Review of the response of emissions to economic growth/recession in the DECC Energy Model

A report for the Committee on Climate Change

26 September 2011

Cambridge Econometrics
Covent Garden
Cambridge
CB1 2HT
UK

Tel 01223 533100 (+44 1223 533100)
Fax 01223 533101 (+44 1223 533101)
Email ps@camecon.com
Web www.camecon.com

Revision and Authorisation History

Version	Date	Authorised for release by	Description
3.3	26/09/11	Richard Lewney	Final report.
3.2	8/09/11	Richard Lewney	Final report, including responses to final round CCC comments.
3.0	16/08/11	Richard Lewney	Final draft of full report, including responses to second round CCC comments.
2.0	15/07/11	Richard Lewney	Revised draft of full report, including responses to CCC feedback.
1.0	June 2011	Richard Lewney	First draft of chapter 3, plus work in progress of other sections.

Contents

Tables and Figures

Tables

Figures

Appendix Tables

Appendix Figures

Executive Summary

The CCC commissioned CE to undertake an analysis of the DECC Energy Model and its projections, which inform the CCCs advice on carbon budgets

- The Committee on Climate Change (CCC) commissioned Cambridge Econometrics (CE) to undertake an analysis of the response of emissions to economic growth/recession in the DECC Energy Model.
- The particular concern is whether a recession might have implications for long-term emissions because of persistent changes to economic growth prospects (especially when considering particular sectors of the economy), global energy prices, and the impact on the energy-consuming capital stock.
- When advising the UK Government on carbon budgets, the CCC makes use of the Department of Energy and Climate Change's (DECC's) emissions projections which, for the most part, are generated from the DECC Energy Model. The DECC Energy Model is a top-down econometric model of energy consumption by sector. The CCC tasked us with assessing whether the DECC Energy Model was a suitable tool for producing these projections and to analyse potential improvements that could be made in the context of the model's long-term responses to a recession.

We analysed the DECC Energy Model, provided alternative projections and assessed third-party modelling approaches

- Our approach was to undertake three pieces of analysis. First, we assessed three sets of projections from the DECC Energy Model, considering the model inputs, outputs and key relationships. Second, we applied the MDM-E3 model using comparable inputs to those used in the DECC Energy Model runs to provide an alternative set of projections for comparison. Third, we assessed energy and emissions modelling approaches from other reputable modelling institutions.

The DECC Energy Model is fit-for-purpose but improvements could be made

- Our assessment is that the DECC Energy Model is, broadly, fit-for-purpose, but that there are a number of improvements that could be made. Our recommendations for improvements have been informed mostly by our assessment of the DECC Energy Model itself, rather than from any lessons drawn from the alternative projections provided in our MDM-E3 model analysis or our assessment of third party models.
- The DECC Energy Model is a partial model and requires sector and sub-sector economic activity projections consistent with HMT economic projections. The two recent runs (2009 and 2010) were based on sub-sector economic inputs which had not been updated with the latest data and which assumed the same forecast of the composition of sub-sector industry output as in the pre-recession run.
- There is some documentation of the DECC Energy Model, mostly undertaken by third party organisations at the request of DECC or the CCC. However, there is insufficient documentation of the technical detail of the modelling approach to allow as comprehensive analysis as we would have liked. An example of this is the interaction of CHP with other parts of the model and the allocation of CHP energy consumption and associated emissions.
- It is difficult to conclude that the DECC energy projections for the economy as a whole are systematically biased in one direction or the other. Of the industry

sectors analysed we find some evidence of over-prediction in energy demand[1]. However, the counterintuitive negative income elasticities are evident in the projections for households and while there are candidate explanations for these negative elasticities, it is generally accepted in the literature that income elasticities are in fact positive, and so there may be a general upward bias in the long-term household energy demand projections following the recession[2]. For road transport we find little evidence to suggest over or under-prediction in fuel demand.

- Our alternative set of projections undertaken in MDM-E3 highlight the difference in projections profiles from an alternative treatment of the residual error (one which assumes some systematic bias in our equation estimates, however small). In contrast to the DECC Energy Model projections, between the MDM-E3 model runs there are considerable differences in the long-term projections for emissions as a result of the three sets of economic growth assumptions. This result is reinforced by the accumulating impact that economic growth has on investment and that this in turn has on long-term energy consumption. The MDM-E3 projections suggests that following the recession, emissions could be significantly lower (up to 40 $MtCO2$) in 2020 than projected by the DECC model.
- Alternative modelling approaches are undertaken by a number of private sector, public sector and academic organisations which make use of more detailed technology specific modelling approaches. These approaches can be beneficial in allowing a framework to assess the impact of new technologies and step-changes in the take-up of both new and existing technologies. An important feature of these models is that they account for the capital stock, which is theoretically more appealing than accounting for technological changes through a time trend parameter (as is currently done in the DECC Energy Model), which is of particular relevance during (and following) a recession.
- We have made the following recommendations, for the short, medium, and long-term:

Recommendations for the short-term

- Ensure that the model inputs make full use of recent economic data, particularly to inform the sub-sector industry equations.
- Clarify (and make transparent) the method for deriving emissions projections from the energy demand projections.
- Where relevant, make use of more in-depth statistical information (or soft data) to account for known events not captured in the data (eg the moth-balling or closure of an iron and steel plant).
- Consider applying a persistent residual adjustment in the projections, particularly if the top-down equations give evidence of systematic over, or under-prediction, consider applying a persistent residual adjustment in the projections.

Recommendations for the medium-term

- Improve the clarity, availability and robustness of the model documentation: most third party organisations had much clearer documentation, especially models used heavily by the public sector (eg PRIMES and E3ME).

[1] Industry sectors analysed account for almost 70% of industry energy demand. We find evidence of an upward bias of 422 ktoe of ‘useful’ energy (3.7% of industry energy consumption) in 2020.

[2] Oxford Economics (2008a) reviewed the BERR Energy Model (as it was known then) and suggested possible bias in the equation if income growth in the projection period were off trend. Such a situation might arise after a recession.

- Consider alternative (third party) sources for developing sub-sector industry economic projections. The projections should be consistent with the macroeconomic forecasts developed by the Office for Budget Responsibility and/or HM Treasury projections.
- Develop the model relationships between wholesale prices and retail prices, giving particular emphasis to the dynamic relationships between wholesale and retail prices, and the retail prices faced by different sectors.

Recommendations for the long term

- Re-estimate the model equations to account for more recent data. The current set of equations was estimated over the sample period 1980-2004; DECC justifies this approach on the basis that the parameter estimates do not include the impact of new policies, which are subsequently added in on the basis of separate off-model estimates as opposed to being captured explicitly within the modelling framework as changes in input assumptions. However, the current approach ignores recent data on the relationship between economic growth and energy consumption in the recession.
- , If our approach is accepted, but policy impacts are to continue to be applied as off-model adjustments, the estimation dataset should include *ex-post* assessments of policy impacts in the extended sample period, to avoid double counting.
- Re-specify the model equations to better account for prices and investment, as well as investigating implausible parameter estimates (such as the negative income elasticity for gas and electricity consumption in the domestic energy equation).
- On a sector-by-sector basis consider supplementing the top-down econometric projections with bottom-up analysis. The Iron and Steel sector is one example where this might be suitable, since the sector is readily identifiable and the energy-using processes (and viable alternatives) can be well described in a technology-driven model. Given the advances in building physics models, DECC could also seek to use bottom-up models to project energy consumption and emissions from households.
- DECC is currently engaged in a review of its Energy Model. It is likely that some of the above recommendations are already being addressed.

1 Introduction

This report is the final report of a project for the Committee on Climate Change (CCC) to review the responses of emissions to economic growth and/or recession in the DECC Energy Model[3].

1.1 Background

The CCC advises the UK Government on the setting of carbon budgets

The CCC was set up to advise the UK Government on a range of issues, including setting legally binding carbon budgets for consecutive five year periods, beginning in 2008, and a target for emissions reductions in 2050.

In making its assessment of future carbon budgets the Committee has considered the potential for cost-effective abatement as against a reference emissions scenario which considers the path of emissions in the absence of mitigation measures (or the absence of mitigation measures beyond those already committed to).

The CCC is concerned that the DECC Energy Model may be overestimating the trajectory of post-recession emissions

These reference emission projections have been derived from the DECC Energy Model. In making its recommendations for the fourth carbon budget, the Committee has raised a concern that the DECC emission projections may be too high – specifically that the DECC Energy Model may underestimate the future extent of decoupling of energy demand from GDP growth.

Given the recent recession, and revisions to the assumed path of GDP going forward, the responsiveness of emissions to GDP/economic activity has become an increasingly significant issue. Projections from the Office of Budget Responsibility (OBR) suggest a permanent impact of the recession, such that GDP in 2020 is expected to be around 10% lower that was projected before the recession.

The potential for emissions to be projected too high could have important implications since:

- it would increase the extent to which the first three carbon budgets could be achieved with reduced policy effort, without implementation of measures to drive necessary emission reduction for the longer-term;
- it could mean that a tighter fourth carbon budget (2023-27) than the Domestic Action budget recommended by the Committee and now legislated by government might actually be appropriate.

1.2 The structure of this report

The project is divided into three tasks:

- Assess the robustness with which the DECC Energy model is able to reflect new information, as available from 2008 to 2010
- Provide benchmark estimates of the impact of the recession on emissions (in 2010, and forward-looking to 2020) based on available information
- Assess wider evidence from energy and emissions modelling, particularly for the industrial sector, and draw implications for modelling approaches for the UK

[3] Prior to the formation of DECC, the model was maintained by BERR and known as the BERR Energy Model. For consistency, the model will be referred throughout this report as either 'the DECC Energy Model' or 'the DECC Model'.

Evidence and existing analysis of the impact of recession on energy demand and emissions is presented in Chapter 2. After that, each of the tasks is addressed in order. Our approach to assessing the DECC Model is presented in Chapter 3 and our findings are detailed in Chapter 4. Results from an alternative set of projections, generated using CE's own model for energy and emissions projections, MDM-E3, are presented in Chapter 5. The final element of the project, a wider review of other modelling approaches, is covered in Chapter 6. Concluding remarks can be found in Chapter 7 and references are listed in Chapter 8.

Additional analysis of the DECC Model results (to supplement the assessment in Chapter 4) is provided in Appendix A. More detailed MDM-E3 results are presented in Appendix B. Appendix C of this report contains a more detailed description of the MDM-E3 model while the model's key classifications with respect to this project are listed in Appendix D. Summaries of the models reviewed in the wider assessment of alternative modelling approaches are provided in Appendix E.

2 Energy Demand and Emissions in the Recession

This chapter provides an overview of the global recession in the context of energy demand and emissions, with particular emphasis on developments in the UK. The possible effects of a recession on energy demand are also considered in this chapter.

2.1 Energy demand and emissions in the recession

World GDP contracted by 0.5% in 2009

IMF (2011) statistics indicate that world GDP growth slowed in 2008 (2.9% compared to 5.4% in 2007) and contracted in 2009, by 0.5%. Compared to the global average (buoyed by slower, but still positive, growth in Asian developing economies) the downturn was more severe in the countries the IMF classifies as 'Advanced Economies'. GDP in the eurozone grew by 0.4% in 2008 and fell by 4.1% in 2009. The adverse effects on the UK economy were somewhat greater, with essentially no growth in 2008 followed by a fall of 4.9% in 2009.

Global oil prices were rising for much of 2007 and peaked in the middle of 2008, before a sharp decline over 2008H2 and into 2009Q1. Prices increased thereafter, such that, on an annual basis, the price of oil was around 25% lower in 2009 compared to 2008. Sustained growth led to prices in 2010 some 33% higher than in 2009.

In 2009, UK GDP fell by 4.9% and final energy demand by 6.8%

While the pre-recession profile of UK energy demand for final use over 2005-07 suggests a slight downward trend in energy demand, changes in energy demand in 2008 and 2009 were more or less in line with GDP; final consumption fell slightly in 2008 and then sharply in 2009, by 6.8% (a fall appreciably larger than the contraction in UK GDP).

This reduction in final demand occurred across all broad sectors (by the definitions of Industry, Transport and Other listed in DUKES 2010), with households (part of Other) and road transport contributing most to the reductions at the sub-sector level. More than one-third of the energy demand reduction came from Industry as a whole; of course, the contributions by individual industrial sub-sector to the overall UK reduction are much smaller than those from households or road transport, because the level of their energy use is much smaller.

Energy-related emissions fell by 9.1%

Over 2004-07, net UK CO_2 emissions (from all sources) were falling, driven by reductions in combustion emissions. A larger fall was seen in 2008, of 2.4%, as energy demand slowed before the recession itself. In 2009, in the recession, emissions fell by 9.8%, with a 9.1% fall in energy emissions. The split of reductions between energy supply and final use was roughly equal.

UK GDP increased by 1.3% in 2010 and final energy demand by an estimated 4.1%

Following the sharp decline in GDP seen in 2009, the UK economy grew once more in 2010, by 1.3%. Provisional data from DECC's *Energy Trends* publication indicate that final energy demand increased by 4.1% in 2010. The increase was driven by strong growth in demand from households for heating in the cold winter of 2010/11. Gas demand in 2010Q4 was 30% higher than in 2009Q4, driving an annual increase in household gas demand of 11%.

Industrial energy demand also helped to drive the 2010 increase, growing, by 4.5%. The increase in aggregate energy demand from industry is more likely to be linked directly to the economic recovery than the increase from households, because the confounding weather effect is less important for industrial use of energy.

Energy emissions rose in line with energy demand

Provisional data for 2010 show an increase in CO_2 emissions from energy use in 2010, in line with the increase in energy demand. Energy-related emissions increased by an estimated 3.9%, driving an increase in all emissions of 3.8%. The increase in energy emissions was driven by increases from households (owing to a substantial increase in gas consumption for heating) and power stations.

2.2 Possible long-term effects on energy demand and emissions

The possible long-term effects of the recession depend on whether the impacts are transitory or persistent

The impact of the cold weather on household energy demand helps to illustrate the motivation behind the project because the weather effect is an example of what would generally be considered a transitory, or one-off, effect. The cold weather increased household gas demand in that period but, if temperatures return to the long-run average, gas demand would be expected to decrease accordingly. The effects of a cold winter are felt once, in that year, and would not be expected to persist; a single cold winter would not be expected to lead to permanently higher gas demand. A transitory effect is reversible.

The alternative to a transitory shock is a persistent shock, an effect that is not so easily reversed. In the context of a recession, an example might be the closures of steelworks in the 1980s and early 1990s. After the recession these plants were still closed, reducing the size of the energy-consuming stock. The steel industry's production capacity, and thus its maximum energy consumption, had been permanently reduced. In this case, the recession has a long-term impact on industry output, energy demand and emissions. Changes in productive capacity (from changes in the stock of fixed capital) and employment affect the structure of the economy and this has implications for energy demand and emissions because different sectors have different energy and emissions intensities.

Permanent shocks tend to affect stocks (eg energy-consuming capital and hence productive capacity) rather than flows (eg a temporary increase in gas consumption, for a fixed housing stock). Distinguishing between transitory and permanent effects (and the extent to which they are represented in the DECC Model) is key to forming a judgement about the long-term impact of the recession.

A recession can have a number of possible long-term effects

A list of the possible effects of a recession on energy demand and emissions is presented in Table 2.1, drawing particularly on the work by Bowen et al (2009). The table shows that a recession has a number of impacts which can lead to either increases or decreases in long-run energy demand and emissions when compared to a business-as-usual case with no recession. The overall impact is thus ambiguous leading to a number of possible paths for energy demand and emissions post-recession. In the following chapters, we relate the impacts listed in Table 2.1 to the drivers in the DECC Model as well as the other models we consider in this analysis.

Table 2.1: Possible Effects of the 2008-10 Recession on Energy Demand and Emissions

POSSIBLE EFFECTS OF THE 2008-10 RECESSION ON ENERGY DEMAND AND EMISSIONS

Impact in the recession	Possible long-term implications	Possible long-term effect on energy demand and emissions*	Comment
Fall in economic output	Estimates of the UK's long-term growth rate are revised down as the nature of pre-recession growth is re-interpreted.	Decrease – lower activity and growth depresses production	Reflected in lower assumptions for growth in the activity drivers of energy demand.
Fall in income	Slower growth if there is sustained unemployment	Decrease – lower income leads to lower expenditure on energy and products	Energy expenditure mostly a necessity; there is a limit to how far it can fall
Fall in energy prices	Unknown – hard to predict	Increase – if prices remain low Decrease – if prices subsequently rise; possibly amplified if it promotes development of low-carbon technologies	Subject to great uncertainty; movements in wholesale prices difficult to predict Note that a fall in energy prices is a difference between the late-2000s recession and most previous ones
Fall in investment	Slower rate of investment/innovation in low-carbon technologies	Increase – slower uptake of carbon-abatement measures	
Plant and business closures	Fall in UK productive capacity 'Weeding out' of energy-inefficient firms and greater turnover of high-carbon technologies	Decrease – permanent reduction in energy-consuming stock – carbon-intensive parts of the stock are shed	

Note(s) : * The likely effect on energy demand and emissions relative to a state of the world without a recession.
Source(s) : Bowen et al (2009), Cambridge Econometrics.

Investment tends to fall in a recession…

Economic theory suggests an important role for expectations (of future demand and financial return) in determining investment, and so the increased business uncertainty in a recession depresses investment.

Of the effects listed in Table 2.1, investment has perhaps the most direct impact on the energy-consuming stock, with lower investment potentially leading to slower uptake of low-carbon technologies, other things being equal[4].

…but the effect on the capital stock depends on the nature of plant retirals and closures

Similarly firms may choose to extend the life of existing stock rather than invest in new capital. Increases in the energy efficiency of the capital stock are thus slowed by both a lower rate of retiral (of older, less efficient plant) and a lower rate of new investment (in lower-carbon technologies).

However, plant closures are also observed in a recession. There is another possible outcome if the plants that are closed are less energy-efficient. Then the retiral of these plants may increase the average energy-efficiency of the stock (see Table 2.1). We might expect this effect to be offset at least in part by slower investment in low-carbon capital elsewhere.

In the national accounts, Gross Fixed Capital Formation (GFCF) measures the net acquisition of fixed assets and improvement of land ie additions to the capital stock. It is a broad macroeconomic indicator that includes investment in energy-consuming assets such as buildings, vehicles and machinery. Figure 2.1 shows UK GFCF over 1970-2009 and the sharp declines in investment in the three most recent recessions are evident in the chart.

Investment fell substantially in each of the last three recessions…

The investment figures in Figure 2.1 measure the additions to the capital stock, whether as replacements for scrapped capital or as additions to firms' existing productive capacity. The declines in investment seen in the chart during the recessions indicate slower additions to the capital stock and, in turn, slower uptake of low-carbon technologies.

…but the breakdown by asset type differed

Investment falls in all three of the most recent recessions, but trends in investment by asset type differ both during as well as after these recessions. This has implications for the energy-consumption characteristics of the UK capital stock.

In the 1980s recession, investment fell by 5% and 9% in 1980 and 1981, respectively. In this recession, investment in all tangible assets fell substantially, particularly in dwellings and transport equipment. The recovery in investment in 1982 was driven by strong growth in dwellings and other buildings and structures.

The falls in investment seen in the 1990s recession were somewhat less severe; 2% in 1990 and 8% in 1991. In this recession the decline in investment was still led by falling investment in dwellings, followed by machinery and transport; investment in manufacturing equipment fell relatively more in the 1990s recession than in the 1980s recession. Investment remained subdued in 1992 and 1993 and growth in the years that followed was led by stronger investment in machinery in particular, as well as transport equipment and dwellings; investment trends in the 1980s and 1990s differed both in and after the recession.

---

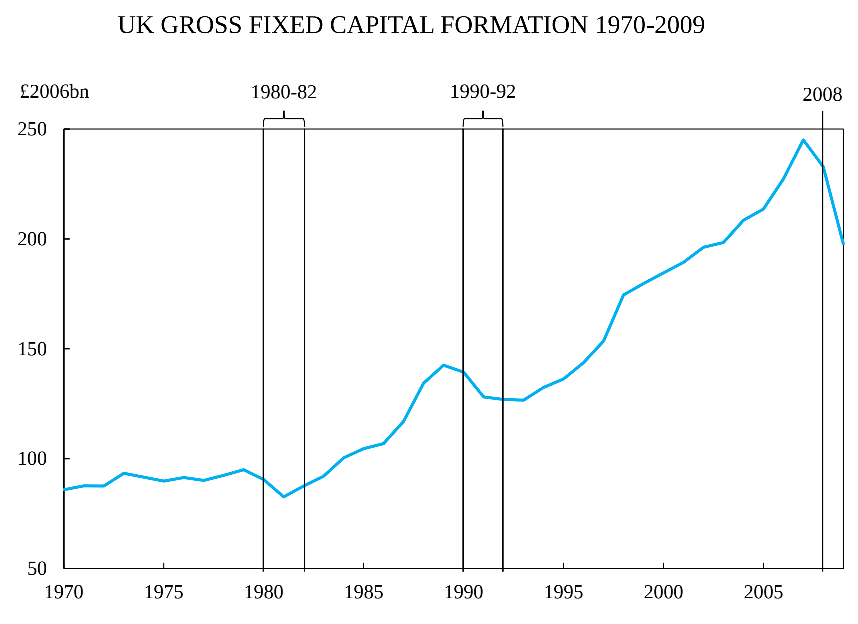
[4] The effect may lead to higher energy consumption if investment is typically in more energy-intensive technologies but we consider this a relatively unlikely future outcome in an economically developed country like the UK in which firms are subject to growing climate-change legislation.

The fall in investment in machinery was most severe in the 2008-09 recession

Of the three most recent recessions, the 2008-09 recession saw the most severe decline in investment; GFCF fell by 5% in 2008 and a further 15% in 2009. As in previous recessions, investment fell sharply in dwellings, but the largest fall this time was seen in machinery and equipment. When the three recessions are compared, investment in manufacturing equipment (relative to total UK investment) fell most in this most recent recession. Investment increased in 2010, by almost 4% and this time the growth was led by transport equipment, followed by machinery and dwellings.Different trends in investment are seen in each of the last three recessions and, consequently, the effects on the capital stocks of the sectors concerned (and their respective energy intensities) are likely to have differed. Indeed, the natures of the recessions themselves have differed, as have the natures of the economic recoveries (see below).

We would expect changes in the capital stock brought about by the recession to be long-lived, typically, and such shocks should generally be viewed as permanent rather than transitory in nature. The importance of changes in investment during and after a recession, and the permanence of the stock effects, is a key feature of the analysis in this report.

Figure 2.1: UK Gross Fixed Capital Formation 1970-2009



Source(s) : ONS.

Only the 1980s recession provides clear evidence of a step reduction in energy demand

Figure 2.2 shows UK energy demand by broad sector over 1970-2009. The three most recent recessions are marked and show a clear permanent fall in energy demand from industry in the 1980s recession. A smaller fall is seen in the 1990s recession (in which falls in service activity played a larger part than in the early 1980s), and it is less clear that there was any impact on the overall, steady downward trend in demand beginning in the mid-1980s.

In the cases of transport and households, there is no clear evidence of a step change in the level of energy demand following the recessions. This suggests that the restructuring effect (the close of energy-intensive plant) was the most important impact (relevant to industry demand, but not transport or households).

The data show a relatively flat profile for energy demand from other final users (public and private services); again there is no evidence of a long-term impact of any recession on energy demand.

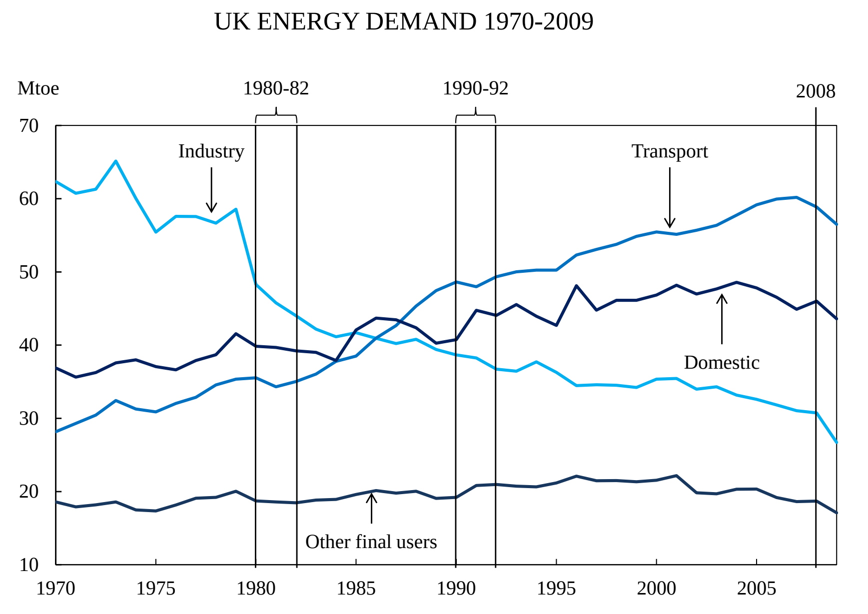
The latest recession has some things in common with both the previous recessions

In terms of energy demand and emissions, the latest recession has some things in common with each of the two previous recessions. The 1980s recession was a global event characterised in the UK by a substantial restructuring away from heavy industry (exacerbated by the high value of sterling), and the closure of British Steel plants in this period illustrates how structural changes can potentially affect energy demand and emissions. The post-1982 period saw a continued shift in the structure of the economy towards services.

In the period following the 1990s recession sterling saw a substantial devaluation when the UK exited the ERM.

The present recession was a global event, like the early 1980s recession, but sterling has depreciated (like the early 1990s recession). Manufacturing industry is less important to the economy as a whole now, and energy-intensive industry is less important within manufacturing. Furthermore, anecdotal information suggests that the

Figure 2.2: UK Energy Demand 1970-2009



Source(s) : DECC.

scale of plant closures has not been on anything like the scale of the early 1980s (for example, it looks like the Corus plant on Teesside has been rescued by SSI Thailand). However, for the energy-intensive industries themselves, further restructuring triggered by the recession remains possible. On the other hand, the current objective of policy is ‘rebalancing’, which in practice means stronger growth in manufacturing industry, but not necessarily the most energy-intensive parts.

In summary, no firm conclusion from the experience of past recessions can be drawn to inform a judgement of what will happen following this recession.

3 Approach to Assessing the DECC Model

This chapter presents our approach to assessing the DECC Model's responses to the recession

This chapter relates to the work to 'assess the robustness with which the DECC Energy Model is able to reflect new information, as available from 2008 to 2010'. It presents our approach to assessing the DECC Energy Model, with particular emphasis on the *long-term* impacts on emissions of the changes made to the forecast following the recession.

An overview of the structure of the DECC Model is provided in Section 3.1, followed by our assessment approach, in Section 3.2. Section 3.3 summarises the three different projections provided to the CCC, focusing on the economic data that was used, the vintages of outturn energy data that were incorporated, and the differences in the long-term projections, identifying trends at a broad level. Analysis of the projections is presented in Chapter 4 and supplemented with further detail in Appendix A.

3.1 Overview of energy demand in the DECC Model

The core of the DECC Model consists of a set of equations to project final energy demand and an electricity supply industry model to determine the price of electricity

Energy demand in the DECC Model is determined by a set of econometric equations to project energy demand from final users, linked to an electricity supply industry (ESI) model that calculates an electricity price that reflects the mix of fuels used to generate electricity. There is feedback through this linkage and the ESI model responds to changes in electricity demand and final-user energy demand responds to changes in electricity prices.

