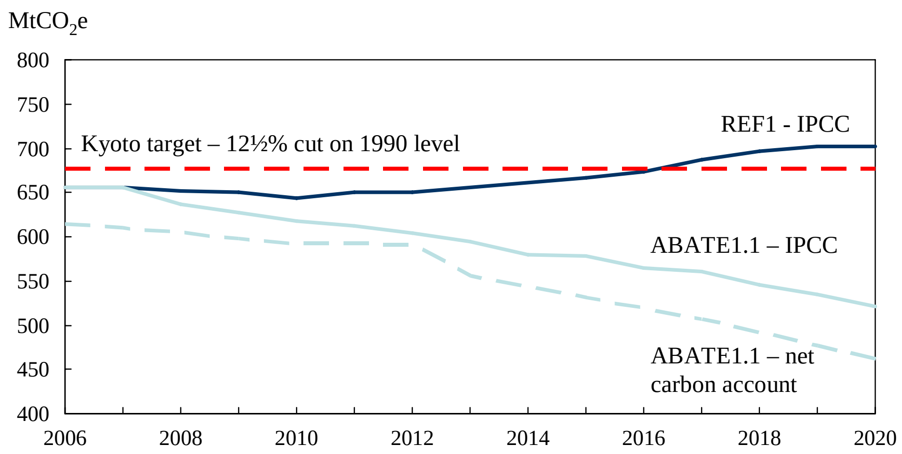
Source(s) : ONS, Committee on Climate Change Secretariat and Cambridge Econometrics

Appendix E Greenhouse gas emissions from central reference (REF) and abatement (ABATE1.1) scenarios

E.1.1 This appendix briefly discusses the projections of UK emissions of all the greenhouse gases (GHGs) controlled by the Kyoto Protocol in central reference (REF1) and abatement (ABATE1.1) scenarios (see Chart E.1). Projections from ABATE1.1 are presented on both the IPCC and net carbon account bases. The trends in these projections mirror those of CO_2 emissions (see Section 5.2) as emissions of CO_2 make up the majority of emissions of GHGs and the projections do not incorporate markedly different outcomes for the non-CO_2 gases. In MDM-E3, the main driver of the projections of emissions of non-CO_2 GHGs is population (for further details, see paragraphs A.5.5 and A.5.6 in Appendix A).

E.1.2 Emissions of the GHGs in both REF1 and ABATE1.1 over 2008-12 are projected to be below the UK's Kyoto target (12½% below the 1990 level). However, emissions of the GHGs in REF1 are projected to rise, so that in 2020 they are projected to be only 9% lower than the 1990 level. Emissions of these GHGs in ABATE1.1 are projected to fall so that by 2020, they are projected to be 32% lower than the 1990 level on the IPCC basis and almost 40% lower on the net carbon account basis.

CHART E.1: PROJECTED UK GHG EMISSIONS



Note(s) : 1. Includes emissions from non-energy uses.
2. Excludes emissions from international travel and land use, land use change and forestry.
3. The estimates cover the greenhouse gases controlled by the Kyoto Protocol. Emissions from non-CO_2 greenhouse gases are weighted by their global warming potential compared to CO_2

Source(s) : NAEI, DEFRA, BERR (DUKES 2007), Committee on Climate Change Secretariat and Cambridge Econometrics.

Ref : C82R1CCC, C82AB83MVAICCC.