The final energy demands from the model are subsequently adjusted to take explicit account of exogenously-determined energy savings stimulated by policies and sectors' ability to meet their energy demand on-site, from autogeneration and CHP, reducing requirements for electricity from the grid.

The model adjusts the fuel mix used in power generation in response to the level of electricity demand, in order to account for the composition of UK generation capacity in each year (assumptions are made in the forward-looking projection period) and technologies' different operating costs and characteristics.

Key drivers in the econometric equations, which are inputs to the model, for which forward-looking assumptions must be made, are:

- economic activity
  - GVA in industry sub-sectors
  - employment in services (derived from the GVA forecasts)
  - income per household
- retail fuel prices faced by final users
  - these are based on projections of wholesale fossil fuel prices, with the exception of electricity, which is determined endogenously (but linked to the assumptions on fossil fuel prices)

For the residential sector, the number of households, the uptake of gas central heating and winter temperatures must also be projected forward.

Car ownership is a driver in the road transport energy demand equation. Previously, projections were provided by the DfT, but since the Oxford Economics (2008a) review of the model, an equation has been developed to project this within the DECC Model, as a function of household income.

A time trend appears in many of the equations, to account for effects not represented by economic activity, fuel prices, stock terms (gas central heating, car ownership) or other demand factors (temperature). Implicitly, it is assumed that the trend captures the adoption of energy efficiency measures, among other things.

Dummy variables are included to account for shocks or periods of structural change.

The DECC Model does not allow for feedback to the economy from changes in energy demand

The drivers in the equations are exogenous inputs to the DECC Model and the model cannot, by itself, account for changes in industry structure due to changes in trends in energy demand.

The example given by Oxford Economics (2008a) is of a carbon tax, which raises the cost of fossil fuels. The increase in the price of energy will lead to an increase in industry production costs[5] and some of that cost increase may well be passed on to consumers in the form of higher output prices. Higher prices will in turn tend to lower demand for industry production, lowering industry output, which is of course a driver in the DECC Model.

Prior to the Oxford Economics review (2008a), industrial energy demand was projected by individual fuel

In the version of the model that was reviewed by Oxford Economics (2008a), energy demand from the industry sub-sectors identified in the model was projected by equations that determined demand for individual fuels (solid fuels, oil, gas and electricity). Total energy demand by sub-sector was derived by summing the individual fuel demands.

The review highlighted some counterintuitive properties of this treatment (in terms of the parameters estimated), in which fuel demands are independent, citing the example of the effect of higher coal prices in the engineering sector. While higher coal prices did indeed lead to a fall in coal demand, the fall in the price of gas relative to coal led to an increase in gas demand that more than offset the reduction in coal demand. The result in this example is that even though average fuel prices have risen, total energy demand increases. Concerns were also raised as to the suitability of such a framework to assess price-based policies such as carbon taxation, which would be expected to raise the relative price of coal (and in the model as originally specified, would lead to higher energy demand).

Oxford Economics (2008c) re-specified the treatment to share out an aggregate energy demand total among individual fuels

Following this review, Oxford Economics (2008c) re-specified the treatment of industry energy demand to more closely resemble the treatments in the Oxford Economics Energy Industry Model and CE's own MDM-E3 model.

Under the new treatment, aggregate energy demand for each industry sub-sector is projected first (and is affected by a weighted-average price term, if found to be applicable). A set of fuel-share equations then calculates the shares accounted for by each fuel. These shares are scaled in order to sum to one and are then applied to the total demand to obtain projections of energy demand by fuel.

The main economic drivers in the fuel-share equations are:

- fuel prices
  - typically the price of one fuel relative to a weighted average of other 'competing' fuels

[5] On the assumption that the price elasticity of demand for energy is less than one.

- output (in a small number of cases)

As with the aggregate equations, time trends are included in a number of equations, as are dummy variables to account for shocks or periods of structural change.

The scaling treatment introduces dependencies between the fuel-share equations of each industry

Some of the individual fuel equations are relatively simple in terms of the number and nature of the drivers included eg the fuel-share equation for coal demand from minerals is driven by a time trend only. However, when viewed as a set of interdependent equations (bound by the scaling treatment), all of the industry fuel mixes include some economic drivers and dynamic effects (previous years' values affect the current year's value). A price term in one fuel-share equation is able to affect the fuel share of another (even if it is driven purely by a time trend) because the shares are scaled to sum to one.

The revised framework implemented by Oxford Economics introduces interdependencies between the demands for individual fuels not present in the original treatment. Moreover, it is likely that aggregate energy demand can be projected with more confidence compared to typically more volatile demands for individual fuels. The sum of the individual fuel demands is thus constrained to an aggregate that is likely to be more plausible. There are statistical or practical reasons for adopting this approach.

The revised treatment in the DECC Model is thus preferable on the following grounds:

- theoretical
  - counterintuitive price responses are removed (owing to the new interdependencies between the equations and the potential inclusion of an aggregate price term)
- practical/statistical
  - a combination of aggregate energy demand and fuel-share equations is likely to be more stable and give a more plausible set of results than equations for individual fuels that are then summed to give the aggregate figure

The treatments of households and road transport were left unchanged

Oxford Economics (2008a) also examined the DECC Model's treatments of energy demand from households and road transport. Household energy demand is projected by fuel (in a similar manner to industry demand before it was re-specified), with demand for gas and electricity as the key equations. Road transport fuel demand is projected in the aggregate and shared out, by assumption, to petrol, diesel and, more recently, biofuels.

Oxford Economics identified some seemingly counterintuitive relationships in these equations. In particular, negative relationships were found between income and energy demand. A number of possible explanations for such a result in the household energy demand equations were put forward, such as:

- higher-income households may spend less time at home
- income-elastic demand for insulation measures
- rising real income may coincide with increasing energy efficiency over time; the household energy demand equations do not include a time trend so real income may be picking up this effect

The Oxford Economics review (ibid) indicates the possibility of bias in the energy demand projections if income growth is off trend over the forecast period eg changes in the long-run income profile as a result of the sharp fall in income in the recession.

Some work was undertaken by Oxford Economics (2008b) to investigate the possibility of re-specifying and re-estimating the household equations. In the end, the original equations were retained.

The absence of a time trend in the road transport equations was also pointed out and may lead to efficiency improvements being inadvertently incorporated into other parameter estimates.

Policy impacts are excluded from the DECC Model, and subsequently added in to give the final projections

The equations in the DECC Model are intended to project energy demand without the impacts of energy-efficiency and climate change mitigation policies. In the existing equations, the justification is made on the basis that the equations were estimated using data no later than 2004, before substantive policies such as the Climate Change Programmes were enacted.

Rather than simulating the policy impacts within the model, the effects are estimated off-model and then applied to the energy demand projections from the model. A similar treatment is applied in the case of CHP. The model's equations project final energy demand and these figures are adjusted using figures from a separate CHP model to determine the additional, primary, demand for CHP fuels and final requirements for grid-based electricity.

3.2 Assessment approach

Our assessment approach is divided into three components

This section outlines the approach we have taken to analyse the DECC Model's projection properties.

The assessment in Chapter 4 is divided into three sections:

- a broad assessment of the DECC Model's structure and the specification of the equations
- analysis of the DECC Model's responses *given* the input assumptions and the equation specifications
  - the focus here is on how the projections change in response to the data and assumptions used
- analysis of the DECC Model's input assumptions themselves, and how they are formed

Table 3.1 summarises the assessment methods applied in each section, along with whether or not they could be applied for this project. Of the assessment methods, only one could not be applied in this project, re-estimation of some of the model's equations. This is because the dataset to do this is no longer available. The implications for the assessment of not being able to re-estimate any equations are discussed and instead we turn to the existing empirical literature to inform this part of the assessment.

Table 3.1: Categorisation of Assessment Methods

CATEGORISATION OF ASSESSMENT METHODS				
	Assessment of model specification	**Assessment of model responses, given the inputs**	**Assessment of input assumptions**	**Assessed in this project?**
Equation specifications	X			Y
Re-estimation of equations*	X			N
Effect of inputs on outputs		X		Y
Treatment of forecast errors in recent history		X		Y
Estimation of sub-sectoral GVA			X	Y
Formation of price projections			X	Y

Note(s) : * re-estimation was not possible because the original dataset was not available.

We first make a broad assessment of the specification of the DECC Model

The first part of the assessment consists of a high-level analysis of the specification of the DECC Model and its equations. Econometric analysis combines:

- economic theory: the relationships we believe, *a priori*, to be important
- measurement: the relationships that are found to fit the data we have, from a statistical point of view

The former is important in guiding the choice of candidate variables for inclusion in the equation (as well as for interpretation), while the latter is important in achieving a set of parameter estimates that both fit the data and have satisfactory forecasting properties.

The focus of this element of the assessment is on how the DECC Model's representation of UK energy demand is to be interpreted and whether there are factors that, *prima facie*, might be expected to be included but are not. These issues are covered in Section 4.1, drawing on existing empirical studies of energy demand.

Re-estimation of the DECC Model equations was not possible

As part of the assessment, we would ideally have re-estimated a number of the model's equations, to test alternative specifications. However, it emerged that the original dataset used for estimation was no longer available, preventing re-estimation. DECC is currently in the process of compiling a new dataset for in-house re-estimation.

Access to the dataset would have permitted re-estimation of the equations and allowed the following to be re-assessed in the light of new data:

- the suitability of alternative specifications to test:
  - alternative variables eg an alternative to the time trend treatment of energy efficiency

  - additional variables eg price effects in the industrial aggregate energy demand equations
- asymmetry in responses eg whether the size of the response to price varies depending on whether prices have increased or decreased eg 'ratchet' effects[6]
- parameter constancy ie whether the relationships estimated are stable over time or if the equation results obtained are actually specific to the sample period (not stable)
- statistical tests for outliers or structural breaks in the series that, if not accounted for, can lead to equation misspecification and forecast error

Where possible, we attempt to address these issues in other parts of the assessment:

- testing for alternative and/or additional variables is addressed more qualitatively in the review of the model's equation specifications (Section 4.1)
- asymmetry in responses is also addressed more qualitatively (Section 4.1 and to some extent Section 4.2)
- the possibility of outliers or structural breaks is dealt with in the treatment of forecast errors (Section 4.2)

The existing responses in the DECC Model are then assessed

After assessing the specification of the DECC Model, we consider:

- the effect of the input assumptions on the energy demand projections
- how new data are incorporated into the DECC Model projections, and the possibility of systematic forecast error (and how it might be dealt with)

The focus is on how the DECC Model projections change given the assumptions fed in and the (existing) specification of the model. We considered three vintages of projections, published in 2008, 2009 and 2010.

The successive incorporation of new data allows the short-term properties of the model to be examined

The 2009 and 2010 projections incorporate information additional to that in the first 2008 run. This is summarised in Table 3.2.

In terms of the short-term forecasting performance, both the 2008 and 2009 runs contain outturn energy demand data up to 2007[7]; the difference is that the 2009 projection includes economic outturn data for 2008 and accounts for a recession in its economic forecast assumptions. The inclusion of these in the 2009 run would be expected to alter the energy demand projections for 2008 and 2009 so that they more closely resemble the figures in the 2010 run, which contains energy outturn data for these years. The extent to which the forecasts move closer to the outturn energy demand figures gives an indication of how well the DECC Model incorporates more recent data and assumptions.

---

[6] A 'ratchet' effect refers to an effect that tends to move in one direction, but not the other, because the key influence is the previous highest (or lowest) value of a particular explanatory factor. It is an asymmetric response.
One example of this stems from the idea that energy is typically consumed via the capital stock, which is typically long-lived. Increases in energy prices may prompt investment in energy-saving technologies. Should energy prices fall, these energy savings are locked into the capital stock and generally not reversed. Energy demand does not necessarily rise back to the levels seen before the price increases.

[7] A small number of historical series appear to have been updated slightly in the 2008 run. The differences of note are:
- a downward revision in gas consumption by the public sector
- slight revisions to road transport demand, although the differences in the totals for the sector are small

The difference in total UK energy demand in 2007 between the 2008 and 2009 runs is less than 0.1%.

Table 3.2: Key Features of the DECC Projections

KEY FEATURES OF THE DECC PROJECTIONS			
	Projection publication year		
	2008	**2009**	**2010**
Last year of economic data	2007	2008	2009
Last year of energy data	2007	2007	2009
Contains a recession?	No	Yes	Yes

The effect on the long-term projections is assessed in the context of changes to the input assumptions

In terms of longer-term forecasting performance, the model equations can be assessed in the light of the changes in the input assumptions and outturn data between runs and their effect on the energy demand projections. This part of the assessment analyses trends in the input and output variables, to identify the key features of the forecasts, but also involves replication of some of the model's equations, to explicitly decompose the contributions of each of the drivers (eg growth/recovery in output or energy-efficiency improvements) to the final estimates of energy demand.

The model's responses to the new data can thus be assessed to determine the nature of the forecast errors in the recession, as well as the implications for the longer-term projection. This analysis of changes between projections is covered in Section 4.2.

Systematic over or under-prediction in the recent history may justify adjustments to the forward-looking projection

The DECC Model industry energy demand equations were estimated by Oxford Economics (2008c) using data up to 2004. This re-estimation work included an assessment of the equations' out-of-sample forecasting properties, which were considered satisfactory at the time.

Since that re-estimation work was carried out, new outturn data have become available that are beginning to cover the recession period; the span of the out-of-sample period has increased.

Drawing on the work to replicate some of the model equations (from the previous assessment method, see above), the *ex-post* forecast errors of the equations can be assessed, including over the recession period. The main focus of this part of the assessment is to identify evidence of systematic over or (less likely) under-prediction in the equations during this time, that may be indicative of a persistent shock to future energy demand ie a structural break. If this is found to be the case, then there may be grounds for adjusting the forecast values to account for this (in contrast to DECC's existing treatment of such errors, which assume no systematic bias), prior to an exercise to re-estimate the equations to take account of the later outturn information.

Section 4.2 examines the equations' year-by-year forecasting performance in the later part of the historical period, to see if there is evidence of such bias. The effects of an alternative 'residual treatment' to account for this are then discussed.

The final part of the assessment considers how the input assumptions themselves are formed

The previous two elements of the assessment examine the DECC Model's specification and its responses given that specification. In the final part of the assessment, we consider the input assumptions themselves:

- DECC's method for constructing sub-sectoral GVA forecasts for industry
- how retail price projections are formed from DECC's wholesale fossil fuel price assumptions

Forecasts of sub-sectoral industry output growth are derived from more aggregate official projections

Official UK Government projections form the basis of the economic forecasts that underpin the DECC Model's energy projections. However, some further processing is required to obtain a set of assumptions in the detail needed for the DECC Model. Specifically, the projections of UK manufacturing GVA must be disaggregated to the level of detail of the industrial sub-sectors identified in the model. The methods to form these GVA projections are reviewed in the following chapter.

Moreover, we understand that regular official forecasts of UK manufacturing GVA will soon be discontinued. Our recommendations on how the sub-sectoral assumptions are formed bear this future development in mind.

The relationship between wholesale prices and the retail prices of energy may have changed in the recession

Another key set of assumptions that underpin the DECC Model forecasts, which also change between the three sets of projections supplied to the CCC, are the assumptions for fossil fuel prices. As Bowen et al (2009) note, the 2009 recession differs somewhat from other post-Second World War recessions in that it was not precipitated by a sharp rise in commodity prices (such as oil), nor by government policies to combat inflation. Instead, while commodity prices, particularly oil, rose prior to the recession, during the downturn they fell substantially.

The nature of forward contracts on commodity purchases, combined with the sharp changes in global prices, suggests that the extent to which changes in wholesale prices are reflected in the retail prices faced by end users (price pass-through) may differ in a recession, and possibly thereafter. This is examined in Section 4.3.

3.3 Overview of the projections

Three sets of projections have been provided to the CCC from the DECC Model

To date, three sets of projections have been provided by DECC to the CCC for reporting purposes, at approximately one-year intervals. In this report, we refer to each run by the year in which it was published (in both this current assessment but also in the alternative projections presented in Chapter 5). Table 3.2 notes the last years of historical economic and energy outturn data incorporated into each projection, as well as whether or not the economic forecast embodied a recession.

The key inputs to the DECC Model are:

- economic activity
  - GVA for industry sub-sectors
  - employment for services (derived from GVA forecasts)
  - household income
- fossil fuel prices

The profiles of each of these sets of assumptions, and how they vary by projection, are discussed below.

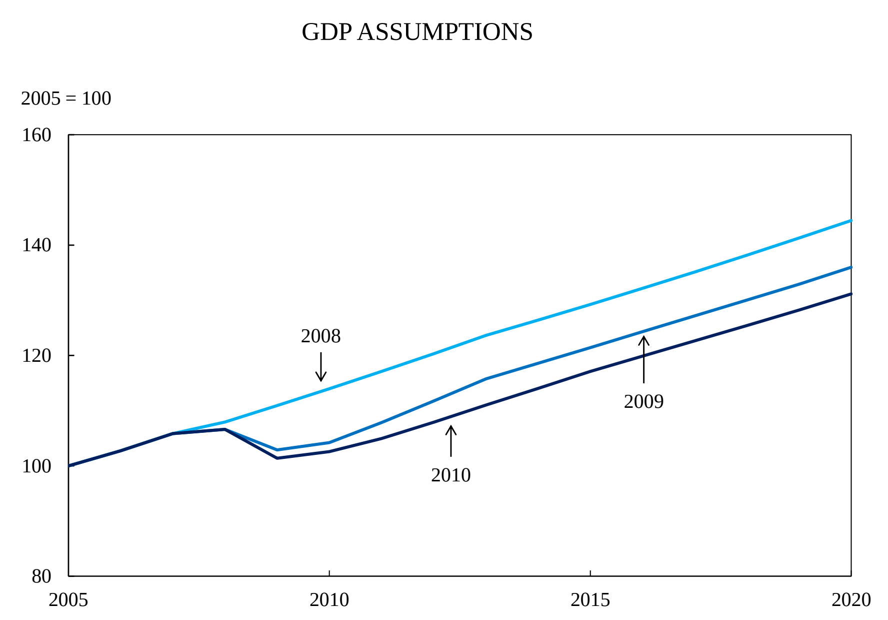
Long-run economic growth is similar across the three runs, differing only in the impact of the recession on the long-run level

The earliest projection was produced in 2008, for the CCC's inaugural report (CCC 2008). This projection contained outturn economic data up to 2007 and did not include a recession in its forward-looking economic growth projections. The economic forecast follows a 'business-as-usual' trajectory, and UK GDP settles on a steady growth path of 2¼-2¾% pa over the medium-to-long term (see Figure 3.1).

By the time of the 2009 run, the global downturn had become apparent and the UK economic growth forecast was revised to take account of outturn data indicating slower economic growth in 2008. UK GDP is projected to fall substantially in 2009, by 3.5%. Modest positive growth is projected for 2010, followed by a period of higher growth over 2011-13. In the 2009 run the recession leads to a substantial loss of output, but some of the output is recovered in the period of above-trend growth. Trend growth prevails thereafter; the recession does not affect long-run UK economic growth.

The 2009 recession proved even more severe than forecast, with GDP falling by 4.9%. This is reflected in the last of the runs, the 2010 run. The projection for growth in 2010 in this latest run is similar to that in the 2009 run. In this most recent run, the medium-term forecast is for economic growth below that in the 2009 run over 2011-13. Long-term GDP growth is identical between the 2009 and 2010 runs. In the 2010 run, the recession leads to a permanent loss of output and, in contrast to the 2009 run, none of this lost output is recovered.

Figure 3.1: GDP Assumptions



Source(s): HM Treasury, DECC.

In the long run, household income in the three projections keeps pace with GDP

Growth in real household disposable income in the 2008 run keeps pace with GDP growth in the long term, at 2¼-2¾% pa. Income per household grows at a lower rate, 1¼-1½% pa; the rest of the growth comes from the general increase in population over time.

Compared to the 2008 run, the 2009 run has been updated with a fall in real household disposable income in 2009, consistent with the Budget 2009 forecast. Modest growth in 2010 (less than 1%) is followed by a period of higher growth consistent with the growth in GDP over 2011-13 (the period of economic recovery). Trend growth then resumes.

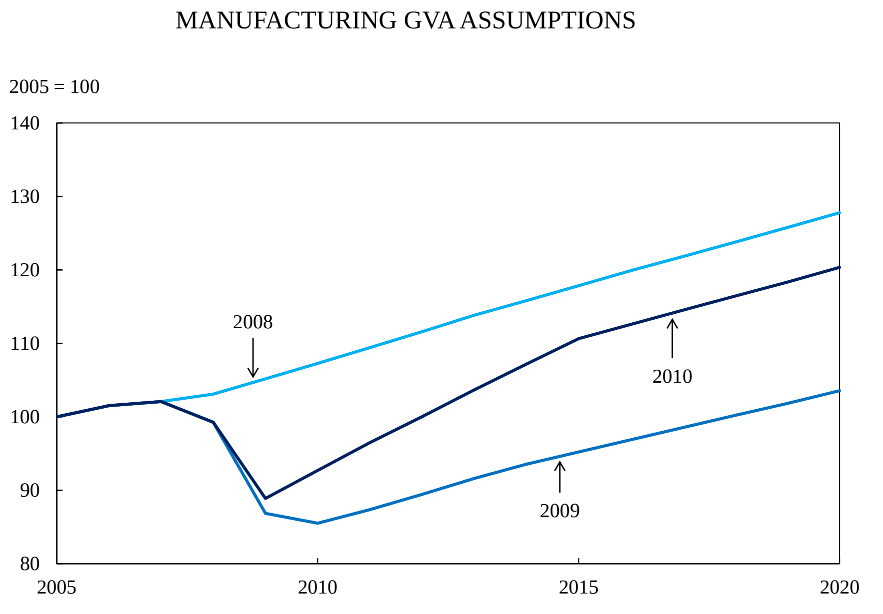
In contrast to the HM Treasury forecast in the 2009 run, more recent outturn economic data indicate that real household disposable income actually rose in the recession. This development is reflected in the 2010 projection. As with the previous projections, in the long term, income growth follows GDP growth. The growth profile in the short-to-medium term shows a gradual increase in growth until the trend resumes.

In contrast to the GDP profiles, a recovery in UK manufacturing is projected in the 2010 run, but not in the 2009 run

The assumptions for UK manufacturing GVA growth in the 2008 run follow a similar business-as-usual trend to the corresponding GDP assumptions, although the contribution of manufacturing to UK economic growth is projected to decline over time. Manufacturing GVA grows by 2% pa in the short term, slowing to 1.5% pa in the long term (see Figure 3.2).

In the 2009 run, the decline in manufacturing GVA in 2009 is projected to be severe, at -12.5%. The projected growth profile of UK manufacturing does not include a period of recovery (in contrast to the higher growth seen in the GDP projection) and trend growth resumes from this lower level. A permanent loss in manufacturing output is forecast in the 2009 run, with the difference in the level explained by the decline in output in 2009 and a further, smaller decline in 2010.

Figure 3.2: Manufacturing GVA Assumptions



Source(s): DECC.

While the 2009 projection is characterised by a faster recovery in GDP growth but a permanent loss in manufacturing GVA, the 2010 projection has a relatively more modest recovery in UK GDP but a stronger post-recession recovery in manufacturing GVA. In the 2009 run, manufacturing GVA declines further in 2010 before trend growth resumes. In contrast, in the 2010 run manufacturing GVA grows in 2010, by 4.3%. A further five years of high manufacturing growth follow before returning to the long-term profile seen in the previous years' runs.

Of the three runs, long-term energy demand is projected to be highest in the 2008 run, the run without a recession

The 2008 and 2009 runs contain outturn energy data (derived from *DUKES 2008*) up to 2007. The 2010 run has been updated with a further two years of data from *DUKES 2010*; 2009 is the last year of outturn in the most recent run.

In the historical periods of the 2008 and 2009 runs, UK final energy demand falls over 2005-07 (see Figure 3.3). A further fall in 2008 (the first year of projection) is projected by the DECC Model in the 2008 run, driven by reductions in demand from households, services and private road transport, and the industrial sectors Chemicals and Other Industry.

In the 2008 run, the DECC Model projects energy demand to be flat in 2009 and 2010 with modest growth thereafter, of around 0.5% pa, slowing to 0.2% pa by 2020. Long-run growth in energy demand is driven by aviation, road transport and commerce; these increases outweigh the demand reductions seen in households and public services. Energy demand from industry as a whole increases, but there is a shift in emphasis, away from energy-intensive production (particularly Chemicals) and towards sectors such as Food, drink & tobacco and Paper, printing etc.

Long-run energy demand is lowest in the 2009 run

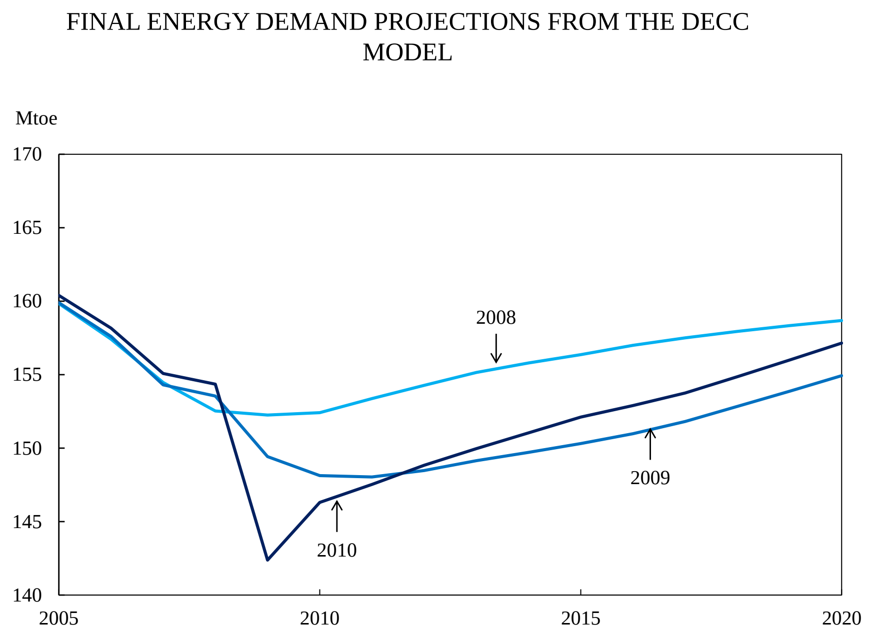
The energy data were not updated in the 2009 run; the last year of history remains 2007. We would expect the updated, more pessimistic, economic forecast to lead to lower energy demand in the short term when the 2008 and 2009 runs are compared.

In the short term, the negative income elasticity for households leads to slightly higher energy demand in the 2009 run

Figure 3.3 shows that UK final energy demand in 2008 is actually higher in the 2009 run than it is in the 2008 run (although the projection is still of a decline in demand). The increase comes from (relatively) higher household energy demand (for gas and electricity) in the 2009 run in this year. This is the result of lower real household disposable income in this run and the negative income elasticities in the gas and electricity demand equations (see Section 3.1); a decrease in household income, all other things being equal, leads to an increase in energy demand. This effect persists into the long run and household energy demand in the 2009 run is above that in the 2008 run.

UK final energy demand in 2008 excluding households in the 2009 run is below that in the 2008 run. The short-run impact of the recession can be seen in the sharp decline in demand in 2009. Final energy demand falls slightly for a further two years before growing once more, from 2012 onwards. Post-recession growth in the 2009 run is similar to long-run growth in the 2008 run and actually accelerates slightly from 2017. This mirrors the slightly higher GDP and GVA growth assumed in the 2009 run in this period.

Figure 3.3: Energy Demand Projections from the DECC Model



Source(s): DECC.

The new outturn data show a sharp fall in final energy demand in 2009

The energy demand data have been updated in the 2010 run and Figure 3.3 shows, quite strikingly, the effect of the recession on energy demand, a fall in final energy demand of almost 7% in 2009 (the last year of data).

At the aggregate level, the economic activity assumptions for this run show:

- no recovery in GDP (a permanent loss of output, in contrast to the 2009 run)
- a recovery in GVA (as opposed to the permanent loss in the 2009 run)

Total energy demand over the projection period mirrors the GVA profile more closely than the GDP profile. Following the sharp fall in 2009, there is a strong recovery in final energy demand, of almost 3%. Growth from 2011 onwards is steady, at ¾-1% pa to 2020.

As with the other runs, energy demand within industry decreases (overall) in the energy-intensive industries, and increases in others. The largest reductions in energy demand over the period are seen from energy-intensive industries (notably Chemicals), Other Industry, and households. Growth in energy demand is driven by aviation, non-energy intensive industries and commerce.

Energy demand falls in the historical period and grows modestly in the 2008-run projection period, in contrast to a downward trend in UK emissions

Over the projection period of the 2008 run, UK emissions (summed across all sectors) generally fall, in contrast to the growth in energy demand projected over the same period. Fuel switching in energy demand from non-transport final users favours electricity over fossil fuels and direct emissions from industry and households contribute most to the reductions in final user emissions when 2020 is compared against 2007.

Emissions from industry (as defined in the UEP classification) in 2020 are around 6.3% lower than the 2007 level due to fuel switching. The reduction in household emissions is substantial (15.7%), principally as a result of the energy-demand reductions, and is compounded by fuel switching.

The largest contribution to UK emissions reductions is projected to be power generation

Fuel switching in final energy demand, towards electricity, reduces the emissions intensity of final users and, for a given amount of total energy consumption, direct emissions fall. However, a greater dependence on electricity raises primary energy demand from the power sector. With respect to climate change targets, shifting final demand from fossil fuels to electricity shifts the emissions-reduction burden to the power sector.

Despite higher final electricity demand, emissions from power generation fall over the projection period, by more than 30%, indicating substantial decarbonisation. Power generation contributes the most to UK emissions reductions by 2020. Generation from coal falls substantially after 2015 (when a number of plants are due to close, under the conditions of the EU Large Combustion Plant Directive) and is replaced with gas and renewables. Renewables capacity in particular grows substantially, a more than five-fold increase on the 2007 level by 2020, by assumption to meet the RED.

The recession in the 2009 run leads to a sustained fall in UK emissions, but the gap between the 2008 and 2009 runs closes in the long run

The reduction in economic activity in the recession, at the UK level, leads to a marked reduction in emissions in the short term of the 2009 run. This run projects an 8.5% reduction in emissions in 2010 compared to 2007 (the last year of data). Among the final users, direct emissions from industry and road transport fall the most in this period. Power sector emissions also fall markedly as a result of lower total electricity demand.

There is a slight increase in emissions in the 2008 run, in 2011, and the increase is larger in the 2009 run owing to the higher economic growth assumed post-recession. As in the 2008 run, there is a general fall in emissions thereafter. However, the long-run decline in emissions is slower than in the 2008 run and by 2020 the levels of emissions barely differ between the two runs (see Figure 3.4).

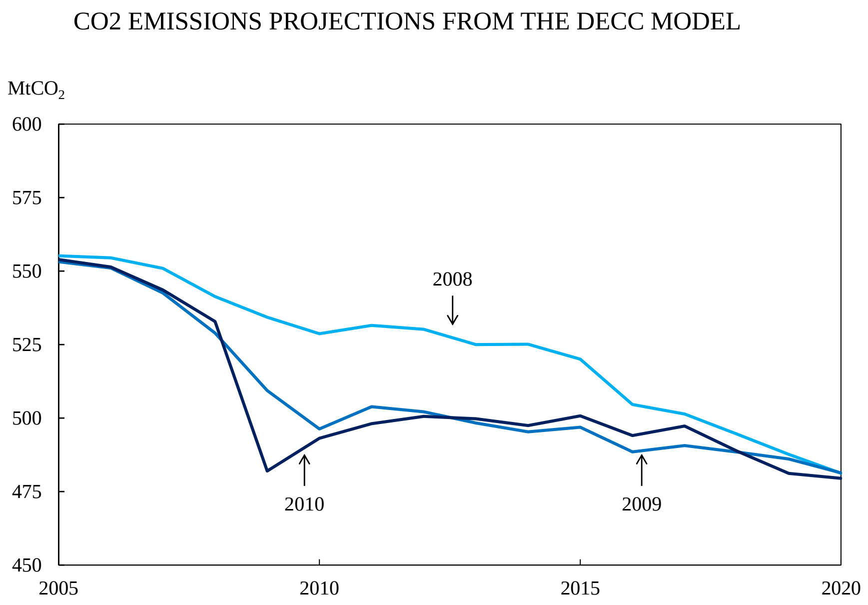
Households and road transport contribute most to the end-user emissions reductions in the 2009 run

As in the 2008 run, in the longer term, households contribute substantially to end-user emissions reductions, although the reductions by 2020 are smaller in the 2009 run. This result arises from lower household income in the 2009 run relative to the 2008 run and the negative income elasticities in the energy demand equations.

In contrast to the 2008 run, industry emissions are little different in the 2009 run between 2007 and 2020. Emissions from road transport are lower in 2020 compared to 2007 in the 2009 run, whereas in the 2008 run there is little difference.

In the 2009 run, industrial emissions fall in the recession, driven by the fall in energy demand. Energy demand grows steadily thereafter, driving emissions growth back to the 2007 levels, although, strangely, energy demand in 2020 remains below the 2007 level. This indicates an increase in the carbon intensity of industry, that we were

Figure 3.4: CO2 Emissions Projections from the DECC Model



Source(s): DECC.

unable to match to the final energy demand projections from the DECC Model; the changes in the fuel shares imply a cleaner fuel mix. This is explained by an adjustment for CHP, since industrial CHP increases substantially in this run. However, the energy use for CHP is not reported in the DECC Energy Model outputs, nor are CHP emissions explicitly reported, despite being aggregated to industrial emissions.

In the 2009 run, emissions from road transport are lower in 2020 than in 2007, contributing to the overall emissions reduction. Emissions do rise over the projection period, but the recession causes a sharp drop in fuel demand and emissions in the short term, that is not fully recovered from in this run.

Higher gas prices in the 2009 run discourage gas-fired power generation

As in the 2008 run, coal is less prominent in the generation mix by 2020 while electricity from renewables increases substantially. Interestingly, while gas-fired capacity increases over the projection period in both the 2008 and 2009 runs, the amount of electricity generated from gas in the 2009 run is lower in 2020 than in 2007; in the post-recession period, generation from gas falls. In the 2008 run, gas generation increases over the projection period; it is higher in 2020 than in 2007. Assumptions of higher wholesale gas prices in the 2009 run explain this difference, discouraging generation from gas (relative to other sources) owing to higher costs.

As in the 2008 run, there is substantial decarbonisation in power generation. The shift to cleaner fossil fuels (gas over coal) and renewables leads to a substantial reduction in emissions from this sector.

In the 2010 run, end-user emissions reductions come from industry, road transport and households

In the 2008 run, the largest contributions from final users to the overall emissions reductions came from households and industry.

In the 2009 run, households continued to contribute to the emissions reductions, albeit less than in the 2008 run due to the income effects in the DECC Model. By 2020, industry emissions were not much different to the 2007 level; industry did not contribute to the 2020 reductions in the 2009 run. Instead, emissions reductions were seen in road transport; energy demand and emissions did not recover to their pre-recession levels.

In the 2010 run, households continue to contribute to the emissions reductions, but emissions in 2020 are higher than in the 2008 run, for the same reasons as in the 2009 run. Of the three runs, emissions from road transport are lowest in the 2010 run (fuel demand is correspondingly lower).

Emissions from industry in the 2010 run are lower in 2020 than in 2007. This is in contrast to the 2009 run (industry emissions recover to the 2007 levels) but similar to the 2008 run. Comparing the level of emissions in 2020 between the 2010 run and the two previous runs is complicated by the fact that the historical emissions series (by the UEP categories) have been updated; industry emissions in the 2010 run are higher in the history than in the previous two runs. Applying the growth rates from the 2010 projection to the historical emissions data in the older runs suggests that, had the starting points been the same, emissions from industry in the 2010 would have been below the levels in the previous two runs in 2020.

Differences in the emissions reductions from industry in the 2009 and 2010 runs cannot be explained by the DECC Model results explicitly

While industry emissions (once the differences in the levels are accounted for) are the lowest in the 2010 run, the level of energy demand is in the middle of the three runs; energy demand from industry is lowest in the 2009 run. This could be explained by a less carbon intensive fuel mix (ie a shift from fossil fuels to electricity), but such an explanation is not supported by the DECC Model results. Demand for fossil fuels in 2020 is higher in the 2010 run than in the 2009 run. However, CHP output is much lower in this run compared to the 2009 run and while emissions and fuel use are not explicitly stated, emissions from industrial CHP are attributed to industry emissions. This seems to explain lower industrial emissions in the 2010 run compared to the 2009 run but it is by no means clear from the available projections detail and the documentation for the modelling framework.

The evolution of electricity capacity does not differ much between the 2009 and 2010 runs and the fuel mixes are broadly similar.

The DECC Energy Model provided a reasonable forecast for 2010, but the sub-sector projections show both large under- and over-predictions

Overall, the 2010 run does not compare particularly well against the DUKES data for 2010 (the first period of forecast). Although aggregate final energy consumption was forecast to increase only slightly less than it did (2.9% compared to 4.7%) the sector composition was quite drastically different from the actual data. For the most part the DECC Energy Model over-predicted energy consumption, and emissions, but this was offset by a large under-prediction in households because of the abnormally cold weather in 2010.

The under-prediction of households is reasonable since future temperatures are hard to predict, however, it could have possibly been improved by the inclusion of quarterly energy data and monthly temperature data. This under-prediction is the main reason DECC has under predicted total final energy demand.

For industrial sub-sectors, much smaller energy users than road transport or households, the DECC energy model widely over-predicted energy consumption with the exception of Chemicals and Mineral products which were under-predicted. The most interesting factor is the size of the discrepancy with the data which is over 10pp for many industrial sub-sectors. This is a result of over-prediction in the sample period, and an abrupt reversion to this long term over-prediction by removing the residual error, rather than allowing it to persist.

Road transport consumption was forecast with reasonable accuracy; although the DECC Energy Model did over-predict energy consumption growth by 1pp: road transport energy consumption is usually quite stable (and therefore predictable).

Without the under-prediction in households, final energy demand would have been over-predicted by about 2.5pp. The model is therefore suggesting a short term response to the recovery from recession which is stronger than the response seen in the recent data. Although this analysis only considers aggregate energy consumption and not CO2 emissions, it is reasonable to assume that the model also over-predicted emissions in 2010, with the exception of households.

Table 3.3: Comparison of DECC 2010 Energy Demand Estimate with DUKES data

COMPARISON OF DECC 2010 ENERGY DEMAND ESTIMATE WITH DUKES

Sector	DECC estimate 2009-10 % growth	DUKES (%) 2009-10 % growth	Difference (pp)
Industry			
Non-ferrous metals	11.9	3.9	8.0
Engineering and Vehicles	6.6	1.9	4.7
Mineral products	-23.4	2.2	-25.6
Chemicals	-11.9	4.1	-16.0
Food, beverages etc	20.0	6.6	13.4
Textiles, leather etc	22.9	0.7	22.2
Paper, printing etc	15.8	3.0	12.9
Construction and Other	16.4	3.8	12.6
Unclassified	14.6	1.8	12.8
Transport			
Air	4.1	-3.6	7.8
Rail	-1.6	0.3	-1.9
Road	1.4	0.4	1.0
Other			
Domestic	0.9	12.6	-11.7
Public Admin	5.1	0.4	4.7
Commercial (inc misc)	6.2	4.8	1.4
Agriculture	4.2	10.7	-6.5
Total (of sectors shown)	2.9	4.7	-1.8

Source(s): DECC Energy Model, DUKES 2011.
Note(s): Sectors in DUKES have been aggregated to match the DECC Energy Model outputs. Figures show the percentage growth in aggregate energy demand for each sector. The final column shows the percentage point difference between the two.

4 The Impact of the Recession in the DECC Model

This chapter presents our assessment of the DECC Model

In this chapter we present our assessment of the DECC Model, using the approach outlined in Chapter 3. This chapter examines, in turn:

- the model's specification/parameterisation (Section 4.1)
- the forecasting properties of the model – its outputs given its inputs (Section 4.2)
- how the model's input assumptions themselves are constructed (Section 4.3)

Recommendations for future development based on the assessment of the above can be found in the final section of this chapter (Section 4.4).

4.1 Assessment of the DECC Model's specification

We begin with a high-level assessment of the DECC Model's specification

In this section we carry out a high-level assessment of the equations and structure of the DECC Model, commenting on their specification as well as pointing out features or characteristics that may be worth revisiting or merit more consideration when the equations are re-estimated (DECC is already in the process of assembling a new dataset in readiness for re-estimation).

As mentioned in Section 3.1, the key variables in the DECC Model equations are:

- economic activity
- retail fuel prices faced by final users (generally in the fuel-share equations, rather than the aggregate equations)
- a time trend term to capture other effects, such as increases in energy efficiency

The car-fuel demand equation includes car ownership as a stock variable and the household equations include terms for gas central heating uptake and winter temperatures.

The DECC Model cannot, by itself, account for large-scale changes in economic structure…

In some sense, the DECC Model industry equations are able to capture permanent losses of industrial demand/output (eg from a recession) and changes in economic structure, insofar as they are reflected in the GVA projections (see Sections 4.2 and 4.3 for further discussion of this).

However, the example given in Section 3.1, of how the effects of carbon taxation might have economic implications (and, in turn, on the drivers of energy demand) is not captured in the DECC Model owing to the one-way nature of information flows from the economic forecasts through to the energy demand projections.

Other policies that stimulate the adoption of energy efficiency measures will be expected to have similar impacts on supply chains. Energy efficiency measures will tend to alter industries' per-unit energy demand. This in turn alters unit costs and may, depending on the nature of cost pass-through (linked to the level of competition in the industry), lead to changes in output prices which may change demand and industry output. The effects of new energy efficiency measures in one industry have implications both:

- upstream
  - changes in demand for energy-sector production

  - possible substitution between other inputs to production (affecting other industries' output)
- downstream
  - changes in demand from other industries for their own production (setting off further rounds of indirect effects, including on energy demand)
  - changes in final demand

From the above, the impacts of energy-savings in one industry can have economy-wide effects. The DECC Model is not able to capture these directly; instead, they must be accounted for in the economic assumptions that feed into the model (provided by/derived from HM Treasury).

A conclusion that could be drawn from the example (and that is supported by other studies on what a low-carbon or 'green' economy, that generates lower emissions, might look like eg European Climate Foundation 2010[8]) is that as-yet unprecedented *large-scale* decarbonisation and climate change mitigation action could lead to very substantial changes in economic structure driven by changes in the energy system, that are really only captured in the DECC Model by assumption.

...although developing this mechanism is likely to be resource-intensive

Other potential characteristics of a low-carbon economy include:

- the future evolution of UK generation capacity and the penetration of low-carbon technologies
- switching to CHP, which operates at a higher efficiency
- energy savings from policy impacts

The above feed into the DECC Model either by assumption (electricity-generation capacity[9], energy savings) or are formed by a separate model (CHP) and are effectively exogenous to the energy demand projections. Consequently, particular care must be taken in forming a consistent set of inputs when analysing low-carbon pathways and other scenarios of large-scale changes in economic structure.

Perhaps the obvious solution is to develop a more integrated model or modelling framework in which all the energy (including CHP and policy impacts) and economy systems (to account for structural change) are inter-related. Such a framework enforces consistency between the elements of the modelling system. To some extent, the DECC Model already embodies this approach, in the way it combines a top-down energy demand model with a bottom-up, optimising electricity supply model. A more modular framework would allow for new sub-models to be integrated (and enabled or disabled as required). However, as will be seen from the analysis of wider modelling approaches (see Chapter 5), such tools have proven costly to develop and maintain. The modelling system will also become more complex and checking results and tracing errors will inevitably become more time consuming and costly in terms of resources.

[8] As an example, modelling results from this study cite construction and mechanical engineering as examples of sectors in which employment might rise to support the adoption of energy efficiency measures. Higher output from these sectors will tend to raise energy demand; if the emissions-reductions achieved elsewhere are insufficient to meet climate-change targets, these sectors may also need to decarbonise.

[9] The DECC Model does project new build, although some future capacity is imposed, such as renewables (under the assumption that the Renewable Energy Strategy is met) and new nuclear plant.

The negative income elasticities for road transport and household energy demand are counterintuitive

The Oxford Economics (2008a) review identified (admittedly small) negative income elasticities for energy demand from road transport and households. While a number of possible reasons for the negative values were put forward (see Section 3.1), the parameter estimates were considered to be counterintuitive and possibly indicative of a missing variable, or the need to include a term to separate income effects on energy demand from income effects leading to the adoption of energy efficiency measures. Indeed, Oxford Economics (2008b) estimated an alternative set of energy demand equations for households that was considered statistically satisfactory and did not have negative income elasticities, but these were not incorporated into the DECC Model.

We agree with the Oxford Economics assessment that the negative elasticities are counterintuitive and believe that further investigation is warranted if negative elasticities are found during the forthcoming round of re-estimation.

A more theory-based treatment of energy efficiency would be worth considering

The time trend term in the equations to represent energy efficiency is difficult to interpret from a theoretical point of view, because these efficiency gains take place regardless of movements in economic variables and have no economic explanation within the framework of the model (this will be discussed further in Section 4.2).

This atheoretic time-based trend in energy efficiency could conceivably be explained by a number of factors not limited to:

- changes in the composition of industry products, favouring less energy-intensive goods
- changes in product quality
- ‘true’ efficiency through technological improvements
  - as mentioned in Chapter 2, in the industry as a whole, these may arise from the closure of less efficient plant (possibly accelerated in the recession) or, potentially, be slowed as a result of lower investment
- econometrically, the trend could be picking up influences not accounted for anywhere else in the equation

Without quantifying the impact of the individual factors, the overall effect of the above is ambiguous, whether or not there is a recession, and the current treatment could lead to either over or under-estimates of energy demand since it fails to explicitly capture improvements in the capital stock and its relationship with economic activity, as a key driver of energy efficiency.

Our recommendation is to at least consider the use of a more theory-based treatment of energy efficiency. One possibility is a term to track cumulative investment, to represent the stock of capital in the economy. This will naturally have slowed in the recession. However, we do accept that a practical constraint on introducing any new terms to the equations is that it must be feasible to project these values into the forecast period. If the variable cannot be feasibly projected, for whatever reason, then it is of little practical use.

The absence of price terms in the aggregate demand equations is surprising

We find it somewhat surprising that energy prices do not feature in the industry aggregate energy demand equations. The Oxford Economics (2008c) review does indicate that the significance of price effects was tested as part of the re-estimation work at the time but that the terms were not found to be important. More detail on price effects is provided in Section 4.3, which also points to some academic literature that suggests that prices may be significant in determining energy demand and, as with the negative income elasticities and the time trend, we would suggest that this be revisited in the upcoming re-estimation work that DECC is due to carry out.

The treatment of policy impacts is suitable, as long as it can be argued convincingly that the dataset does not include any policy effects

The current treatment of policy impacts is to use the equations in the DECC Model to project energy demand 'before policy'. The rationale for this is that the sample period of the estimation dataset goes up to 2004, before any substantive energy-efficiency policies were introduced[10]. Proving definitively that the data in the sample period used does not include *any* policy impacts is difficult[11]. However, if it can be argued convincingly that the sample does not include policy impacts, or that they are not large enough to be significant, adding in estimated policy impacts (derived by DECC off-model) to the raw DECC Model projections seems reasonable.

The advantage of DECC's current approach to including policy is that it separates clearly the underlying energy demand from the policy impacts.

The alternative to the off-model adjustments is to model the policy mechanisms directly in the DECC Model. However, not all policies are straightforward to model and the DECC Model would likely have to be developed further to account for some.

Policies that target energy prices directly are straightforward to implement in the DECC Model framework, as an increase in energy prices[12]. Other policies are not necessarily so straightforward to implement.

For example, the boiler scrappage scheme would ideally be modelled as turnover in the stock of household heating appliances. This would require a representation of the UK housing stock and a model of household investment decisions, which are only just being developed, for the UK National Household Model. Similarly, there is no obvious way to include the effect of feed-in tariffs directly in the DECC Model without a model of technology specific household investment. However, as part of a longer term model development strategy, DECC should consider the implementation of (bottom-up) technology specific models.

The current, restricted, sample period excludes the information emerging about the recession

A drawback of restricting the sample period is that around five years of new data (2005-2009) are being ignored (including data in the recession) that may provide additional information.

DECC is preparing to re-estimate the equations in the model using the longer sample period now available. We also recommend that the equations are re-estimated more regularly. This will be useful in assessing the properties of the equations and detecting shocks and structural breaks. This is discussed in more detail in Section 4.2, in the analysis of forecast errors.

Extending the sample period will require adjusting the new years of data to account for policy impacts

However, if the existing treatment of projecting energy demand 'before policy' and adding in the policy estimates to the equation results is to be retained, then the sample data from 2005 onwards must be adjusted to exclude policy. Accounting accurately for these policy effects is critical if the extended sample period is to be used, because it has implications for the constructed data to be used for estimation. There is a risk that the new parameters obtained will be heavily influenced by the estimated policy

---

[10] The Oxford Economics (2008c) re-estimation of the industry energy demand equations intentionally excluded 2005 and 2006 from the sample owing to these policy impacts, stating that the effects of the policies were uncertain.

[11] See, for example, CE et 2005 that includes some analysis on the possibility of 'announcement effects'; that the anticipation of a policy may have effects before the date of implementation.

[12] Although currently, prices responses are absent in a number of DECC Model equations.

effects. Uncertainty around the estimates of the policy impacts is inevitable and it would be useful to carry out a sensitivity analysis of the parameter values to alternative levels of policy effectiveness.

The parameters currently in the DECC Model were estimated on data over the period 1980-2004. Later years of data are to be included in the sample for re-estimation (once adjusted for policy impacts) and, ideally, the sample would also be extended back to cover the 1970s, a period of higher price variation that may help to identify price effects. The 1970s period was considered in the last round of re-estimation, but was dropped, possibly due to excessive price volatility from the oil-price shocks of the time. This may be bypassed with an estimation strategy that incorporates outlier and structural break detection.

Re-estimation provides an opportunity to re-examine the drivers in the DECC Model

Our assessment of the specification of the DECC Model can be summarised as follows:

- large-scale decarbonisation or other changes in economic structure must be reflected in a carefully constructed set of input assumptions
  - integration into a more complete framework with two-way linkages is possible, but may be prohibitively costly
- as pointed out in a previous review, the negative income elasticities are counterintuitive and are worth re-examining during re-estimation
- the treatment of energy efficiency is atheoretic and difficult to interpret
  - a theory-based explanation should be tested during re-estimation
- the absence of price effects in the aggregate energy demand equations for industry is surprising
  - the significance of these effects is worth revisiting
- re-estimation over a longer sample period is desirable, to include the 1970s (more price variation but also volatility) and 2005-09
- the treatment of policy impacts is suitable, but re-estimation over the extended sample (to include 2005-09) requires some data construction that may introduce additional uncertainty into the new parameter estimates; sensitivity analysis is recommended

4.2 Assessment of the DECC Model's forecasting properties

The focus of this section is on the DECC Model's projections of energy demand from industry

In this section we consider:

- the effect of the input assumptions on the energy demand projections
- how new data are incorporated into the DECC Model projections, and the possibility of systematic forecast error (and how it might be dealt with)

Short-term forecasting performance is assessed in terms of the extent to which the forecasts move closer to the outturn energy demand figures as more recent data and updated assumptions are incorporated.

The impact of changes in the data and input assumptions on the longer-term demand projections is also assessed. Trends in the input and output variables are analysed to identify the key features of the forecasts, and some of the model's equations are replicated to explicitly decompose the contributions of each of the drivers.

The data presented in this chapter represents a subset of our analysis to illustrate the points made in the assessment. The focus is principally on the industry projections, excluding iron and steel, although we make reference to findings from our analyses of households and road transport.

The evidence for systematic bias in the projections is mixed

The analysis is not complete in its coverage and it is difficult to conclude that the energy projections for the economy as a whole are systematically biased in one direction or the other. We were unable to replicate the equations for all industry sub-sectors but did find, for the group of sub-sectors we could analyse, some evidence of over-prediction in energy demand (and a possible risk of over-estimates of future emissions).

We were unable to replicate the energy demand equations for households but the effects of the counterintuitive negative income elasticities are evident in the projections. There are candidate explanations for the sign of these parameters (see Section 3.1) but if, as is generally accepted in the literature, income elasticities are in fact positive, then there may be upward bias in the household energy demand projections.

For road transport, again, we were unable to replicate the equations for all runs, but we find little evidence to suggest over or under-prediction in fuel demand.

A detailed assessment of iron and steel and CHP would have required more resources and assistance from DECC than could feasibly have been provided

The iron and steel sector both produces and uses fuels, such as blast furnace gas and coke oven gas, at different stages in the production process; these supplement its demand for primary fuels. This creates a number of dependencies between stages in the production process and affects both the sector's supply and demand for energy. Consequently, the treatment in the DECC Model is more complex than for other industries, with many more equations and interdependencies across equations. Analysing the DECC Model treatment of this sector would have required more resources and assistance from DECC than could feasibly be provided within the scope of this project. In any case, DECC is in the process of revising its modelling approach for iron and steel, and so it was decided that the sector would not be assessed in this project.

Projections of CHP capacity and generation have changed between DECC Model runs but, as with iron and steel, too much in the way of resources would have been required from DECC; we have not investigated CHP as part of this review.

This section also does not focus in any detail on the projections of energy demand from households and road transport. The outcomes and recommendations from assessing these sectors do not differ markedly from the conclusions drawn from analysing the industry sectors. Some remarks on the equations and the estimated parameters for these sectors were given in Section 4.1.

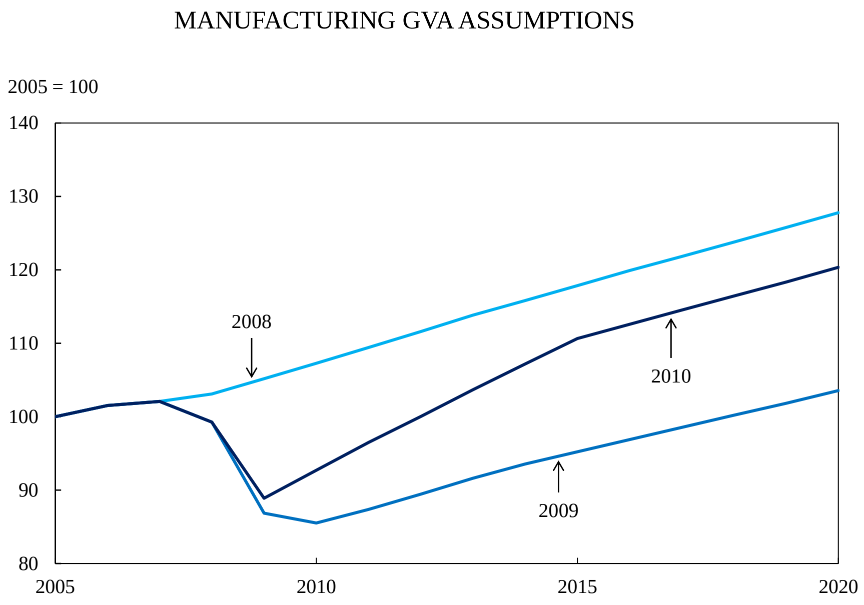
Further information from the assessment (covering other industry sectors not explicitly mentioned in this section, as well as road transport and households) can be found in Appendix A of this report.

From the previous chapter, the projections of manufacturing GVA used in the three runs are characterised as follows:

- 2008 run – steady, 'business as usual' GVA growth
- 2009 run – sharp decline in GVA followed by trend growth; a permanent loss in industrial output
- 2010 run – sharp decline in GVA, followed by a period of recovery (higher growth) and then a return to trend; some, but not all, of the lost output is regained in the medium term

We noted in Section 3.3 that the 2009 economic forecast implies a recovery (higher growth) in UK GDP, but the manufacturing forecast is the most pessimistic of the

Figure 4.1: Manufacturing GVA Assumptions



Source(s): DECC.

three DECC runs, with a permanent loss of output. In contrast, the 2010 forecast does not project such a period of recovery, although manufacturing GVA does recover somewhat. Evidently a stronger 'rebalancing' of the economy in favour of manufacturing is embodied in the 2010 forecast assumptions.

Figure 4.1 shows the growth profiles of manufacturing GVA in the three sets of economic forecasts that fed into the DECC projections, and these are reflected in the GVA projections for Chemicals in the DECC assumptions (see Figure 4.2). The analysis of Chemicals presented here illustrates the general finding for industry that energy demand depends on the rate of GVA growth and the time trend in the aggregate energy demand equations.

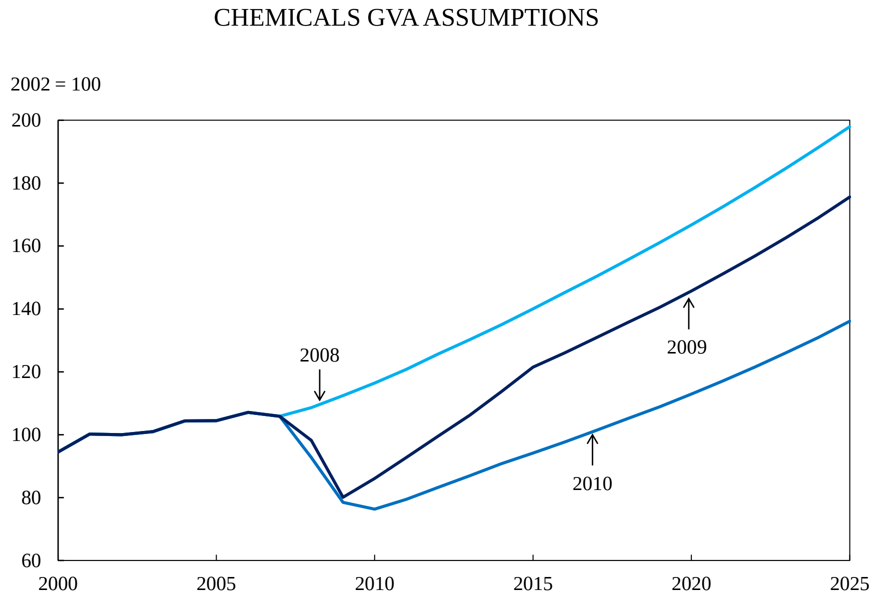
The pattern of revisions to assumptions for Chemicals GVA mirrors that for manufacturing as a whole

In the 2008 projection, Chemicals GVA growth is steady, at 3½-4% pa. After the recession, this trend growth prevails in the 2009 run, with a permanent reduction in the level of industry output. The 2010 run incorporates a projected economic recovery post-recession, with faster growth in the medium term before trend growth re-asserts itself. In the two most recent runs, the effect of the recession is assumed to be on the level, rather than the growth of output.

The level of Chemicals energy demand is determined by output and trend efficiency

Aggregate energy demand from Chemicals is driven by the assumptions for output, and a time trend. Like the majority of the industrial energy demand equations, energy prices do not affect the level of aggregate demand. The energy demand projections for this sector show the effect of output and the time trend quite clearly (see Figure 4.3).

Figure 4.2: Chemicals GVA Assumptions



Source(s): DECC.

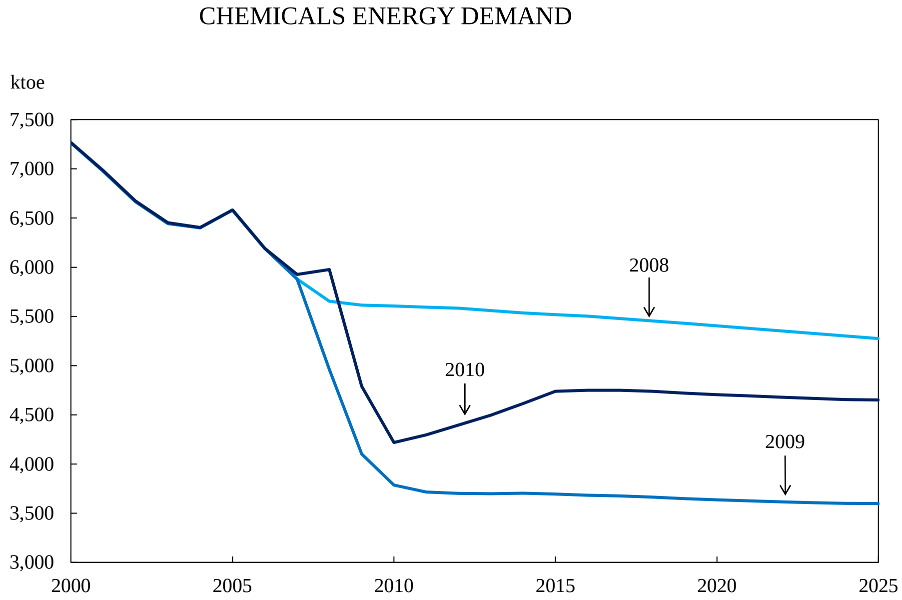
In terms of the short-term forecasting performance, energy demand from Chemicals is projected to fall in 2008 in both the 2008 and 2009 runs. In the case of the 2008 run, this fall occurs even though GVA is forecast to grow in 2008. When decomposed, this result is driven by the energy efficiency implied by the time trend term, which outweighs the effect of the output growth. The fall in GVA in the 2009 run in that year exacerbates the fall in the energy demand that the DECC Model projects, even without a recession; lower activity in the recession leads to lower production and lower energy demand, relative to the 2008 business-as-usual projection.

However, the outturn data for this year (as seen in the 2010 run) show an increase in energy demand, despite a fall in Chemicals GVA. In DUKES, the definition of the Chemicals sector covers both chemicals and pharmaceuticals; while GVA did fall, the share shifted in favour of pharmaceuticals. The change in sector composition does help to explain the change in the fuel *mix* seen in this year, but the overall *increase* in energy demand remains surprising, given that chemicals is typically more energy-intensive than pharmaceuticals. This is an example of a forecast error in the DECC Model, although one that is admittedly counterintuitive; it is not an outcome that we would *a priori*, have expected.

The extent to which the updated economic assumptions in the 2009 run moves short-term energy demand closer to the outturn varies among the industry sub-sectors (see Appendix A for further details). One possible reason for increasing forecast errors is that the DECC GVA assumptions in the three runs analysed do not include updated historical data; the starting points for the output projections may be deviating from actual outturn figures as the runs become more recent.

Another possibility is that sectors' energy consumption has changed markedly in the

Figure 4.3: Chemicals Energy Demand



Source(s): DECC.

recession (as evidenced by the growth profile for Chemicals) and the DECC equations are unable to account for this in their specification[13]. There may be a case for introducing 'soft' information into the projection in the form of off-model adjustments, to account for developments that DECC is able to observe in the primary data. Both of these issues are discussed in greater detail later in this chapter.

In the 2008 run, after the last year of data, a sustained decline in energy demand can be seen in Figure 4.3, at a largely constant rate. Formal decomposition of the trend shows that a negative coefficient on the time trend term (representing efficiency gains over time) outweighs the impact of the steady growth in output from this sector, explaining the long-run downward trend.

[13] It is not necessarily the case that we should expect this, however, because behaviour tends to become less linear in a recession (or a boom) so the equation will not necessarily be able to capture the change fully.

The time trend term in the Chemicals equation has the effect that energy-efficiency improvements take place regardless of the level of output

The shocks to industry output from the recession are evident in the energy demand profiles in the two subsequent runs, and the 2010 run does show the effect of higher output growth in the medium term. In both cases, however, trend growth in Chemicals GVA in the long run is the same and energy demand falls at the same rate, regardless of the level of output. Without an explanation routed in economic theory, interpreting the time trend effect is problematic and, as recommended in the previous section, it would be worth investigating more theoretically-satisfactory explanations of energy efficiency.

Aggregate energy demand equations for other industry sub-sectors that are also driven by output and a trend efficiency term show similar results, with the level of the projection determined by the output projection and its growth determined by the relative sizes of output-growth and the efficiency terms. Graphs and analysis of other sub-sectors to support this finding can be found in Appendix A.

The breakdown by fuel affects sectors' emissions intensity

As discussed in the previous section, energy prices only appear in one of the industry aggregate energy demand equations, Other manufacturing. The Oxford Economics (2008c) re-estimation generally identified significant price elasticities at the fuel-share level only. The price terms (typically, the price of a fuel relative to the prices of other fuels) are the main drivers in the industry fuel-share equations.

A small number of fuel-share equations also include sub-sector output as a driver. The output term relates the type of energy consumed to the size of the industry. Implicitly, higher levels of output are correlated with a shift towards certain types of energy-consuming capital stock ie technological progress. It is difficult to separate this progress into 'scale' effects (higher production permits investment in higher-capacity processes that use a different type of energy) and trends in technology that are simply correlated with output[14].

Because the carbon-intensity of fuels differs, the impact of prices on the fuel shares has consequences for emissions. In the long run, real fossil fuel prices are similar in the 2009 and 2010 runs. Prices in the 2009 and 2010 runs are higher than in the 2008 run, particularly for coal (44% higher in 2020) and gas (54% higher). Differences in prices by fuel across the runs means that relative prices will differ and we would expect changes in the fuel shares (and thus emissions), provided the variables are accounted for in the equations.

The DECC Model projects a shift in industry energy demand, from fossil fuels to electricity

In terms of the breakdown by fuel type, in the 2008 run, industry as a whole shifts somewhat away from oils and solid fuels towards gas and, to a lesser extent, electricity. Over the long-term, to 2020, the shift away from more carbon-intensive fossil fuels continues and the share of gas also declines. The updated economic data and assumptions in the 2009 run do not lead to a substantial difference in the trends seen in the 2008 run; the shift from oil to gas is less pronounced owing to higher gas prices in the 2009 run assumptions.

When the short-term projected fuel shares from the 2008 and 2009 runs are compared to the outturn data included in the 2010 run, it can be seen that:

- for electricity:

[14] If production technologies in an industry favour, say, electricity over time, and industry output grows over the same period (as it tends to, in the long run), then the two variables are *correlated*, but we cannot say that higher output *causes* the switch to electricity, it is simply picking up the co-movements in the series.

  - the DECC Model over-predicted the share of electricity in total industry demand in 2008 and in 2009
  - the forecast error for 2009 increased when new data and assumptions accounting for the recession were included in the 2009 run
- for gas:
  - the updated data and assumptions in the 2009 run moved the share of gas closer to the outturn figures in 2008
  - the figure for 2009 was below the outturn share, by ½ pp, but the 2008 run over-predicted the share by a similar amount; the revision in the 2009 run was in the right direction
  - however, the trend in the outturn data, of a steady increase in the share of gas, is better reflected in the 2008 run than in the 2009 run (in which the share is flat). The revised projections did move closer to the outturn, but the trend over time was not captured
- for other fossil fuels (oil and solids):
  - the projected shares in the 2008 run were generally closer to the outturn
  - the 2009 run over-predicted the oil shares and an increase was projected for 2009, when a decrease was predicted in the 2008 run (and borne out in the data)
  - the share of coal in final industry demand was projected to fall in both the 2008 and 2009 runs but actually increased in the outturn data

It is important to note that the interdependencies between the fuel-share equations make it difficult to draw any conclusions from the above as to which equations are actually performing better than others because a change in one fuel share necessarily reduces the other shares. Broadly, we might say that the shift to electricity was over-predicted by the DECC Model.

In the long run, the fuel shares are similar across all three runs

In the long run, the fuel shares for industry as a whole are largely unchanged when comparing between runs (all runs imply a shift towards electricity). In all three runs, from the raw DECC Model results, electricity accounts for 46-47% of demand for useful energy (an increase of around 7 pp on the historical figures). Gas accounts for around 35% and the rest is taken up by oil and solid fuels. There is a reversion to a similar state in all three runs, even though the outturn data suggest changes in the fuel mix in the recession.

At the sub-sector level, there are appreciable short-term forecast errors in the projected shares in a number of sectors which appear to have little impact by 2020 (there is little difference with the 2009 run results), including:

- Non-metallic minerals
  - over-prediction in electricity demand (and consequently an under-prediction in gas demand)
- Chemicals
  - over-prediction in electricity demand (under-prediction in gas demand)
- Food, drink & tobacco
  - under-prediction in electricity demand (over-prediction in gas demand)
- Paper, printing etc
  - (large) over-prediction in electricity demand (under-prediction in gas demand)

The 2009 and 2010 runs have very similar assumptions on fossil fuel prices, leading to similar long-run projections for the fuel shares

The common characteristic of the above sectors is a strong relative price response in one or more of the fuel share equations[15]. Under the current specification of the equations, these are the key drivers and the relative prices implied by the underlying fossil fuel prices are the key determinants of the fuel shares. The fuel shares in the 2009 and 2010 runs are similar in the long run because the forward-looking assumptions on the prices of fossil fuels are similar, leading to similar relative prices.

Under 'normal'/non-recession conditions, substitution between fuels of the kind observed in the DECC Model may well be valid, under the implicit assumption that the capital stock has not changed substantially. In a recession, the trends in the fuel shares may not be a valid representation of the UK energy system, if the overall characteristics of the energy-consuming stock have changed[16], altering the potential for fuel substitution. Re-estimation and outlier/break detection would be suitable methods to gauge this (see below). In the interim, when the equations have not yet been re-estimated, it may be useful to introduce adjustments or constraints to the projections to reflect, say, the permanent closure of a large plant known to be a larger consumer of electricity than gas. Such information may be gleaned from primary statistics; for large plants, the EU ETS registry; and, possibly, media and press releases.

When comparing the long run shares, the 2008 run appears to embody the most carbon-intensive fuel mix, and the 2010 run the least. However, we are unable to reconcile the implied carbon intensities with the projected emissions from the runs (the projected emissions imply a more carbon intensive fuel mix than that implied by the fuel share results). This may be due to different CHP projections, but we were unable to assess this as part of the project.

In summary we find two key results for the industry fuel shares projected by the DECC Energy Model:

- in the long run, the DECC Energy Model projections for industry favour electricity over fossil fuels, almost irrespective of the short term pathway
- we find evidence of over-prediction of the share of electricity for industry as a whole in the short run, when comparing the 2009 and 2010 runs

The combination of these two factors suggests that the DECC Energy Model might be systematically over-estimating electricity consumption from industry and therefore underestimating industry emissions per unit of energy demand. However, total industry emissions is also dependent on total energy demand, for which we find some evidence of over-prediction. It is also dependent on the amount/characteristics of CHP/autogen, for which detailed analysis is outside the scope of this study. Whether there is any systematic bias in the projection of total emissions are will depend on the balance of these factors.

[15] The coefficients are negative, so, as currently specified, the effects are compounded if more than one equation contains a price – an increase in the relative price of one fuel by definition decreases the relative price of another.

[16] From Bowen et al 2009, possible impacts include the closure of less efficient plant, which may be more carbon-intensive (emissions relative to a business as usual case are lower) or, conversely, a slower rate of low-carbon investment and innovation (relatively higher emissions).

Household energy demand moves closer to the outturn data in the 2009 run…

Energy demand from households is not projected at the aggregate level and then shared out. Instead, demand for gas and electricity are projected by separate equations and summed together with projections of demand for oil and solid fuel (linked to a time trend) to give the aggregate figure.

All three runs project growth in household electricity demand in 2008 and 2009. Modest growth is projected in the 2008 run, with higher growth in the 2009 run. The outturn data show even higher growth; the results from the 2009 run were closer to the actual data than the results from the 2008 run.

Prices are relatively higher in the 2009 run (which reduces electricity demand) but electricity demand is projected to increase over the 2008 run. We were unable to replicate the household energy demand equations so are unable to precisely quantify the contributions of each of the drivers, but it is likely that the increase in demand is driven by the assumption of lower income growth in the runs that include the recession, combined with the negative income elasticities.

…but it is difficult to conclude that the negative income elasticity is appropriate

However, this does not necessarily justify the negative income elasticity in the equation, because real incomes actually rose slightly in the recession owing to price effects; a more intuitive positive income elasticity and updated outturn data on real income would also have driven an increase in energy demand. Moreover, if the increase in real income were included in the DECC Model assumptions, the projected level of energy demand would be lower, increasing the size of the forecast error. Without replicating the equation, it is not possible to quantify this.

The possibly unsuitable nature of the negative income elasticities is supported by the results for household gas demand. A 4% increase in demand is projected in the 2008 run in 2008, but an 11.5% increase projected in the 2009 run, presumably from the effect of higher prices being outweighed by lower income. The outturn data for this year show a 4% increase; the updated economic data and assumptions in the 2009 run led to a revised gas demand figure further from the outturn.

The effect of the negative income elasticity can be seen clearly in the long-run

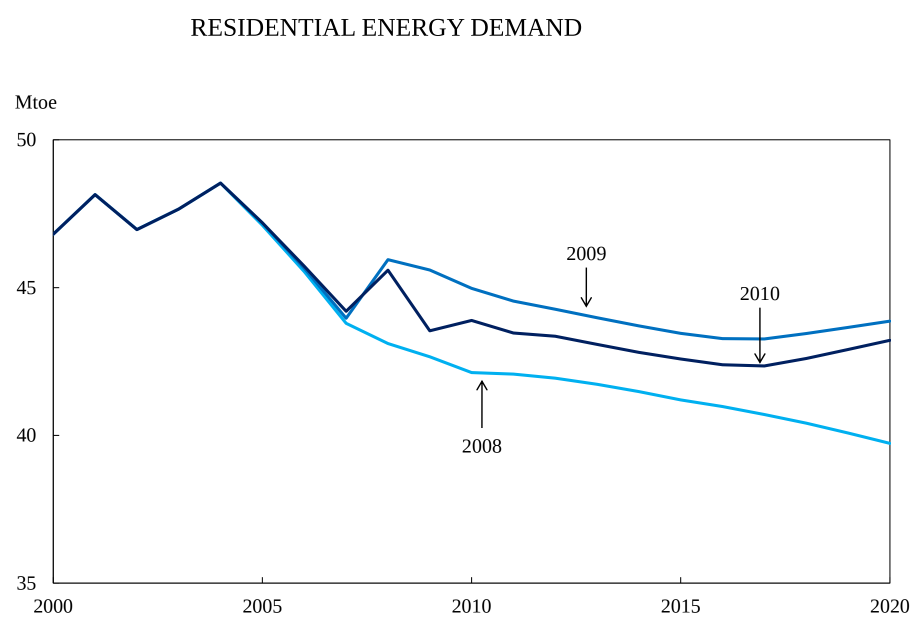
The counterintuitive nature of the negative income elasticity truly becomes apparent in the long term. As mentioned in Section 3.3, projected incomes are lower in the most recent two runs, after the recession, but energy demand and emissions in these two runs is higher than in the 2008 run. The level of income is highest in the 2008 run, and lowest in the 2009 run. The 2010 run falls somewhere in between. The negative income elasticity in the household equations reverses this ordering for energy demand (see Figure 4.4). The 2009 run has the lowest level of income but the highest level of energy demand and, conversely, the 2008 run has the highest level of income but the lowest level of energy demand.

As mentioned in Section 3.1, Oxford Economics (2008a) put forward a number of candidate explanations for this result:

- higher-income households may spend less time at home
- income-elastic demand for insulation measures
- rising real income may coincide with increasing energy efficiency over time; the household energy demand equations do not include a time trend so real income may be picking up this effect

A more plausible positive elasticity would produce projections of energy demand more in line with the growth profiles for income and, of the above reasons, the second and third may present cases for a missing variable in the equation. If this is the case, then the DECC Model projections for household energy demand are likely to be biased upward. The negative income elasticities in the household equations would certainly be worth revisiting should they be re-estimated or re-specified.

Figure 4.4: Residential Energy Demand



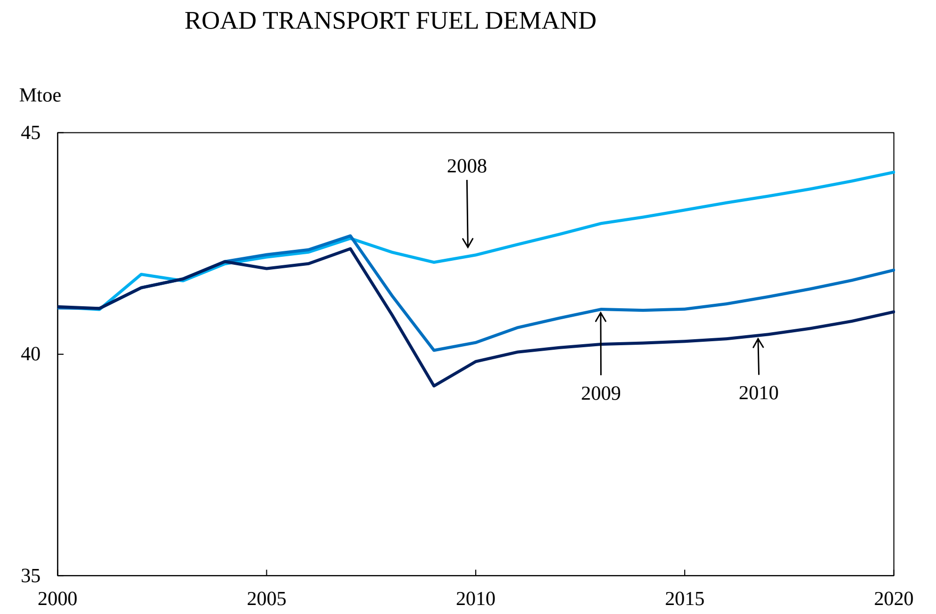
Source(s): DECC.

Road transport energy demand and emissions appear to grow in line with income and economic activity

The data revisions in the 2010 run suggest that total fuel demand (the sum of private [cars] and commercial [CVs] transport) was ½-1% lower than in the 2008 and 2009 runs in the historical period (see Figure 4.5). At the aggregate level, the data revision aside, the short-term projection for road transport fuel demand does move closer to the outturn data (in the 2010 run) in the 2009 run; the forecast error is reduced when the updated income assumptions (to include a fall in the recession) are used. Oil prices are also higher in the 2009 and 2010 runs, when compared to the 2008 run, which also contributes to the reduction in demand (the price elasticity in the equation is negative).

However, the private/commercial split has changed substantially between the 2010 run and the 2008 and 2009 runs. In the historical period, fuel demand from commercial road transport is much lower in the 2010 run than in the previous two runs (by 12-14%). Private road transport fuel demand accounts for a greater share of the total, and is 7-9% higher in the 2010 run (see Figure 4.6). The re-allocation from commercial to private transport makes judging the short-term forecast performance somewhat more complicated because the starting levels have changed. If the growth profiles from the 2010 run are applied to the levels in the historical data common to the 2008 and 2009 run, the 2009 run and the modified 2010 run are similar in their short-term profiles for both private and commercial transport. The updated inputs in the 2009 run appear to have improved the short-term forecasting performance at this more disaggregated level.

Figure 4.5: Road Transport Fuel Demand



Source(s): DECC.

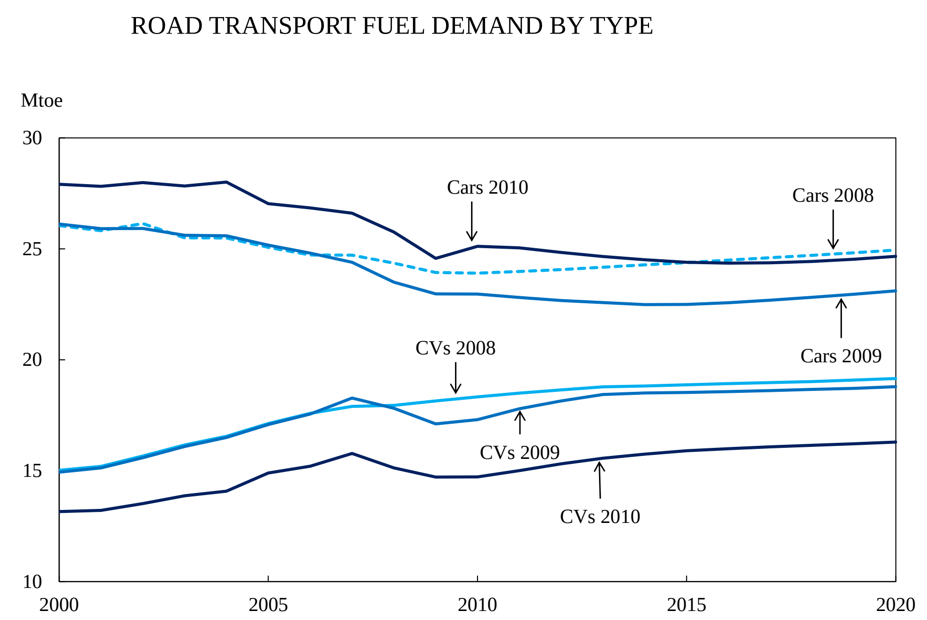
The possibility of a negative income response is not evident in the road transport projections

The Oxford Economics (2008a) review pointed out an implied negative long-run income elasticity on private road transport fuel demand. The relationship is more complex than for household energy demand because, in addition to the direct income effect on transport demand, income enters into the demand equation through a car ownership term, which is driven by household income. The Oxford Economics report does note that the significance of this implied relationship is unclear, presumably owing to the greater complexity; formal analysis of the interactions is less straightforward and the negative relationship between income and fuel demand may not necessarily be borne out in the actual projections. When the three vintages of road transport projections are compared, there is no obvious evidence of a negative income effect in either the short or long runs (as seen in the household equations); lower levels of projected income in the two runs that include a recession are reflected in lower fuel demand.

Long-run private road transport fuel demand is highest in the 2008 run and lowest in the 2009 run. The updated outturn data in the 2010 run contain revisions such that the starting level of fuel demand in the 2010 run is higher than in the 2008 and 2009 runs. However, fuel demand falls over the projection period such that fuel demand in 2020 is just below that in the 2008 run. The 2009 run has the lowest level of projected fuel demand by 2020, but this appears to be the result of a lower starting level compared to the 2010 run; had the historical data been the same, the 2009 and 2010 projections would have been more similar.

Private road transport fuel demand is projected at the aggregate level and shared out to individual fuel types by assumption, rather than by a set of equations. The shares do not differ much between runs so the carbon intensities do not differ much, either. Consequently, emissions from private road transport move in line with energy demand.

Figure 4.6: Road Transport Fuel Demand By Type



Source(s): DECC.

Fuel demand from commercial road transport is linked to GVA only and thus moves in line with economic activity (as do emissions). The permanent losses in economic activity are thus reflected in permanent reductions in the energy demand from this sector, when the 2009 and 2010 runs are compared against the 2008 run. In the long run, the projections for commercial road transport fuel demand are relatively flat in all three projections. The Oxford Economics (2008a) review indicates no other terms to explicitly capture effects such as energy efficiency improvements or prices[17], which we agree is theoretically unappealing when considering long-term energy demand and emissions.

The equations do not deal with stock effects, and policies must be added as off-model adjustments

It is not clear if or how stock effects are treated in the DECC Model. For example, the UK Vehicle Scrappage Scheme temporarily increased the turnover of the vehicle stock, with smaller (more fuel-efficient), petrol-driven cars generally favoured as new purchases under the scheme. Such an adjustment must presumably be made off model; there is no obvious policy lever to model the changes in energy consumption or efficiency.

The re-allocation of fuel demand in the 2010 run, from commercial to private road transport leads to fuel demand being lowest in the most recent 2010 run and highest in the 2008 run and emissions match that profile. Both fuel demand and emissions thus grow in line with the assumptions on income and economic activity although the impact of fuel efficiency and policy, both of which affect the stock, are not factors that can be introduced directly into the model equations. These adjustments must be made off-model.

We have no particular reason to think that there is any evidence of over or under-prediction in road transport fuel demand, but we do note that the projections may be sensitive to the off-model assumptions on policy.

The forecasting properties of the equations were considered satisfactory when they were estimated…

We now consider the possibility of systematic forecast error in the DECC Model projections, and how it might be dealt with.

Because an equation is only a summary of the underlying process, the values it predicts will not match the data precisely, even if the inputs fed into the equation are correct: there will inevitably be some degree of equation error. Within the sample period used for estimation, the estimation procedure will have been conducted to include the aim of avoiding systematic errors in the equations' current-period estimate of energy demand. The Oxford Economics review (2008c) also indicated that the industrial energy demand equations were then tested for their forecasting properties in the period not covered by the sample used for estimation, and, 'comparing the model's forecast to observed energy demand […] provides similar results' (ibid, page 12). The forecasting properties of the equations were considered satisfactory. These equations were used in the version of the model that generated energy and emissions projections for the CCC's inaugural report (CCC 2008), as well as the later projections.

…but new outturn data, including the recession, have since been released

New outturn energy data have since become available, up to the 2009 recession (at the time of analysis). These new data, and the replication of some of the DECC Model's equations (see Section 3.3), provide an opportunity to assess the equations' performance further into the future, and in light of the recession.

[17] The absence of a constant in the equation was also pointed out; risking bias in the parameter estimates.

Forecast errors can be identified by comparing the equations' forecasts of energy demand against the actual figures in the data, possibly revealing periods of persistent over or under-prediction that may indicate systematic forecast bias. Whether or not these errors can be considered significant in terms of their size is a further question that is ideally dealt with by re-estimating the equation over the extended sample period and testing for the presence of outliers and/or structural breaks.

In the DECC Model, forecast errors in the last year of history are assumed to be random and transitory; the equations are allowed to correct for the deviation and will tend towards the estimated long-run equilibrium relationship. However, if the error is significant in its size, and it persists into the future, then the equation may be correcting to a long-run levels relationship that no longer holds. If this is the case, then the equation results will tend to be biased. Another way of interpreting this is that, had the inputs to the equations not changed between runs but the outturn energy data had been updated, the projections would have been identical in the long run. The plausibility of such an outcome rests on the nature of the discrepancies between the equations' forecasts and the outturn data.

Outliers and structural breaks are best identified econometrically…

Outliers and breaks (significant transitory and permanent forecast errors) are best identified econometrically, by re-estimating the equations using the new data and testing the significance of the shocks. Should an outlier be detected in the last year of history, judgement will be required to decide whether the shock is transitory or if it represents a shift in the relationship (a structural break).

…but re-estimation was beyond the scope of this project

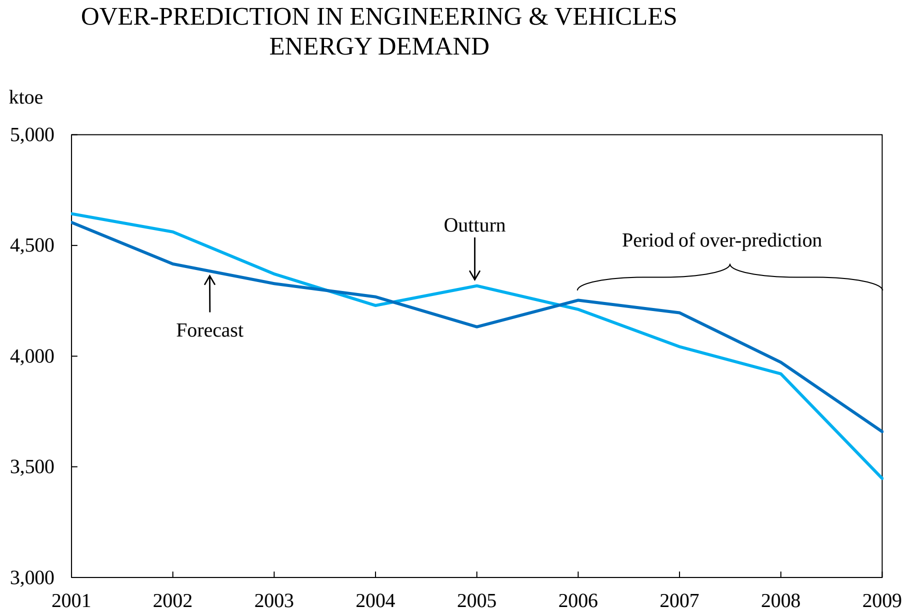
Because re-estimation of the equations is not possible as part of this project, detection of outliers and breaks is not possible by statistical means. This, however, does not preclude some assessment of the equations' forecasting properties.

Having replicated some of the equations in the DECC Model, it is possible to compare the forecast values from the equations against the actual values over the historical period. This is shown for the Engineering & vehicles sector identified in the DECC Model in Figure 4.7, from the inputs and outputs for the 2010 run. The equation values shown are 'one-step ahead' forecasts of energy demand; the equation's prediction of energy demand in the following year, based on actual values for the equation drivers (in this case, just output). Forecast errors in this chart are represented by the differences between the two lines in the chart.

Graphically, persistent over or under-prediction by the equation shows up for periods in which the two lines do not cross (one series is persistently above the other). It can be seen from Figure 4.7 that, in the last four years of history, the equation has a tendency to over-predict energy demand.

If this period of over-prediction is thought to be significant and likely to persist into the future, then allowing the equation to simply correct for the deviation may potentially lead to the re-assertion to a long-run relationship that no longer holds. One possible symptom of this might be an overly-strong adjustment in the early year of the projection period, as can be seen in a comparison of the energy demand projections for Engineering & vehicles in Figure 4.8, with a sharp correction evident in the 2010 run.

Figure 4.7: Over-prediction in Engineering & Vehicles Energy Demand



Source(s): DECC, CE calculations.

While it is true that output growth in the short term is higher in the 2010 run than in the earlier two vintages, the profile of output growth (which is above-trend post-recession) cannot fully explain the marked increase in energy demand in 2010, nor the levelling off in 2011; the error correction (possibly exacerbated by an incorrect level of GVA in the last year of history; see below) accounts for much of the short-term response.

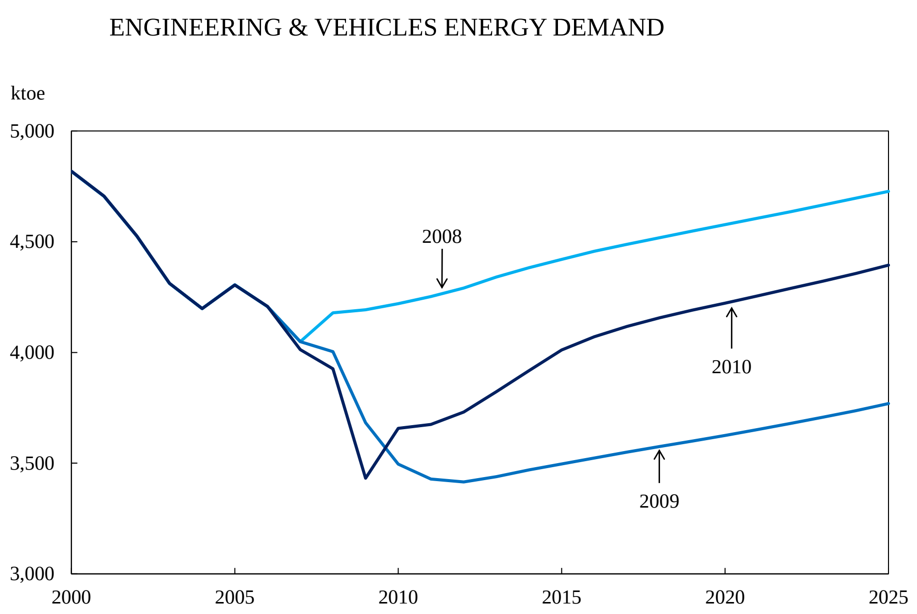
There may be a case for introducing a 'residual adjustment', if persistent bias is suspected

Rather than allow the equation to react to the error as if it were a one-off shock, the chart of forecast errors in Figure 4.7 suggests that there may be a case for correcting the equation result into the future by adjusting the projections for this 'residual' error.

The effect of this is shown in Figure 4.9, in which the results from the DECC Model 2010 are charted against the same run, but with a residual adjustment applied. The equation was found to over predict by around 6% in the last year of data (a relatively large forecast error) and this is accounted for in the adjusted projection; energy demand remains around 6% lower over the projection period.

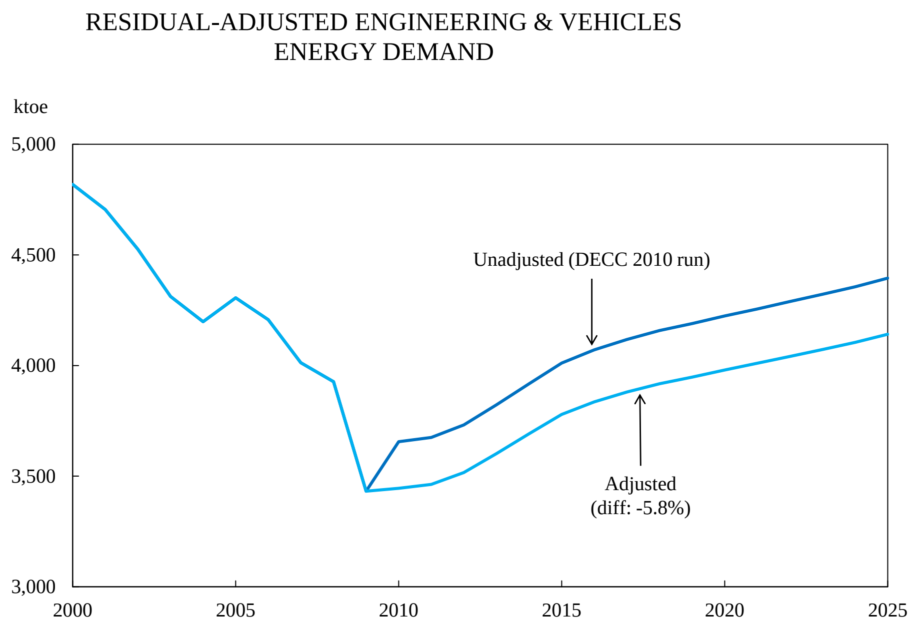
A residual adjustment may also be useful to correct for input data that are not fully updated. For example, GVA is an input to the industry energy demand equations, but the series were not updated with the latest outturn data for the additional years of history (this is analysed further in Section 4.3). The residual error in the last year of data includes both the forecast error, but also the discrepancy in the GVA data. DECC is now correcting its historical GVA series but, in the projections provided to the CCC, the series were not updated; in these cases, it may have been desirable to compensate for the discrepancy by including the residual adjustment.

Figure 4.8: Engineering & Vehicles Energy Demand



Source(s): DECC.

Figure 4.9: Residual-Adjusted Engineering & Vehicles Energy Demand



Source(s): DECC, CE calculations.

For the industry sector equations we were able to replicate, the residual adjustments suggest that energy demand could have been 3.7% lower in 2020 in the 2010 run

Our estimates of the size of the residual adjustments in the 2010 run, for industry (for the equations we were able to replicate) are shown in Table 4.1. Excluding 'Unclassified', these sectors accounted for 68% of industry energy demand in 2009. Industry energy demand accounted for 17% of UK final energy consumption and around one-third of final-user combustion emissions in 2009. From our analysis, the aggregate energy demand equations for these sectors over-predicted energy demand by 422 ktoe units of 'useful' energy. Energy demand would have been around 3.7% lower in the long run with these residual adjustments. Converted back to total energy the gap remains at around 3.7%.

The direction and sign of the residuals adjustments in Table 4.1 does identify evidence of systematic bias in the equations we were able to replicate. In general the bias suggests over-prediction in the DECC Model equations (negative residual adjustments). However, the size of the implied adjustment is appreciably larger in 2009 than in 2007 or 2008. While it is not possible to assess this increase statistically, these figures do point to the possibility that the residual is a combination of systematic bias (or a structural break, if the equation is well specified) in the equations and a shock (an outlier). It is valid to apply the residual treatment to compensate for the systematic bias/structural break, but not a transitory shock. A transitory shock must either be treated as an outlier in the equation or the equation must be allowed to correct for it in the dynamic solution.

In principle, an outlier in the last year of data can be detected during re-estimation but judgement is involved to decide whether it should be treated as a shock (a dummy variable for that year) or a structural break that should be carried forward into the projection period.

We were unable to successfully reproduce the household and road transport equations so were unable to calculate similar adjustment factors for these sectors.

The application of a residual treatment is in many ways a pragmatic treatment of forecast errors arising from an equation, to guard against systematic bias in the projections over recent history. It does, however, remain an issue of judgement and, if applying the adjustment across all of the DECC Model equations was not considered desirable, would require clearly-defined criteria governing its use.

'Softer' information may help to inform the projections

DECC may also be able to make use of additional statistical information, such as the known closure of certain industrial plants, that could help to inform the treatment of the demand shock, as well as in the development of the GVA forecasts. To some extent this 'softer' information is already incorporated eg the closure of the Teesside steel plant is reflected in adjusted GVA figures for iron and steel. If the type of energy-consuming technology is known, it may be possible to go further and introduce a correction directly into the energy demand projections (an 'energy saving' from mothballed capital, possibly at the level of individual fuels, if enough is known about individual plants). Care must of course be taken to prevent double counting from adjusting both GVA (an input) and energy demand (the output).

Table 4.1: Estimated Size of Industry Residual Adjustments

ESTIMATED SIZE OF INDUSTRY RESIDUAL ADJUSTMENTS					
	2007	**2008**	**2009**	**2009 (ktoe)**	**Comment**
Non-ferrous metals	+4.6%	+1.3%	-8.9%	-103	Equation over-predicts in 2009, but under-predicts in 2007 and 2008 – evidence of bias is weaker
Chemicals	+1.6%	+12.4%	+6.7%	+215	Equation shows signs of under-prediction
Engineering & vehicles	-3.7%	-1.3%	-5.8%	-160	Equation shows signs of over-prediction
Food, drink & tobacco	-5.9%	-4.8%	-10.6%	-260	Equation shows signs of over-prediction
Textiles, leather, etc	-2.9%	-6.6%	-16.2%	-85	Equation shows signs of over-prediction
Paper, printing, etc	-3.0%	-6.8%	-10.4%	-29	Equation shows signs of over-prediction

Note(s) : Residual adjustments are calculated from the raw DECC Model results, which are expressed in 'useful' units of energy.
Source(s) : DECC, Cambridge Econometrics.

4.3 Assessment of input assumptions to the DECC Model

The method for constructing forecasts of GVA by industrial sub-sector fails to take into account possible changes in industrial structure following a recession

In the final part of the assessment, we consider the input assumptions to the DECC Model themselves. We examine:

- DECC's method for constructing sub-sectoral GVA forecasts for industry
- how retail price projections are formed from DECC's wholesale fossil fuel price assumptions

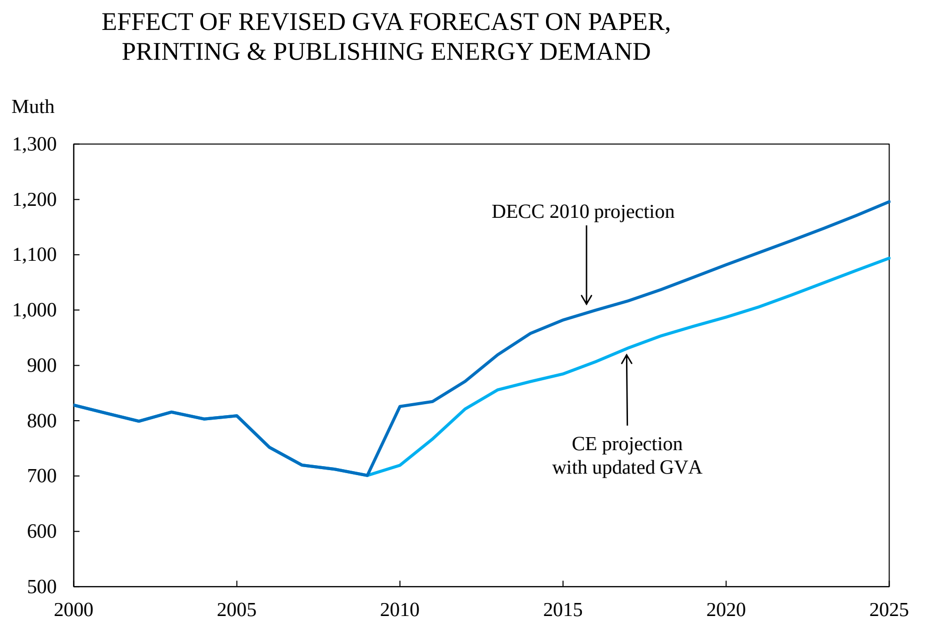
The way in which industry sub-sector GVA forecasts have been constructed as inputs to the DECC model in recent runs is a cause for concern and has, to a certain extent already been recognised by DECC. The sub-sector GVA forecasts for the 2008 vintage of energy and emissions projections were provided by Oxford Economics. However, later vintages were only revised in line with changes to total manufacturing GVA as supplied by HMT/OBR: forward looking sub-sector growth rate differentials are then imposed from the 2008 vintage supplied by Oxford Economics to derive sub-sector estimates.

This methodology has two implications:

- the latest sub-sector GVA data is not included in the projections
- post-recession changes in the structure of the economy (such that pre-recession growth rate differentials no longer hold) are not accounted for

The first point is important because the starting point for the projections is incorrect. This would not be a problem if manufacturing sub-sectors were homogenous, but they are not, and energy intensities and responses of industry energy demand to economic activity (as shown by the estimation results) vary. This has implications for the long-

Figure 4.10: Effect of Revised GVA Forecast on Paper, Printing & Publishing Energy Demand



Source(s): DECC, ONS, CE calculations.

run because it alters the long run energy demand projections. In some cases the differences between the data and the estimates have quite strong implications for the projections. For example, Pulp, Paper and Printing (PPP) GVA in 2008 and 2009 is much lower in the Blue Book 2010 than anticipated by the DECC method. By incorporating these revised GVA estimates into the DECC energy model, we estimate that energy demand for PPP in 2020 would have been nearly 10% lower (nearly 100 Muth, see Figure 4.10). DECC has already noted this problem and will update GVA data in its next set of projections.

A residual adjustment may help to absorb the forecast error from an incorrect level of GVA

Failure to incorporate the latest GVA data leads to an incorrect level in the historical period (the starting point), before the transition into the forecast period; it is a form of forecast error. This error persists into the forecast period (from applying the growth rates) and is illustrated in Figure 4.10. In such a case, it is possible to compensate for the discrepancy using the residual adjustment described in the previous section. The residual helps to absorb the additional forecast error caused by the wrong level of GVA that is an input to the equations.

The second point is important because the structure of the economy, and particularly the growth in different manufacturing sub-sectors, has implications for projections of energy consumption and emissions. Following a recession, it is unlikely that the relative structure of sub-sectors will persist as forecast prior to the recession (see Chapter 2). Each sub-sector is affected differently, both in the recession and in the recovery stage, and we might expect the forward looking projections to differ quite significantly with strong implications for energy and emissions projections. However, it is too early to tell whether the assumptions fail to capture important structural changes to the post-recession economy.

We recommend, therefore, that DECC seeks to account for the latest GVA data in its projections to better project energy demand (and emissions) in the short-term and allows for the impact of economic structural change in the long-term energy projections.

The absence of energy prices in the aggregate equations is surprising

Our assessment of prices has been separated into two sub-tasks; first, we consider the role of prices in the energy demand equations (focussing on the industrial energy demand equations) and; secondly, we consider the formation of prices, from wholesale price assumptions to retail prices, and whether this changes significantly as a result of the recession.

In the estimation work carried out for the DECC Model, energy prices were not found to be significant in any of the aggregate industrial energy demand equations. So, while the household energy demand equations (which are estimated separately for each fuel), road transport and air transport equations all contain price terms, the aggregate energy demand equations for industry do not. That there might be relatively less effect is perhaps unsurprising since final consumers might be regarded as being more sensitive to price changes, and, for commercial road transport and air transport, fuel prices represent a reasonable proportion of the input costs; whereas industrial energy users can potentially pass fuel costs onto consumers in full, or, depending on the sub-sector, energy costs may be small in comparison to other business costs and are simply absorbed by industry in the form of lower profits.

Yet there is evidence in the literature, and indeed from our own econometric estimates which inform the MDM-E3 model, that prices do have a significant, albeit sometimes small, impact on industrial energy demand in the long term (for examples, see: Dimitropoulos, et al 2005, Roy et al 2006, Pyndick 1979).

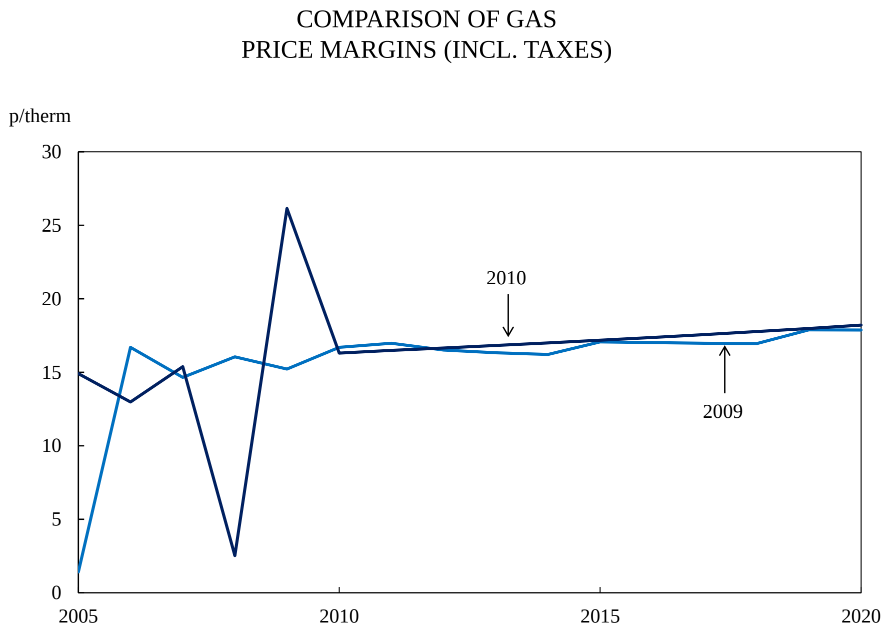
In part this might be a result of the period estimated in the DECC industrial energy demand equations (1980-2004) where energy prices were for the most part both low and stable[18]. By contrast, many of the other estimates which find prices to be significant are estimated either to include the 1970s oil price spikes, or to include the recent period of global energy price volatility (2005 -2010).

However, the DECC model does attempt to account for energy prices in the industrial energy demand share equations to capture the effects of fuel switching. This potentially introduces an inconsistency into the modelling, as it suggests that on the one hand industries do not respond to changing energy prices in terms of total demand for energy, but on the other hand industries do respond to changing relative energy prices in terms of the relative fuel mix.

Emissions might also be further affected by prices through the impact of prices on the CHP sub-model, which as a technology-driven bottom up model is potentially driven by relative prices, specifically the spark spread (the difference between gas and electricity prices). It was beyond the scope of this project to investigate the treatment of CHP in the DECC Model and the reasons for differences between forecasts.

[18] The 1970s period is not included in the sample because it is difficult to derive sub-sector energy consumption statistics for this period. The post-2004 period is not included because the data for these later years include the effects of policy, which DECC attempts to separate from the underlying ‘without-policy’ baseline; unmodified, these data should not be included in the estimation sample.

Figure 4.11: Comparison of Gas Price Margins (Incl. Taxes)



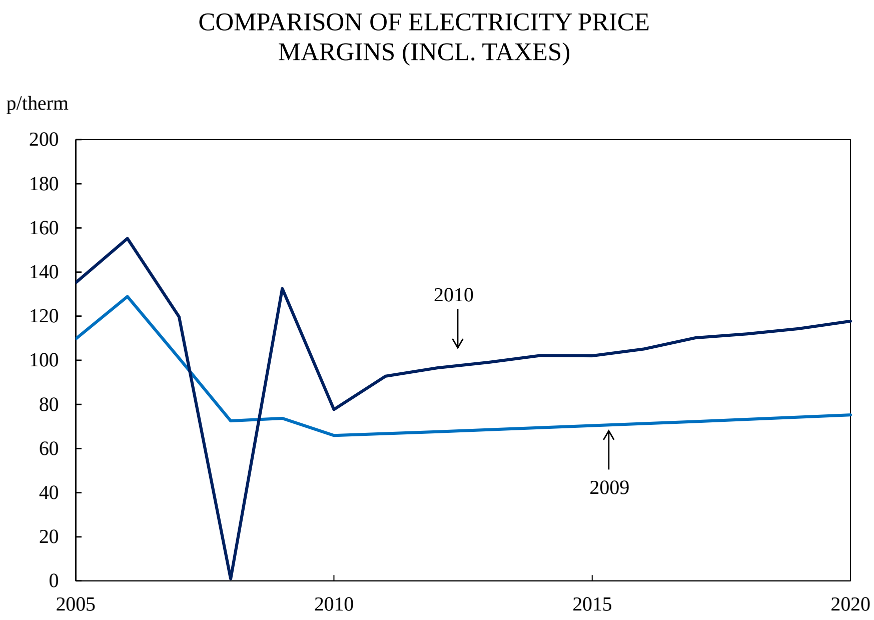
Notes(s): Margins are calculated as the difference between wholesale and industrial retail prices.
Source(s): DECC, CE calculations.

Given that prices have no impact in the DECC model on aggregate industrial energy demand and therefore emissions, the formation of energy prices in the DECC model becomes a secondary issue for analysis. However, energy prices (and DECC's expectations of future energy prices) varied greatly as the recession proceeded.

The data also suggest that price pass-through changed dramatically over the period 2007-2009. In the DECC model, the assumption made on price pass-through in forming forward-looking retail energy prices will impact on industrial emissions through fuel shares. Interestingly, a decomposition of the retail prices of gas and electricity shows that while gas margin assumptions are relatively stable (and similar) in the projections period; electricity margins vary greatly between runs (see Figure 4.11 and Figure 4.12). This impacted on relative energy retail prices faced by industry, with electricity prices growing faster in the 2010 vintage compared to the 2009 vintage (owing in part to increasing margins), while retail gas prices are very similar between the two runs. This has implications for the fuel mix (and therefore emissions) between the 2009 and 2010 run as gas is relatively cheaper in the 2010 run than in the 2009 run (in comparison to electricity). There was insufficient data to assess price margins in the 2008 run.

We recommend that the relationship between wholesale prices and retail prices is investigated further. Currently, a fixed margin is carried forwards into the projection period (although the difference between retail and wholesale prices can diverge due to taxes), but in a recession margins are volatile and as such carrying a margin forward from a year within this period might not be suitable (over time the margin is likely to recover to more normal levels).

Figure 4.12: Comparison of Electricity Price Margins (Incl. Taxes)



Notes(s): Margins are calculated as the difference between wholesale and industrial retail prices.
Source(s): DECC, CE calculations.

4.4 Recommendations for future development

This chapter has assessed the DECC Model's overall specification, its responses to changes in inputs, and the formation of the input assumptions themselves

This chapter presents our assessment of the DECC Model, with more detailed supporting analysis consigned to Appendix A of this report.

The analysis has been divided into three distinct parts, assessing:

- the specification of the model itself
- the responses of the model given its existing specification and the changes in input assumptions (and how they are incorporated)
- how new assumptions are generated

Our recommendations for future model development are summarised in Table 4.2, along with an assessment of how soon they could be implemented.

Table 4.2: Recommendations Arising from DECC Model Assessment

RECOMMENDATIONS ARISING FROM DECC MODEL ASSESSMENT			
Recommendation	**Time frame for implementation**	**Comments**	**Section(s)**
Consider alternative methods and sources for sub-sectoral industry GVA forecasts; of relevance both post-recession but also with respect to large-scale structural change eg from decarbonisation	Medium-to-long-term	Comprehensive treatment of inter-industry relationships and structural change potentially complex; may be difficult to bring in-house, if desired	4.1, 4.3
Consider supplementing projections with more bottom-up treatment/analysis	Long-term	More holistic approach combines advantages of top-down and bottom-up analyses Potential coordination issues and/or greater complexities in reconciling differences in results	4.1 (and Ch 5 and 6)
Possible re-specification of equations (including re-assessment of energy efficiency)	Long-term	Counterintuitive negative income elasticities worth reviewing Endogenous treatment of energy efficiency at least theoretically more appealing than a time trend term; introduces another variable that must be projected, however Apparent insignificance of prices in aggregate energy demand equations worth revisiting	4.1, 4.2, 4.3
Re-estimation over the extended sample period/ more regular re-estimation of equations	Long-term	If the equations are still to project energy demand 'without policy', some (*ex-post*) assessment of the impacts of recent policy initiatives is required (involves an element of data construction to obtain the final dataset for estimation). DECC has acknowledged this requirement and was investigating it before this review. Sensitivity analysis of how the parameters change under alternative levels of policy effectiveness would be desirable. Permits more statistics-based tests for outliers and structural breaks (residual adjustment above becomes unnecessary, although requires criteria to distinguish outliers from breaks) Clearly-specified (or appropriately automated) estimation strategy desirable	4.1, 4.2, 4.3
Apply a residual adjustment to sectors where there is evidence of systematic over or under-prediction	Short-term	Possibly requires development of clear criteria for deciding whether or not to apply the adjustment if not used as standard If the equations were more regularly re-estimated, the preferred alternative would be to test for outliers and structural breaks as part of the estimation procedure (see below)	4.2, 4.3

RECOMMENDATIONS ARISING FROM DECC MODEL ASSESSMENT

Recommendation	Time frame for implementation	Comments	Section(s)
Make use of more in-depth statistical information/’soft’ data to account for known events not captured by the equations	Short-to-medium-term	To some extent already accounted for in DECC projections	4.2
Further analysis of the link between wholesale and retail energy prices (nature of margins and tax elements)	Medium-to-long-term	Implications for emissions of errors in this regard likely to be small relative to errors in actually forecasting wholesale prices	4.3

Source(s) : Cambridge Econometrics.

5 Alternative Emissions Projections from MDM-E3

MDM-E3 was used to generate alternative emissions projections

This chapter presents the results from a set of emissions projections generated using CE's own model of the UK economy, MDM-E3, to provide benchmark estimates of the impact of the recession on emissions (in 2010, and forward-looking to 2020) based on available information.

Three projections of UK emissions by sector were produced, corresponding, as closely as possible, to the inputs to the DECC Model for the projections provided to the CCC in previous reports.

The emissions projections are annual to 2020 and identified as follows, corresponding to the years in which the DECC projections were produced (see Section 3.3 for further details):

- the '2008 run' (2007 as the last year of data)
  - containing no recession in the underlying economic forecast
- the '2009 run' (2008 as the last year of data)
  - incorporating a revised economic forecast with a recession characterised by a permanent reduction in UK industrial GVA
- the '2010 run' (2009 as the last year of data)
  - also incorporating a recession, but with a period of post-recession recovery in manufacturing before trend growth prevails

The next section of this chapter provides a brief overview of MDM-E3. Section 5.1 outlines in more detail how the projection inputs were specified. The model inputs, and comparisons between MDM-E3 projections, are presented in Sections 5.2 and Section 5.3. The differences between the MDM-E3 projections and those from the DECC Model are discussed in Section 5.4.

5.1 Overview of MDM-E3

MDM-E3 is an integrated model of the UK energy-environment-economy system

MDM-E3[19] is an energy-environment-economy (E3) model of the UK maintained and developed by CE as a framework for generating forecasts and for scenario analysis. MDM-E3 is intended to provide a one-model approach for examining the consequences of economic activity and policy on UK energy consumption and emissions and, conversely, the economic implications of energy and emissions policies.

The model is characterised by:

- a high level of disaggregation in terms of industrial sectors and categories of final expenditure identified
- an input-output framework that explicitly identifies interdependencies between sectors
- two-way linkages between the economy and the energy system such that changes in one (eg from policies) impact on, and are reflected consistently in, the other

[19] Multisectoral Dynamic Model, Energy-Environment-Economy: http://www.mdm-e3.com/

- dynamic econometrically-estimated equations, capturing short-term impacts followed by medium-term adjustment to a long-run steady state

For the purposes of the current task, the sectoral detail is important, to account for differences in industries' energy-consuming characteristics. Moreover, the correspondence between the MDM-E3 fuel users and those identified in the DECC Model is sufficiently close to permit comparisons between the models' projections.

As will be seen later, in the discussion of the results, the last of the characteristics listed, empirically-validated dynamics, is another key feature of MDM-E3. This feature is important because it places an emphasis on the time path and non-equilibrium transition states of an economy; the results presented later in this chapter show how the nature of the post-recession recovery can affect the long-term path of emissions.

For more information on MDM-E3, the reader is referred to Appendix C.

5.2 Projection inputs

The projection inputs have been made as consistent as possible with those in the DECC Model

For this project, as in previous projects we have carried out for the CCC, the key economic elements of MDM-E3 have, where possible, been made exogenous in order to focus on the inputs to and outputs from the model's energy-environment system.

The economic drivers have, as closely as possible, been made consistent with those used in the DECC Model for the three runs described above, allowing for differences in the specifications of the drivers eg gross output as the industrial economic activity driver in MDM-E3 compared to net output (GVA) in the DECC Model.

The key exogenous inputs to the DECC Model that have been made consistent in the MDM-E3 projections are:

- economic activity by industry sector (GVA)
- household income
- fossil fuel prices (global coal, gas and oil)

The treatment in MDM-E3 for each of the above drivers, as well as the construction of additional input variables, is discussed below.

Gross output is assumed to grow in line with the GVA forecasts

In contrast to the DECC Model, the economic activity driver of industrial energy demand in MDM-E3 is gross output, not GVA. For the MDM-E3 projections, it was assumed that the growth in UK gross output would be the same as the growth in GVA in the economic forecasts, after the last year of history (which differs by run). For MDM-E3 fuel users not covered by the DECC Model GVA forecasts, an average growth across sectors was calculated and applied instead.

Household income growth is derived from the DECC Model inputs

MDM-E3 requires projections of both household income (to drive investment in dwellings and purchases of vehicles) and household expenditure (to drive household energy demand).

The DECC Model series for real disposable income per household have been converted to total real disposable income using the 2006-based population projections (as used in the DECC Model). As with the industry output projections, the growth rates are then applied to the historical series to form the income projection.

Household expenditure assumptions are based on official forecasts

The economic activity driver for household energy demand in MDM-E3 is household expenditure, rather than household income (the DECC Model driver). The economic forecasts that form the inputs to the DECC Model are underpinned by official forecasts from HM Treasury[20] and the Office for Budget Responsibility[21] (OBR). These forecasts include projections of household expenditure in the short-to-medium term that have been used in the MDM-E3 projections. In the long term, to 2020, household expenditure is assumed to grow at the same rate as income ie the saving ratio is assumed constant.

Fossil fuel price assumptions were converted to nominal prices

Energy price assumptions in the DECC Model are expressed in 'real terms'(ie removing the effect of changes in the general price level). These series are deflated by the UK GDP deflator (and projections thereof). We have performed the calculation in reverse to give the nominal wholesale prices of fossil fuels. The nominal values are fed into MDM-E3 as assumptions.

As in the DECC Model, the end-user fuel prices in MDM-E3 are then calculated from the wholesale prices plus taxes and margins.

5.3 MDM-E3 Projections

In this section we present three sets of energy and emissions projections for the UK economy from the MDM-E3 model based on inputs consistent with the DECC Energy Model runs reported previously.

The three runs represent different views on the forward-looking path of the economy and energy prices as made in 2008 (pre-recession), 2009 (during the recession) and 2010 (as the economy emerged from recession). Figure 5.1 shows GDP projections[22] for each of the three runs considered; correspondingly Figure 5.2 shows economy-wide carbon emissions projections for each of the three runs from MDM-E3.

The summary figures show that in the MDM-E3 model, the ordering of emissions to GDP is consistent (the 2010 run represents both the lowest economic growth forecast and the lowest set of emissions projections). It also shows some responsiveness of long-term emissions projections to the input economic growth assumptions, this is unlike the DECC projections where total emissions are fairly unresponsive (see Section 5.4).

[20] http://www.hm-treasury.gov.uk/budget_archive.htm

[21] http://budgetresponsibility.independent.gov.uk/category/topics/economic-forecasts/

[22] Note that the DECC model inputs matched were for each sector and so might not be exactly consistent with the GDP indicator, since MDM-E3 offers a general coverage with an accounting framework to represent the system of national accounts, while the DECC model coverage is only partial with no such requirements for the economic inputs to be internally consistent.

Figure 5.1: GDP Assumptions

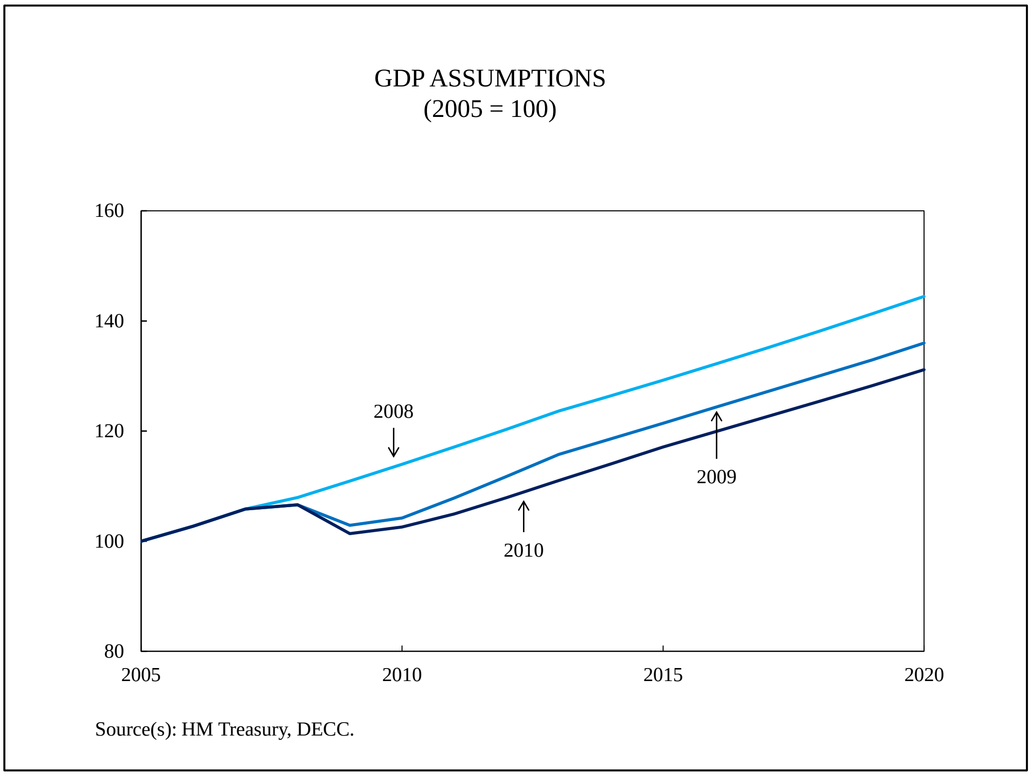
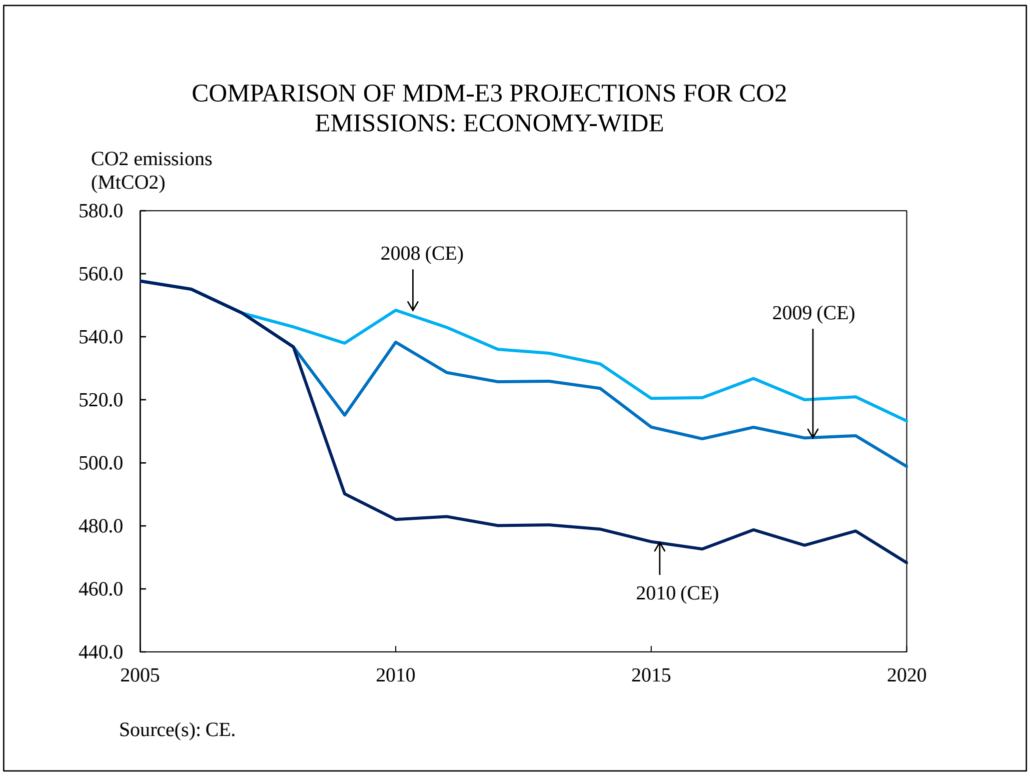


Figure 5.2: Comparison of MDM-E3 Projections for CO2 Emissions: Economy-wide



To better understand each of the driving factors behind the MDM-E3 emissions projections we have divided our analysis of the results to cover five key sectors:

- Industry
- Transport
- Domestic
- Services
- Power generation

Industrial output varies substantially between the model runs with implications for industrial energy consumption

Industry output varies quite substantially between the three runs; by 2020 industrial economic activity is 14.3% lower in the 2009 run compared to the 2008 run, and 7.4% lower in the 2010 run compared to the 2008 run. Industry emissions, however, do not follow this same pattern in the MDM-E3 projections. While industrial emissions in the 2008 run are the highest (some 13.5% above the 2009 run in 2020), industrial emissions in the 2010 run are lower than in the 2009 run in 2020 despite increased economic activity (see Figure 5.3 and the DECC equivalent projections in Figure 5.8). This is explained by three factors:

- energy prices
- industry investment
- the industrial fuel mix

Industrial energy prices are highest in the 2010 run

Energy prices faced by industry are the highest in the 2010 run, by 2020. This is a result of the revision to the wholesale gas price assumption made by DECC and, to a lesser extent the revised oil price assumption (which is also higher in the 2010 run), and the impact these assumptions have on the electricity price.

Table 5.1: Factors Affecting Industry Energy Consumption and Emissions in 2020

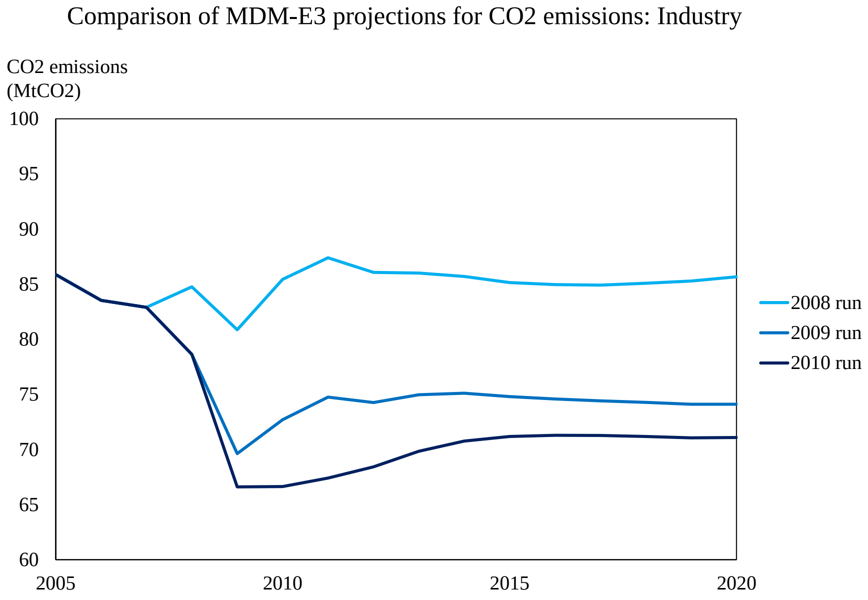
FACTORS AFFECTING INDUSTRY ENERGY CONSUMPTION AND EMISSIONS IN 2020

	2008 run	2009 run	2010 run
Activity indicator (2006 = 100)	127.2	109.3	119.0
Implied average energy price (2006 = 100)	209.0	209.3	287.9
Technological progress indicator (2006 = 100)	149.6	132.0	147.6
Energy consumption (ktoe)	30881	28665	28011
Emissions (MtCO2)	85.7	74.1	71.1

Source(s): MDM-E3, CE.

According to our empirical analysis, the technological progress indicator has a small impact on the energy consumption of most industrial sub-sectors (representing the better energy efficiency characteristics of newer plant). Investment is a function of industrial output in MDM-E3 based on both the theoretical argument that investors seek returns in companies (and therefore sectors) where returns (as measured by output) are greatest and that higher output needs to be supported by higher investment and capacity; the theory is backed up by econometrically estimated investment equations. Technological progress is defined as a function of cumulative investment – adjusted for the proportion of investment which is R&D related. As a result, and because of the dynamic structure of the model, the relationship between technological

Figure 5.1: Comparison of MDM-E3 Projections for CO2 Emissions: Industry



Source(*s*): CE.

progress and industry output is not linear. However, as the economic growth assumptions are stronger in the 2010 run, technological progress is 11.9% higher by 2020 in the 2010 run when compared to the 2009 run (see Table 5.1).

These two factors (price and investment) explain why energy consumption in the 2010 run is lower than the 2009 run in the MDM-E3 projections. However, total energy consumption is only 2.2% lower by 2020, while emissions are 3.9% lower. The remaining difference is explained by the fuel mix. The fuel mix is quite different between the 2009 run and the 2010 run, mostly as a result of changes in relative prices, but also because the impact of economic activity and investment on the consumption of the various fuels differs across sub-sectors. By 2020 industrial consumption of gas, oil and coal are all projected to fall (-6.4%, -4.1% and -5.5% respectively), while electricity demand increases by 5.0% in the 2010 run.

Domestic energy consumption and emissions do not follow the same pattern as income between the runs

There are substantial differences in household expenditure between the three model runs. Household activity (expenditure) in 2020 is 7% lower in the 2009 run as compared to the 2008 run, and 13% lower in the 2010 run as compared to the 2008 run. But while household emissions in the 2010 vintage are at the lowest level (around 7% below the 2009 vintage and 2% below the 2008 vintage in 2020), emissions in the 2009 vintage are 6% *above* the 2008 vintage in 2020, despite the fact that economic activity is considerably lower (see Table 5.2).

Table 5.2: Factors Affecting Domestic Energy Consumption and Emissions

FACTORS AFFECTING DOMESTIC ENERGY CONSUMPTION AND EMISSIONS IN 2020

	2008 run	2009 run	2010 run
Activity indicator (2006 = 100)	140.4	130.4	122.3
Implied average energy price (2006 = 100)	239.3	213.1	354.9
Investment in dwellings (2006 = 100)	159.2	106.0	101.3
Energy consumption (ktoe)	40967	43189	40379
Emissions (MtCO2)	73.7	78.2	72.3

Source(s): MDM-E3, CE.

This result can be explained by a combination of three factors:

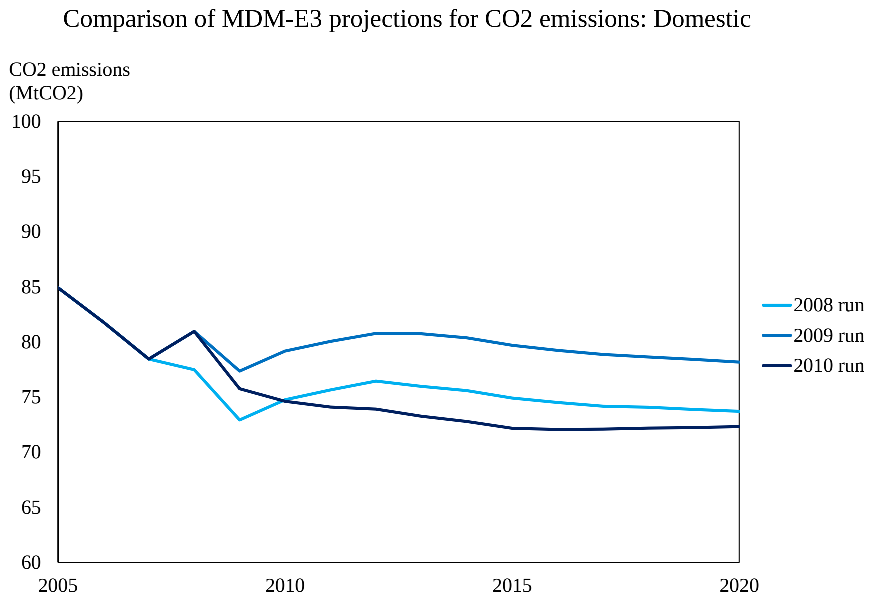
- energy prices
- investment in dwellings
- household energy mix

The collapse in economic activity reduces investment in dwellings in the 2009 run

In the 2009 run, energy prices faced by the domestic sector were at their lowest level compared to the other two runs, by 2020. Moreover, investment in dwellings in the 2009 run was 33% below the 2008 run as a result of the recession, this pushes up the energy demand projection in this run because investment in dwellings is estimated to have a negative impact on domestic energy consumption. This can be because the investment is directly aimed at improving energy efficiency through, as an example, improved insulation, or because of indirect effects – investment into a conservatory might improve the overall air-tightness of a building.

In the 2010 run, energy prices faced by households were the highest and the activity

Figure 5.2: Comparison of MDM-E3 Projections for CO2 Emissions: Domestic



Source(s): CE.

levels were the lowest, compared to the other two runs. This explains why energy demand in the 2010 run is lower than the other two vintages in MDM-E3 (6.5% lower as compared to the 2009 run). However, the level of investment in dwellings was 36% below the 2008 run and as a result, the difference in energy demand between the 2010 run and the 2008 run is quite small (-1.5% by 2020).

Services

Economic activity in the services sector (as measured by gross output for a combination of public administration and private services) varies considerably between the three model runs. By 2020, activity in this sector was 13% lower in the 2009 run as compared to the 2008 run, and 2% higher in the 2010 run as compared to the 2008 run. Despite this, by 2020, emissions in the services sector were 18% and 15.5% *higher* in the 2009 and 2010 runs as compared to the 2008 run, while energy consumption is highest in the 2008 run and substantially reduced in the 2010 run (see Table 5.3).

The differences in emissions between the runs can be explained by three factors

- energy prices
- investment (as a factor of economic activity)
- fuel mix

Energy prices faced by the services sector were the highest and energy consumption was the lowest in the 2010 run. This was primarily due to higher gas price assumptions. In the three runs, changes in activity drive changes in investment which have an offsetting impact on energy consumption.

Table 5.3: Factors Affecting Services Energy Consumption and Emissions in 2020

FACTORS AFFECTING SERVICES ENERGY CONSUMPTION AND EMISSIONS IN 2020

	2008 run	2009 run	2010 run
Activity indicator (2006 = 100)	125.6	108.1	127.1
Implied average energy price (2006 = 100)	254.7	196.6	352.4
Technological progress indicator (2006 = 100)	132.5	116.4	130.4
Energy consumption (ktoe)	18411	18206	17152
Emissions (MtCO2)	20.5	23.7	22.8

Source(s): MDM-E3, CE.

CO2 emissions do not follow the pattern of energy consumption because the fuel mix is altered by the relative shifts in energy prices. In the 2008 run electricity is relatively cheaper compared to gas. By 2020, electricity accounts for 62% of the fuel mix in services, compared to 55% and 54% in the 2009 and 2010 runs respectively.

Transport emissions are lowest in the 2010 run, as a result of lower real incomes and higher energy prices

Of the three runs, emissions after the recession from transport are lowest in the 2010 run. The largest reductions between runs are seen in road transport, by far the biggest transport sector in terms of fuel demand and emissions. By 2020, transport emissions are 5.5% lower in the 2010 run when compared to the 2008 run. Emissions are 3% lower in the 2009 run compared to the 2008 run, again, in 2020 (see Table 5.4).

Table 5.4: Factors Affecting Road Transport Energy Consumption and Emissions in 2020

FACTORS AFFECTING ROAD TRANSPORT ENERGY CONSUMPTION AND EMISSIONS IN 2020

	2008 run	2009 run	2010 run
Household Income (2006 = 100)	138.9	131.2	123.1
Implied average energy price (2006 = 100)	213.7	186.3	175.4
Energy consumption (ktoe)	38484	37484	36370
Emissions (MtCO2)	104.9	102.0	98.8

Source(s): MDM-E3, CE.

The main factor driving the lower emissions from road transport in the more recent runs is lower household income, which is:

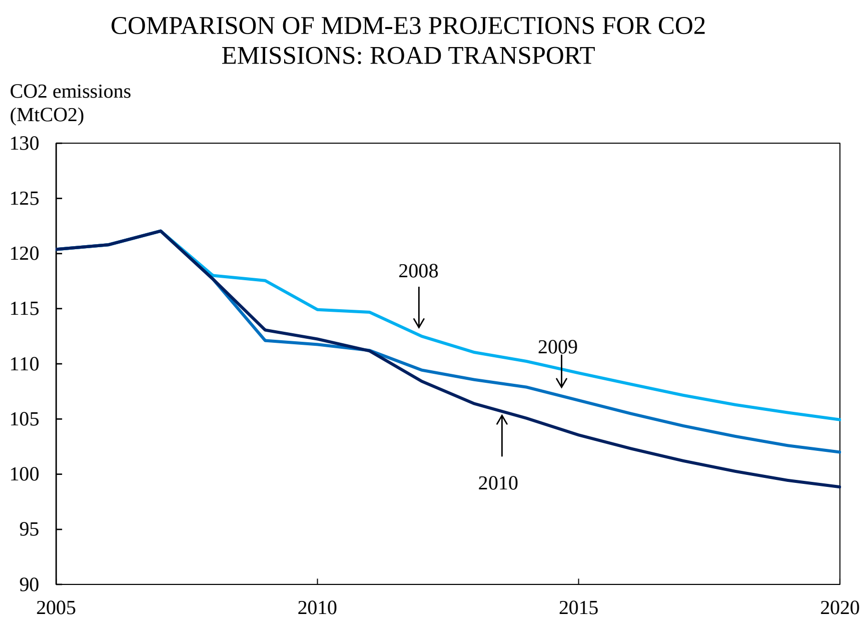
- 5.5% lower in 2020 in the 2009 run compared to the 2008 run
- 11% lower in 2020 in the 2010 run compared to the 2008 run

Lower incomes lead to lower travel demand in the 2009 and 2010 runs. Incomes are lowest in the 2010 run, leading to the lowest levels of travel demand by 2020.

There is increased fuel efficiency from technological progress as a result of stronger economic growth

Fuel demand and emissions are slightly lower in the 2010 run than is implied by the lower travel demand, owing to a small increase in the average fuel efficiency of the UK vehicle stock. This occurs because of a pick-up in technological progress as a result of stronger economic growth. . Fuel consumption per kilometre is thus slightly lower, leading to lower fuel demand for a given amount of travel demand.

Figure 5.3: Comparison of MDM-E3 projections for CO2 emissions: Road Transport



Source(s): CE.

Power generation emissions are lowest in the 2010 run as a result of low electricity demand

End-user demand for electricity in 2020 is lowest in the 2010 run and highest in the 2008 run and electricity supply follows the same pattern, since autogeneration/CHP supply is accounted for in power generation in MDM-E3. Similarly, emissions from power generation are lowest in the 2010 run in that year and highest in the 2008 run, although these changes are not fully aligned with the changes in energy demand owing to changes in the generation mix.

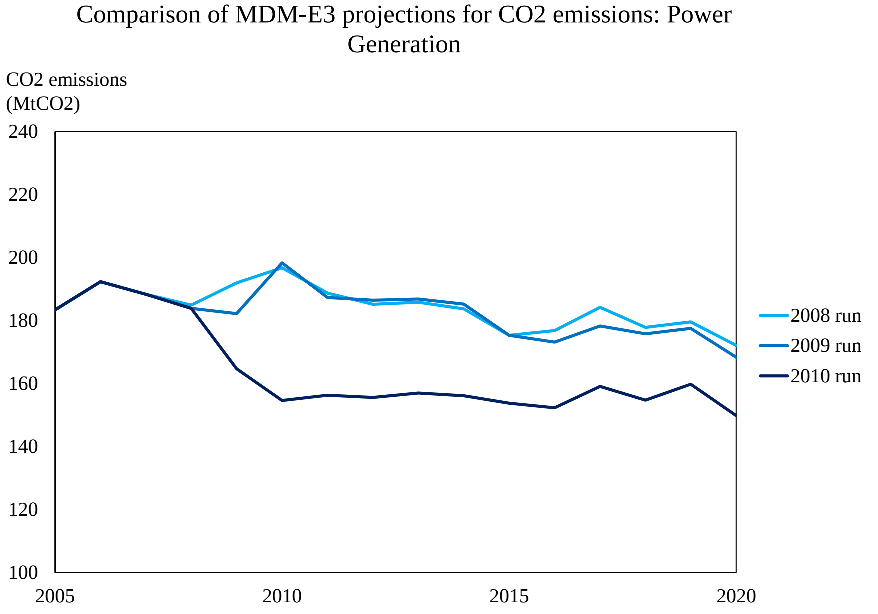
Projections of generation capacity to 2020 differ little between the runs owing to the relative shortness of the projection period, giving limited time for new investment beyond that already known or planned. The differences in capacity are more a reflection of the projections having different last years of 'history'. The 2009 and 2010 projections incorporate more recent data that show UK capacity (principally, gas-fired capacity) to have been slightly higher than that projected by MDM-E3 in the 2008 run.

The last year of data impacts on the generation mix, particularly in nuclear generation as a result of outages in 2008

The last year of history has similar impacts on the composition of the generation mix across the three runs. This is seen most clearly in the amount of electricity generated from nuclear power.

In the 2008 run, electricity generated from nuclear power is largely flat to 2012, with decreases thereafter explained by the closure of aging sites. New nuclear capacity comes online in the later part of the period (in all runs), leading to an increase in generation.

Figure 5.4: Comparison of MDM-E3 projections for CO2 emissions: Power Generation



Source(s): CE.

In contrast, the outturn data for 2008 show a fall in generation from nuclear power owing to extended periods of maintenance and repairs. This carries through to the remainder of the projection period in the 2009 run, leading to a step change in the profile of nuclear generation. In other words, in MDM-E3 we assume that the level of downtime for a particular technology follows the last year of history. However, in this case there is evidence to suggest that the downtime of nuclear power generation was greater than usual, but by contrast there is also evidence suggesting that more repair and maintenance work will be required as the nuclear stock ages. While electricity demand is lower in this run, there is still a gap to be met from the lower nuclear generation. This gap is met by an increase from other forms of generation that are more carbon-intensive than nuclear power. While electricity generation is around 5% lower in 2020 in the 2009 run compared to the 2008 run, emissions are just 2% lower.

The combined impact of higher nuclear generation and lower demand for electricity lead to quite substantial differences in power generation emissions in the 2010 run

Compared to the 2008 run, emissions from power generation in the 2010 run are around 13% lower in 2020, with the amount of electricity generated around 6% lower. The contrast between the result from this run and that of the 2009 run (2% reduction in emissions from a 5% reduction in generation) is again due to the effect of new outturn data on nuclear generation. Data from DUKES 2010 show that, following the outages in 2008, electricity generation from nuclear power increased substantially. The share of electricity generated from nuclear sources is the highest in the 2010 run, reducing the carbon intensity of power generation, leading to a further reduction in emissions on top of the lower level of generation.

5.4 Comparison of emissions projections with those from the DECC Energy Model

This section draws a comparison between energy and emissions projections in the DECC model and MDM-E3

This section draws a comparison of emissions projections between the MDM-E3 model analysis, as presented in the previous section, and the DECC model analysis. It is worth noting that while the economic and price inputs between the DECC model runs and the MDM-E3 runs have been standardised as far as possible, certain differences remain. The main difference is the treatment of the power sector, where the two models rely on different modelling treatments and different data classifications. However, it is still possible to draw broad conclusions. Another difference between the two models is the calibration to emissions data across differing classification categories, which makes a comparison of levels difficult[23]; and so for the most part this is a discussion of the relative differences between the three runs in each model. At an economy-wide level, the sets of projections differ quite markedly between the MDM-E3 projections and the DECC Model Projections (see Table 5.5 and Figure 5.7).

Table 5.5: Comparison of Energy Consumption and Emissions between the DECC and CE MDM-E3 Model Runs

COMPARISON OF ENERGY CONSUMPTION AND EMISSIONS IN 2020 BETWEEN THE DECC AND CE MDM-E3 MODEL RUNS

	CE Projections			DECC Projections		
Final Energy Consumption (ktoe)	**2008**	**2009**	**2010**	**2008**	**2009**	**2010**
Total (excl non-road transport)	128742	127545	121912	136302	132884	135460
Industry	30881	28665	28011	31328	26392	30011
Domestic	40967	43189	40379	39477	43407	42794
Services	18411	18206	17152	21389	21185	21699
Road Transport	38484	37484	36370	44108	41900	40957
Emissions (MtCO2)	**2008**	**2009**	**2010**	**2008**	**2009**	**2010**
Total (excl non-road transport, refineries and LULUCF)	457	446.4	414.9	437.5	437.5	436.6
Industry	85.7	74.1	71.1	103.5	106.7	105
Domestic	73.7	78.2	72.3	65.5	71.5	71.8
Services	20.5	23.7	22.8	23.7	25.6	25.3
Road Transport	104.9	102	98.8	120.4	114.4	111.7
Power Sector	172.2	168.4	149.9	124.5	119.3	122.8

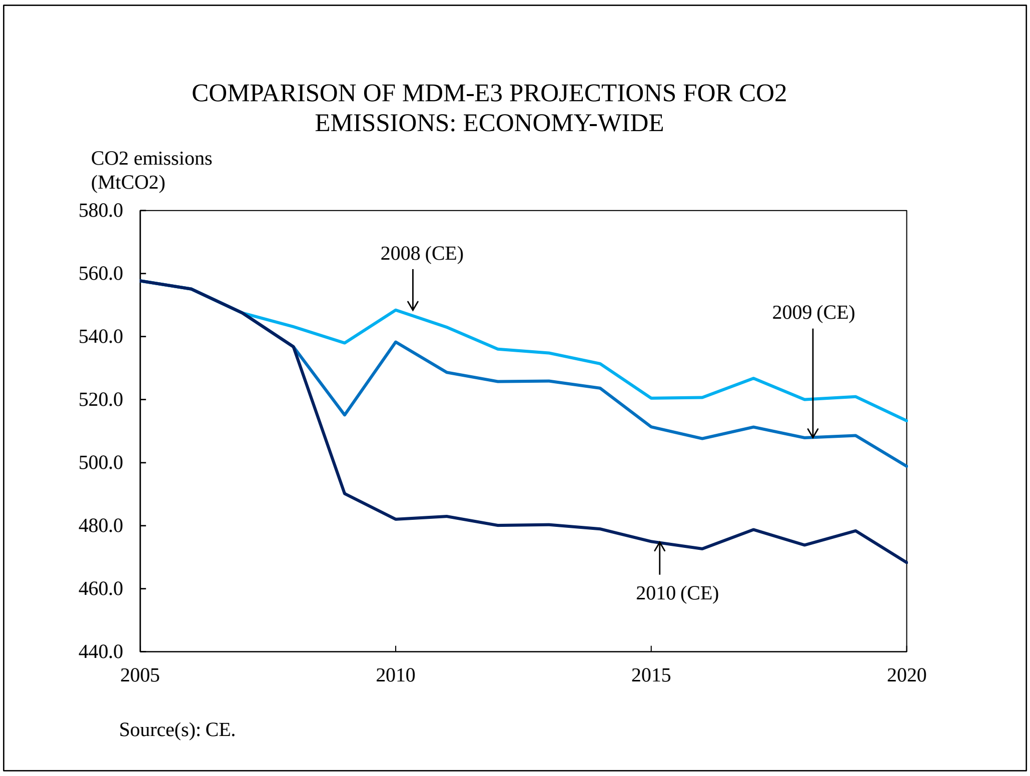
Note(s) DECC CO2 emissions for industry include industrial energy combustion emissions, process emissions and emissions from autogeneration and energy supply industries. CE's emissions for industry include industrial energy combustion emissions and process emissions, while autogeneration emissions are attributed to power generation. For both sets of projections, energy consumption from industry does not include autogeneration or energy supply industries own use of energy

Non-road transport emissions have been excluded because of differences in accounting aviation and maritime emissions between the two models. Emissions from LULUCF are also omitted from both sets of projections.

Source(s): DECC and CE.

[23] Emissions arising from the Domestic, Services and Transport sectors are comparable, while MDM-E3's definition of Power Generation includes 'Autogeneration' and MDM-E3's 'Industry' definition does not include autogeneration or the energy supply industries.

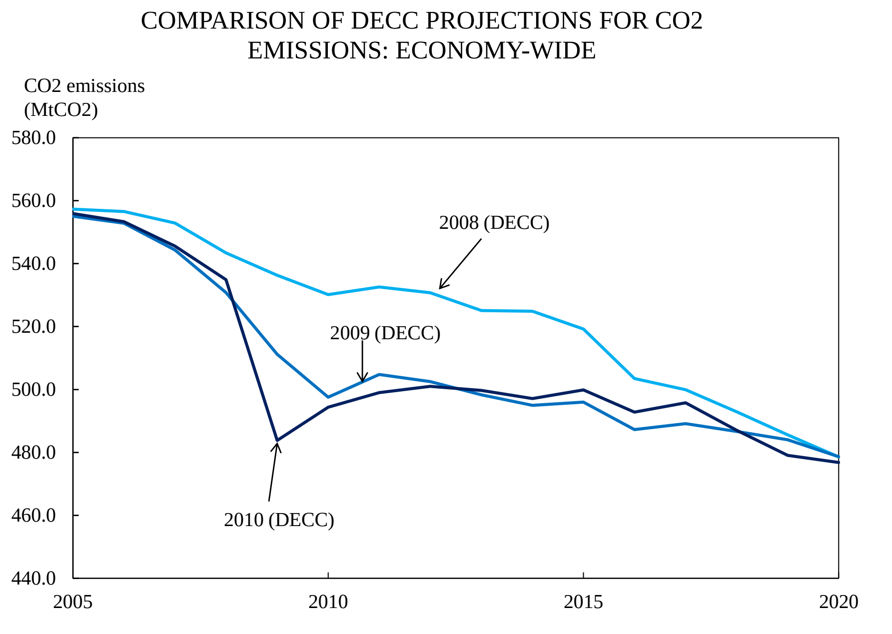
Figure 5.5: Comparison of MDM-E3 Projections for CO2 Emissions: Economy-wide



Most notably, emissions projections from the DECC Energy Model broadly return to the same values by 2020 in each of the three runs, while large differences persist in the MDM-E3 projections: emissions in 2020 are over 40 MtCO2 lower in the 2010 MDM-E3 run than in the 2008 run, compared to a difference of less than 1 MtCO2 in the equivalent DECC projections. In summary, this can be explained by three key reasons:

- Industry emissions are substantially lower in the MDM-E3 runs in 2009 and 2010 relative to the 2008 run because in these runs economic activity is lower and energy prices are higher (particularly in the 2010 run). However, economic activity is also lower in the DECC Energy model runs, since we have used the same economic input assumptions, but emissions do not follow this pattern. In the 2009 DECC run, industrial energy demand falls compared to the 2008 run as a result of persistently lower economic activity but emissions remain constant because of strong growth in CHP which shifts emissions from the power sector to the industrial sector in the DECC model. In the 2010 DECC run, energy demand is recovered (compared to the 2009 run) as a result of increased economic output, but emissions remain similar to the 2009 (and 2008) run because CHP (autogeneration) emissions are reduced. Domestic emissions are higher in the 2009 and 2010 runs than the 2008 run in the DECC model, while the 2010 run in the MDM-E3 model falls below the 2008 run level for 2020. In the DECC Energy Model the higher level of emissions is the result of a negative income elasticity, while in the MDM-E3 projections 2009 emissions are higher as a result of lower investment in dwellings , while in 2010, the pick-up in investment in dwellings, the persistence of lower household spending and higher energy prices all combine to lower energy

Figure 5.6: Comparison of DECC Projections for CO2 Emissions: Economy-wide



Source(s): CE.

consumption and emissions considerably compared to the relative changes in the DECC model runs.

- Power sector emissions in the MDM-E3 model are substantially reduced in the 2010 run (compared to the 2008 run) as a result of revisions to data on the different types of generation in the last year of history, combined with lower electricity demand. By contrast, the DECC Energy Model predicts little change in electricity supplied by MPPs, although there is a slight decline in 2009 as electricity from autogeneration increases to 63TWh by 2020 (compared to 46TWh in the 2010 run) displacing MPP generation. However, emissions from the power sector are broadly unchanged between the two runs because the additional power supply comes from low/zero carbon generation technologies.

For a clearer comparison, it is useful to look at the five major sectors in turn:

- Industry
- Domestic
- Services
- Transport
- Power Generation

Industry

As discussed in Section 5.3, the order of industrial CO2 emissions levels in 2020 (from highest to lowest emissions) between the 2008, 2009 and 2010 runs in MDM-E3, does not follow the order of economic output. The ordering of emissions, does however, follow the ordering of energy consumption and this difference is caused by the impact of energy prices and investment on energy consumption (as described in Section 5.3). The DECC projections have different characteristics: energy consumption follows the pattern of output (reflecting the fact that the long-term output elasticities are one for industrial sub-sectors, and other factors have very little impact), but the emissions projections do not follow this pattern (see Table 5.6 and Figure 5.8).

Table 5.6: Energy and Emissions Projections in 2020: Comparing DECC Model Projections with MDM-E3 Projections for Industry

ENERGY AND EMISSIONS PROJECTIONS IN 2020: COMPARING DECC MODEL PROJECTIONS WITH MDM-E3 PROJECTIONS FOR INDUSTRY

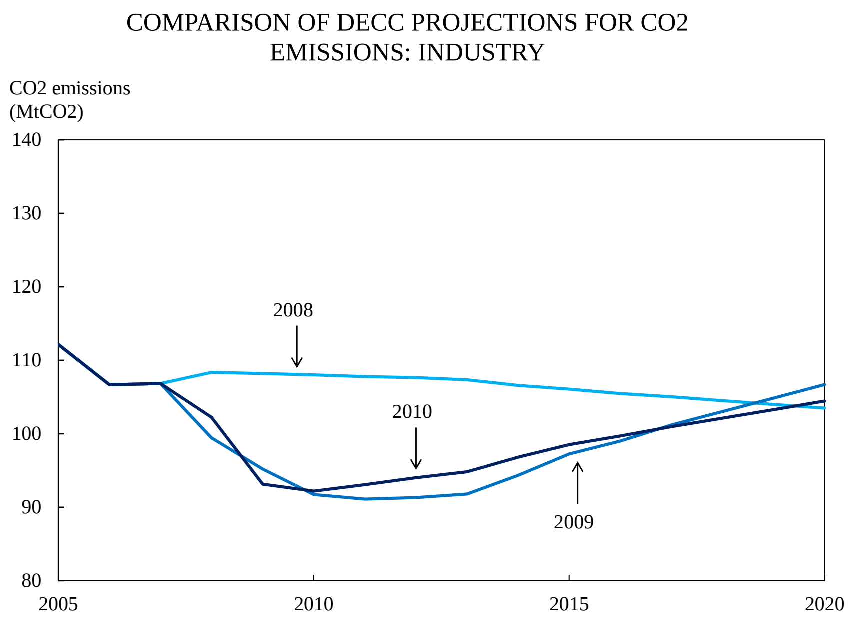
	DECC Model Projections			CE MDM-E3 Projections		
	2008	2009	2010	2008	2009	2010
CO_2 emissions ($mtCO_2$)	103.5	**106.7**	**105.0**	85.7	74.1	71.1
Energy consumption (mtoe), of which:	31.3	**26.4**	**30.0**	30.9	28.7	28.0
Electricity (%)	37.6	37.4	37.8	30.9	30.0	32.3
Gas (%)	39.1	37.9	37.8	40.7	41.6	39.9
Oil (%)	19.6	21.1	19.8	20.5	19.9	19.5
Solid Fuels (%)	3.6	3.6	4.6	4.2	3.9	3.7

Source(s): DECC Energy Model and MDM-E3.
Note(s): MDM-E3 industry CO_2 emissions do not include autogeneration and energy industry emissions. Energy consumption can be compared on a like for like basis.

The change in fuel shares is not sufficient to explain the relationship between CO_2 emissions and energy consumption in the 2009 and 2010 DECC runs

The fact that the ranking of runs in terms of CO_2 emissions is different from the ranking of energy consumption in the DECC run does not seem to be explained by any marked shift in fuel shares. The only explanation for this apparent inconsistency in the DECC model runs therefore seems to be the impact of CHP/autogeneration emissions, but this is not possible to assess with the information currently provided by DECC. The link between energy and emissions in the DECC 2009 run needs to be understood because it has implications for the robustness of the DECC modelling approach, particularly when considering carbon budgets.

Figure 5.7: Comparison of DECC Projections for CO2 Emissions: Industry



Source(s): DECC Energy Model.

Domestic In both the CE and DECC model runs, the 2009 projection set predicts the highest domestic energy consumption in 2020 (see Table 5.7). This occurs, mainly, because the 2009 projection set includes an increase in domestic energy consumption in 2008 (as historical data) which persists throughout the projection period. By contrast, the 2008 projections do not include this data, while the 2010 projections include the 2009 data point, which was a considerable decrease in energy consumption on 2008 levels. However the differences between the three vintages are small, as expected, since outcome is dominated by the growth in the number of households which does not change much between projections (the long-term responses to income and price are small).

Table 5.7: Energy and Emissions Projections in 2020: Comparing DECC Model Projections with MDM-E3 Projections for the Domestic Sector

ENERGY AND EMISSIONS PROJECTIONS IN 2020: COMPARING DECC MODEL PROJECTIONS WITH MDM-E3 PROJECTIONS FOR THE DOMESTIC SECTOR

	DECC Model Projections			CE MDM-E3 Projections		
	2008	2009	2010	2008	2009	2010
CO_2 emissions ($mtCO_2$)	65.5	71.5	71.8	73.7	78.2	72.3
Energy consumption (mtoe), of which:	39.5	43.4	42.8	41.0	43.2	40.4
Electricity (%)	27.8	27.9	26.7	21.8	21.7	22.5
Solid fuels (%)	0.6	0.4	0.9	1.8	1.8	1.8
Gas (%)	66.1	66.0	66.8	69.1	68.9	67.6
Oils (%)	5.6	5.7	5.6	6.3	6.5	6.9

Source(s): DECC Energy Model and MDM-E3.

The fuel mix in the DECC runs is responsive to the growth in the number of households

In each of the DECC model projections there is a shift towards electricity by 2020, while in MDM-E3 the relative shares in each fuel do not deviate greatly from the 2007 shares. As a result, emissions are quite considerably lower in the DECC projections than the MDM-E3 projection (approx. 8-10%) for broadly comparable energy consumption. This trend in the DECC model is a result of a large elasticity (1.7) between the growth in the number of households and electricity demand.

The DECC energy model and MDM-E3 are quite different in the specification of energy demand equations, and so it is difficult to draw robust conclusions explaining the differences between runs

In the domestic sector there are a number of reasons why energy consumption projections, and corresponding emissions projections would vary between the DECC Energy Model and the MDM-E3 projections. As a result it is difficult to draw detailed conclusions about the differences between the DECC projections and the MDM-E3 projections. The MDM-E3 projections of energy consumption for households are based on an aggregate energy consumption equation and a series of fuel share equations, which include the following drivers:

- household expenditure
- air temperature (annual deviation from the long term mean)
- investment in dwellings
- real energy prices

By contrast, the DECC Energy Model separates out the energy demand equations by fuel; the electricity demand equation is a function of:

- household income per household
- number of households
- winter degree days
- real electricity prices

While the gas demand equation is a function of:

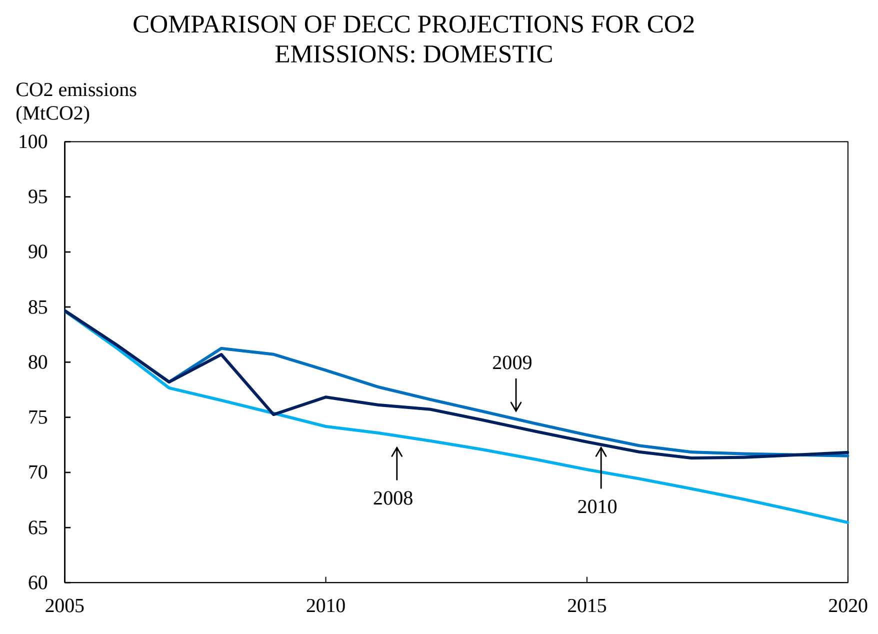
- household income per household
- number of households with gas central heating
- winter degree days
- real gas prices

The main differences, beyond the separation of equations by fuel, can therefore be summarised as follows:

- MDM-E3 includes an investment term to try to reflect the impact of investment in dwellings on long-term energy consumption. This investment term is linked to economic factors and therefore possibly underestimates the role of new policy on domestic efficiency improvements. By way of comparison, the DECC projections attempt to account for this by making a series of off-model adjustments, based on policy assessments.
- MDM-E3 uses household spending, rather than income, as the main driver of domestic energy consumption. This is intended to allow for a first decision by households between spending and saving. This had important implications in the recession period, as incomes actually increased in 2009, while real household spending collapsed as households rebalanced their finances – energy consumption also decreased markedly in 2009.
- MDM-E3 uses an aggregate household spending term, rather than a per household spending term, since the impact of increasing population (which is highly correlated with the increase in the number of households) is a key driver of aggregate household spending. This means that the number of households does not need to be included as an explanatory variable as it is in the DECC model.
- The DECC model is estimated over the period 1980-2004, while the MDM-E3 parameters are estimated over the period 1970-2009 and so the MDM-E3 parameters include the impact of recent policy initiatives.
- The DECC model does not include a time trend (or any other term) to try to account for improvements in energy efficiency.

It is perhaps surprising, then, that the projections are reasonably similar between the 2008 and 2009 CE and DECC model runs (see Figures 5.9 and 5.4, and Table 5.7),

Figure 5.8: Comparison of DECC Projections for CO2 Emissions: Domestic



Source(s): DECC Energy Model.

with the main difference being the shift towards electricity in the DECC model projections. In the MDM-E3 runs, the impact of investment in dwellings offsets the impact of higher (or lower) economic activity, while in the DECC model there is a (counter-intuitive) negative response of energy consumption to the changes in real incomes.

In the long term, the MDM-E3 results are also more strongly affected by the impact of the last year of data, this is particularly noticeable in the 2010 run following the sharp reduction in energy consumption in 2009: in the MDM-E3 run this impact persists whereas in the DECC Energy Model the discrepancy is treated as a transitory shock. In the DECC 2010 run there is also slightly less of a shift towards electricity consumption, while in MDM-E3 there is more of a shift towards electricity in 2010, compared to the other runs. This is a result of relative fuel prices and the differences between household spending and investment on the various fuel share equations in MDM-E3. By contrast the income elasticities for electricity and gas (the two main fuels used by households) are both -0.03; in other words, the level of income has a negligible bearing on the household fuel mix in the DECC model. Moreover, the investment effect in MDM-E3 is persistent, as investment leads to an accumulation of more efficient capital stock over time; such investment is slowed in the recession.

The most surprising feature of the DECC model is that the income elasticities for both gas and electricity consumption are negative and very small, while the equivalent elasticity (between household expenditure and household energy consumption) in MDM-E3 is significant and positive.

Services The main difference in the results for energy consumption between the two models is that in MDM-E3 the 2010 run has a lower outcome than the 2008 and 2009 runs, whereas in the DECC model energy consumption follows activity. This reflects the impact in MDM-E3 of higher energy prices in the 2010 run.

In the DECC projections, emissions are higher compared to the MDM-E3 runs because MDM-E3 has a higher share of electricity (see Table 5.8).

Table 5.8: Energy and Emissions Projections in 2020: Comparing DECC Model Projections with MDM-E3 Projections for the Services Sector

ENERGY AND EMISSIONS PROJECTIONS IN 2020: COMPARING DECC MODEL PROJECTIONS WITH MDM-E3 PROJECTIONS FOR THE SERVICES SECTOR

	DECC Model Projections			CE MDM-E3 Projections		
	2008	2009	2010	2008	2009	2010
CO2 emissions (mtCO2)	23.7	25.6	25.3	17.6	20.8	20.3
Energy consumption (mtoe), of which:	21.4	21.2	21.7	16.4	16.2	15.5
Electricity (%)	43.3	44.0	43.6	61.6	55.4	54.3
Solid fuels (%)	50.3	49.5	48.9	31.4	37.8	38.5
Gas (%)	5.7	5.8	6.3	4.2	4.0	4.0
Oils (%)	0.1	0.1	0.6	0.1	0.1	0.3

Source(s): DECC Energy Model and MDM-E3.
Note(s): Energy data in the DECC model is higher in the history than DUKES and MDM-E3.

Road Transport The ranking of emissions projections from road transport across the three runs is the same in the DECC Model and MDM-E3, but the underlying trend in all three runs is different in the two models: the DECC Model has emissions recovering with activity after the recession (Figure 5.10), whereas MDM-E3 has a continued fall reflecting the impact of higher prices over time (in all three runs) (Figure 5.5).

It is much more difficult to explain the differences in emissions outcomes between the DECC Model and MDM-E3 for transport than for industry, domestic and services because although the high-level theory behind each model is broadly similar, the detailed treatment in the two models is quite different.

Fuel demand and emissions from air, rail and water transport are small in comparison to those of road transport and it is thus the projections for road transport that drive the results for the transport sector as a whole.

Demand for fuel for private road transport in the DECC Model is driven by:

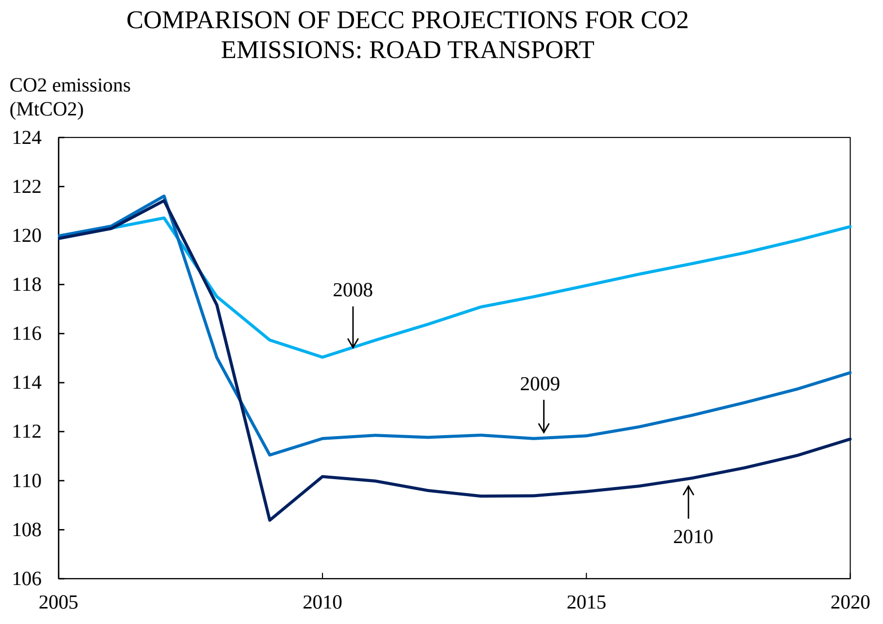
- income per household
- fuel prices
- car ownership

All the above represent drivers of travel demand with car ownership acting as a measure of capacity. Car ownership is in turn determined by income per household.

Commercial demand is linked to GVA with a 1% increase in GVA linked to a 0.97% increase in fuel demand in the short term, and a 0.19% increase in the long term.

The Oxford Economics (2008a) review notes an implied negative income elasticity in the private road transport equation, rather than the positive value that might be

Figure 5.9: Comparison of DECC projections for CO2 emissions: Road Transport



Source(s): DECC Energy Model.

expected. Given that income is projected to be lower in the 2009 and 2010 runs compared to the 2008 run, other things being equal, emissions would be higher in the more recent runs. However, fuel prices are higher in the later runs and GVA lower, leading to the overall lower emissions.

At a high level, the treatment in MDM-E3's Transport Sub-model is not markedly different, although certain effects are separated more explicitly:

- travel demand is determined by income/activity, prices and the size of the vehicle stock
- fuel demand is derived by applying the average fuel efficiency of the vehicle stock to the travel demand projections

The treatment of car ownership and the vehicle stock is a key difference between the models' treatments and, in MDM-E3, allows fuel efficiency over time to be modelled explicitly. In the DECC Model, efficiency improvements appear to be implicitly captured in the income terms with further off-model adjustments for Voluntary Agreements (which must be adjusted for the efficiency improvements embodied in the DECC Model equation).

MDM-E3 includes a representation of the vehicle stock with inflows of newly-purchased vehicles and outflows of scrapped vehicles. The corresponding fuel efficiencies of new vehicles are also projected by a set of equations to account for increases in fuel efficiency through:

- technological improvement
- consumer preferences for higher efficiency in times of high prices

New vehicles are added to the stock and older vehicles are scrapped such that the older a vehicle is, the more likely it is to be scrapped. The implication of this treatment is that turnover of the vehicle stock and changes in average fuel efficiency are slower than that implied by the DECC Model (in which changes in income can bring about potentially rapid changes in the size[24] of the overall stock – in the DECC Energy Model, vehicle ownership is tied to income and so a large fall in income leads to a large fall in the size of the vehicle stock). The MDM-E3 treatment exhibits a far greater level of path dependence. This permits the analysis of policies such as vehicle scrappage schemes and EU legislation on emissions standards for new vehicles that can, and have been, incorporated into the MDM-E3 projections. In contrast, while the DECC Model does appear to capture some energy efficiency trends, these effects are included in the income terms, making policy analysis more difficult.

Power generation

The treatment of electricity supply, given a set amount of generation capacity, appears to be quite similar in the DECC Model and MDM-E3. Both incorporate the technical characteristics of different plant types (although the levels of detail in these classifications differ) and both operate on a least-cost basis to determine the generation mix, which in turn determines the electricity price faced by end users; both models have feedback to final energy demand.

The DECC model projects much lower carbon intensity per unit of electricity produced than that projected by MDM-E3 (see Table 5.9). This is because, in the projections produced for the CCC, an assumption of 30% renewable generation was

[24] The average fuel efficiency in the DECC model is implicitly unchanged because there are no terms to explain fuel efficiency.

applied, while the MDM-E3 model has a treatment of the EU ETS and the Renewables Obligation which doesn't lead to the required 30% of power generated from renewable sources. In the DECC Energy Model, electricity supply and emissions are lower in the 2009 run, we presume this is partly because more electricity is generated by CHP (which is attributed to industry) rather than a reduction in demand. In 2020, the demand for electricity is 2.4% lower in the 2009 run compared to the 2010 run, while the reduction in generation is 8.3% lower when comparing the same two vintages. The shortfall is partly CHP (autogeneration): CHP emissions are classified to industry not power generation in the DECC Energy Model and CHP electricity generation is 17 TWh lower in the 2010 run (by 2020) compared to the 2009 run.

Table 5.9: Power Sector Electricity Supply and Emissions in 2020

POWER SECTOR ELECTRICITY SUPPLY AND EMISSIONS IN 2020			
	2008	2009	2010
Power Sector Emissions (MtCO2)			
DECC (MPP)	124	119	123
CE MDM-E3 (total)	172	168	150
Electricity Supply (TWh)			
DECC (MPP)	387	362	395
DECC autogeneration		63	46
DECC (total)		425	441
CE MDM-E3 (total)	412	391	386
Carbon Intensity of Generation (kgCO2/kWh)			
DECC (MPP)	0.322	0.330	0.311
CE MDM-E3 (total)	0.418	0.431	0.388

Note(s): Autogeneration is classified to the Power Sector in MDM-E3, but to industry in the DECC model.
MPP is a standard acronym for Major Power Producers, see DUKES (2010) for a list of companies defined as MPPs.
Source(s): CE and DECC.

The Oxford Economics (2008a) review suggests that the DECC Model is able to project new investment in future electricity generation capacity although the specifics of this treatment are not covered, making it difficult to draw comparisons with the Energy Technology Model in MDM-E3, which fulfils a similar role. The capacity projections in MDM-E3 change little between runs, reflecting the short projection period relative to the time it takes to construct new plant and possibly in keeping with the IEA (2011) assertion that a large proportion of power-sector emissions in 2020 are already 'locked in'.

5.5 Concluding Remarks

In this chapter, we have assessed the differences between two sets of model projections based on similar inputs. The results suggest that the MDM-E3 runs are more reactive to changes in economic growth, revisions to the recent historical data, and to energy prices: emissions in 2020 are projected to be over 40MtCO2 lower in the 2010 run than in the pre-recession 2008 run, compared to difference of just 1MtCO2 in the DECC model. Furthermore, the MDM-E3 results for most sectors also include the impact of a technological progress indicator which in turn is linked to economic development.

It is not clear that the MDM-E3 projections are better or worse than the DECC model projections. They provide an alternative view which suggests that following the recession, emissions could be significantly lower (up to 40 MtCO2) in 2020 than projected by the DECC model for a number of reasons. First that the recent historical data impacts on the long term MDM-E3 results more than the DECC Energy model results because of the treatment of the residual error. It is a matter of judgement as to whether the residual error should be treated as transitory or permanent, but we recommend that if the DECC Energy Model equations exhibit systematic bias, that the residual treatment should be treated as permanent.

We also note that both the price and investment terms make a difference to the projections. We recommend that DECC considers the re-estimation of the model parameters to assess whether there is scope to include a price term for industry sectors, this is particularly important because the introduction of a carbon price is central to DECC's emissions reductions policy, and so it seems inconsistent that the aggregate energy demand equations for industry are completely unresponsive to price.

The introduction of an investment term which is linked to economic growth is much more difficult to introduce, since it requires a detailed whole-economy model. However, the introduction of a capital stock term (or proxy) would allow for more detailed projection analysis and force the modeller to consider future changes to the capital stock; an economic factor which is particularly affected during and post-recession.

6 Review of Alternative Modelling Approaches

The final part of the project is to 'assess wider evidence from energy and emissions modelling, particularly for the industrial sector, and draws implications for modelling approaches for the UK'. This chapter summarises the findings from this research.

6.1 Summary of the characteristics of the models that have been reviewed

In addition to the DECC Model, we have reviewed seven other models…

Table 6.1 below presents a summary of the characteristics of the models we have reviewed, which are:

- the DECC Energy Model
- E3ME (Cambridge Econometrics)
- E3MG (University of Cambridge and Cambridge Econometrics)
- MDM-E3 (Cambridge Econometrics)
- Medpro (Enerdata)
- POLES (Enerdata)
- WEM (IEA)
- PRIMES (E3M Lab, Athens)

…and AEA has reviewed the NEMS model

We have also included summary analysis of the NEMS model taken from AEA's more detailed report of the NEMS model 'Comparative Review of the DECC Energy Model', (AEA 2011).

Partial equilibrium approaches view the energy system in isolation from the rest of the economy

The models reviewed are a mixture of 'partial equilibrium' models and economy-wide models. This distinction separates modelling approaches that view the energy system in isolation from the rest of the economy (partial equilibrium) from approaches that represent the energy system as one element of the economy. The latter approach is characterised by two-way feedback between the energy system and other sectors of the economy. Changes in the energy system affect other sectors and changes in the economy in turn feed back into the energy system. Equally, changes in the energy system can lead to changes in its own inputs. Partial approaches on the other hand, take the rest of the economy as exogenous, solving the energy system *given* a set of fixed inputs. The rest of the economy is assumed not to react.

Bottom-up approaches rely on engineering-based representations of technology

The approaches embodied in the above models differ. Some are classified as 'bottom-up' models which are specified at the level of individual agents and processes. In energy modelling, this approach is usually engineering-based with the emphasis on individual agents and processes that give rise to macro-level behaviour when they interact during simulation.

Conversely, the focus of a 'top-down' model is to achieve some abstraction of the system and the aggregate behaviour of groups of agents. This does not mean that they cannot possess a high level of detail; but that the factors that drive these models are typically more aggregated. For example, a top-down model might capture the general effect of investment in energy efficiency measures on energy demand, whereas a bottom-up model would explicitly identify the measure and its technological characteristics.

As will be seen, it is common for models to be hybrids of top-down and bottom-up approaches, to make best use of the available data.

E3ME E3ME is an energy-environment-economy (E3) model for Europe, primarily used for scenario analysis. It is a macro-sectoral econometric model. The scenarios are constructed as variants around baseline projections consistent with projections published by the European Commission (EC) and International Energy Agency (IEA). E3ME has explicit two-way linkages (ie feedbacks) between the economy, energy systems, and the environment. The model includes an endogenous treatment of technical progress based on (R&D-adjusted) cumulative gross investment, to account for effects such as increasing energy efficiency. Because investment is determined within the model, technical progress (and energy efficiency) responds to changes in economic activity such as those seen in the recession. This is in contrast to a time trend to represent changes in efficiency, which is used as an exogenous input to many modelling approaches and which does not change with economic conditions. The specification of E3ME would be considered, for the most part, top-down, with equations for individual countries and sectors. Energy demand is projected by sector and then disaggregated according to a set of fuel share equations. There is a special bottom-up treatment of the power generation industry distinguishing different types of generating plant.

E3MG The E3MG model has a very similar structure to E3ME but its scope is global rather than European.

MDM-E3 MDM-E3 is used to produce annual forecasts of energy demand for the UK economy and is also suitable for scenario analysis. It shares most of the characteristics of E3ME and E3MG but its coverage is limited to the UK. It is also a macro-sectoral econometric (E3) model, which provides a detailed disaggregation of both the energy and economic systems and includes a representation of the two-way interactions between the two systems. It follows a similar treatment for technology as described in the above paragraph on E3ME.

MedPro MedPro is a national energy demand forecasting model which can be set up to different datasets for different countries. It provides a partial equilibrium analysis in that it takes assumptions for economic activity and prices. It is a bottom-up model in which energy demand is represented at a detailed level (equipment, uses, etc). Our access to detailed information on MedPro is limited.

POLES POLES is a model of the world energy system, which is primarily used to produce annual estimates of energy demand. The model takes macroeconomic and demographic factors as exogenous, thus generating a partial equilibrium solution for the global energy system. The model is a hybrid of top-down econometric equations and detailed bottom-up, engineering-based representations of energy-consuming processes. Endogenous technological improvement, in the form of cost reduction through learning is possible within the model.

WEM WEM is a partial equilibrium global model, which is used to explain energy demand from key world regions. It is primarily used for scenario/policy analysis and information flows from the economy to energy demand are one-way only. In the WEM model, technology is treated exogenously and differentiated across energy users

PRIMES PRIMES is a partial equilibrium model used for forecasting and scenario analysis. It is designed to produce five-yearly forecasts for Europe. PRIMES incorporates top-down economic drivers with a bottom-up (process) driven treatment of energy demand by sector, based on market optimisation. A major focus of the model is to represent different technologies that are now available or will be available in the future.

The DECC Energy Model

The DECC Energy Model is a set of top-down econometrically-estimated model used to produce annual forecasts for energy demand for the UK. It is a partial model, with exogenous assumptions for the economy. Its treatment of technology is to include a time trend to capture improvements in energy efficiency.

Table 6.1: A Summary of Alternative Modelling Approaches

A SUMMARY OF ALTERNATIVE MODELLING APPROACHES							
Model name	**Primary use**	**Frequency**	**Modelling approach**	**Scope**	**Geographical coverage**	**Treatment of technologies**	**Treatment of energy and economy**
E3ME	Scenario analysis	Annual	Top-down econometric and bottom-up (power generation only)	General	Europe	A top-down approach for technological change, which is treated endogenously. Technology is specified as a function of investment and R&D. Bottom-up approach used for technologies in power generation	Two-way feedbacks
E3MG	Scenario analysis	Annual	Top-down econometric and bottom-up (power generation only)	General	World	Same as above	Two-way feedbacks
MDM-E3	Forecasting energy demand and scenario analysis	Annual	Top-down econometric and bottom-up (power generation only)	General	UK	Same as above	Two-way feedbacks
MedPro	Forecasting energy demand	Annual	Bottom-up	Partial	National	Unknown, but bottom up characteristic suggests an endogenous selection of future technologies.	The rest of the economy is exogenous
POLES	Forecasting energy demand	Annual	Top-down econometric and bottom-up	Partial	World	Where energy demand is econometrically projected, energy efficiency is trend-based. Bottom-up approaches elsewhere (eg power generation) model changes in technology endogenously based on changes in the costs of competing technologies. Learning rates can be modelled, reducing costs over time.	The rest of the economy is exogenous
WEM	Scenario analysis	Annual	Top-down econometric and bottom-up	Partial	World	Energy efficiency is represented: energy consumption per unit of output is projected econometrically for industry and there are bottom-up technology choices in power generation, household appliances and vehicle purchases.	The rest of the economy is exogenous

A SUMMARY OF ALTERNATIVE MODELLING APPROACHES

Model name	Primary use	Frequency	Modelling approach	Scope	Geographical coverage	Treatment of technologies	Treatment of energy and economy
PRIMES	Scenario analysis	Five year periods	Top-down econometric and bottom-up	Partial	EU	Bottom-up approach for technological changes, which are treated endogenously to determine different technologies in future. The model uses a list of alternative technologies, which are differentiated by various economic characteristics such as plant size, fuel type, cogeneration techniques, country and type of producer. However, the availability of future technologies at different points in time is determined by an exogenous parameter. Bottom-up approach used for technologies in power generation	The rest of the economy is exogenous
DECC Model	Forecasting energy demand	Annual	Top-down econometric	Partial	UK	Top-down approach, with a time trend for technological changes	The rest of the economy is exogenous
NEMS	Forecasting energy demand and scenario analysis	Annual	Top-down econometric combined with bottom up process	General	US	Effectively a bottom-up optimizing model, with four overarching modules to deal with supply, demand, conversion (ie power and refineries) and an integration module to bring in macro-economic factors and global fossil fuel prices	Two-way feedbacks to macroeconomic module

Source(s) : Cambridge Econometrics.

6.2 Criteria for reviewing models

We set out here the criteria that we would ideally use to assess the value of alternative modelling approaches that might be used in the UK. This provides a prompt for the kind of information that has been sought about the various approaches, although in practice (as seen in the review in Section 6.3) the information is not always available.

Accuracy of forecasts In principle, we should have greater confidence in a modelling approach which has a track record in producing forecasts that are close to actual outturns than one whose forecasts have been wide off the mark. In practice, this criterion is not particularly useful in the present context. In order to be operational, the criterion requires data to be gathered on forecasts published at particular dates and a comparison with outturns. This is feasible for, say, one-year ahead forecasts, since it is only necessary to wait a year until the outturn is available, but forecasts for ten or more years ahead cannot be assessed until a decade later. Hence, the most that could be achieved would be to examine the performance of forecasts made a decade ago for models that have been in existence that long, but these may not be relevant as a benchmark for future forecasting performance: new factors may need to be taken into account in the coming decade which did not apply in the past decade, and in any case the model may have been developed and adapted during the past decade so that its forecasting accuracy can no longer be judged by an assessment of the accuracy of old forecasts.

Ability to reproduce history We may have more confidence in a modelling approach if it reproduces reasonably well the characteristics of past experience. In the present context that would include how well the model captures the main long-term trends, and it might include how well it captures the experience during the recession and recovery. The emphasis here is different from the first criterion, in that a model may capture the past well but may never have been used for forecasting, and a model might be used for forecasting without ever having been solved to reproduce past history. The weight to be given to this criterion depends upon how relevant historical experience is thought to be as a guide to future developments.

Whether it incorporates all relevant drivers This is a key test of the logical appeal of a modelling approach: does it explicitly incorporate the factors that theory or intuition suggest are important in determining energy use and emissions. By their nature, models are a simplification of reality, and so no model will (or should) incorporate everything: the question is whether the approach captures the essential drivers. In Section 6.3 below we comment on certain issues in the DECC model’s treatment of particular drivers and compare this treatment with that followed in other models.

Sectoral detail This is another key test of logical appeal, in the context of forecasts of energy demand and emissions. Because the energy-using characteristics and technological opportunities of different sectors of the economy vary greatly, it is essential for the model to distinguish sufficient sectoral detail to allow important differences to be identified separately.

Peer review comments We will have more confidence in a modelling approach if it is well-regarded within the energy modelling community.

Adaptation in the light of the experience of the recession This study has been prompted by the way in which the experience of the recession has affected long-term projections of energy demand and emissions. Under this criterion we are interested in the way in which the modelling approach has responded to the experience of the recession: to what extent does it seem to have learned from that experience or, if no adaptation is deemed necessary, how persuasive are the arguments that this is so. A particular issue here is whether the model regards historical forecasting errors as random and stationary, so that they contain no information helpful for forecasting in future, or does it regard such errors as persistent, so that they are incorporated as an intercept shift to the mean forecast? And, in either case, what justification is given for the choice of approach adopted?

6.3 Review of the models

Accuracy of forecasts

As discussed in Section 6.2, the accuracy of forecast criteria is not easily analysed. Moreover, there is a practical constraint in collating previous forecasts and drawing fair comparisons between models.

Ability to reproduce history

All top-down econometrically-estimated models have been estimated over historical time series data and so automatically have the property that they can reproduce historical trends (and hence embody the experience of past trends/relationships in their forecasting properties). The main question, therefore, is whether there is any evidence of systematic over- or under-prediction towards the end of the historical period which might suggest that the parameter estimates cannot be relied upon to be constant in the forecast period. However, the published documentation on the models does not provide us with any evidence on which to make this judgement.

Conversely, bottom-up models are typically not developed on the basis of historical time-series data, and so they cannot be solved over the historical period to compare model projections with actuals, and nor do they necessarily embody past experience in forecast trends, since bottom up models reflect technical characteristics and not relationships in historical trends. The main question in this case is whether any attempt has been made to compare the implied forecast trend in energy efficiency with historical experience as a broad check on plausibility (or, if there is a break in trend, that this is understood and justified). Again, the published documentation does not provide evidence for us to draw any conclusions on this.

Sectoral detail

Table 6.2 provides a summary of the detailed classification of energy users in each of the different models.

The DECC model has an adequate level of sectoral detail, distinguishing four energy-intensive industries in addition to the other main energy using sectors (transport, households, commerce, the power sector, and other industry). MDM-E3, E3ME, E3MG and PRIMES also have four energy intensive sectors as well as separating out the other key energy sectors, but the PRIMES model further disaggregates each of these sectors into the main energy uses (processes).

In total MDM-E3 has 14 sub-sectors within manufacturing, including the four distinguished as energy-intensive. PRIMES has nine sectors (called sub models) within manufacturing, all of which are further disaggregated into energy uses (processes) which are usually individual to each sector. Enerdata's POLES and IEA's WEM are somewhat more limited in their sectoral detail than the other models, with 3 broad classifications for the energy-intensive industries. They both have a single broad category (called Other Industry), consisting of certain important energy consuming sectors (such as Food, Drink & Tobacco, Non-Ferrous Metals, etc), which differ in their energy using characteristics. Such a broad classification means that these models have a slightly lesser ability to account for differing energy intensities within sub-sectors.

Table 6.2: Classification of Energy Users, by Model

CLASSIFICATION OF ENERGY USERS, BY MODEL

	E3ME and E3MG	**MDM-E3**	**MedPro**	**POLES**	**WEM**	**PRIMES**	**DECC**	**NEMS**
Industry: Energy Intensive	Iron and Steel	Iron and Steel	Industry	Iron and Steel	Iron and Steel	Iron and Steel	Iron and Steel	Iron and Steel
	Chemicals	Chemicals		Chemicals	Chemicals	Chemicals	Chemicals	Chemicals
	Non-Metallics nes	Mineral Products		Mineral Products	Mineral Products	Mineral Products	Mineral Products	Cement
								Glass Products
	Non-Ferrous Metals	Non-Ferrous Metals				Non-Ferrous Metals	Non-Ferrous Metals	Aluminum
								Fabricated Metals
Other Industries	Engineering, etc	Mechanical Engineering		Other Industries		Engineering	Vehicles and Engineering	Machinery
		Electrical Engineering						Computers and Electronics
		Vehicles						Transportation Equipment
	Food, Drink &Tobacco	Food, Drink & Tobacco			Food, Drink &Tobacco	Food, Drink and Tobacco	Food, Drink and Tobacco	Food products
	Textiles, Clothing & Footwear	Textiles and Clothing				Textiles	Textiles	
	Paper and Pulp	Paper and Pulp			Paper and Pulp	Paper and Pulp	Paper and Pulp	Paper and Allied Products
	Other Industry	Other Industry			Other Industry	Other Industry	Other Industry	Other industries (agriculture, mining and construction)
	Other Mining (non-energy)	Unclassified						Plastic products
								Wood Products
Other sectors: Transport	Air	Air	Transport	Air	Aviation/freight	Air/passenger	Air	Freight/passenger aircraft
					Aviation/ passenger			
	Road	Road		Road/goods	Road/freight	Road/goods	Road	Light duty vehicles

								(cars and light trucks)
				Road/passenger	Road/passenger	Road/passenger		Commercial light trucks, freight trucks
	Rail	Rail		Rail/good Rail/passenger	Rail/ freight Rail/passenger	Rail/good Rail/passenger	Rail	Freight/passenger rail
		Water			Water/good Water/passenger	Water/good Water/passenger	Water	Freight shipping
	Other transport			Other transport				Miscellaneous transport
Other sectors: Domestic	Households	Domestic	Household	Residential: Dwellings Residential: Electrical equipment	Residential	Domestic	Domestic	Residential
Other sectors: Tertiary	Other final use	Public Administration	Service	Tertiary		Public services	Public Administration	
		Commercial				Market services	Commercial	Commercial
		Agriculture		Agriculture		Agriculture	Agriculture	
		Miscellaneous				Trade		
Other sectors: Power Generation	Power own use and transformation	Power Generation		Power Generation	Power Generation	Power Generation	Power Generation	Power Generation
Other sectors: Other transformation		Other transformation			Refinery and other transformation		Other transformation	Refining
Other sectors: Energy Industry Own use	Energy own use and transformation	Energy Industry Own use					Energy Industry Own use	

Source(s): E3ME, E3MG, MDM-E3, Med-Pro, POLES, WEM, PRIMES, DECC Energy Model.
Note(s): Detailed classification of Med-Pro is not known.

Drivers

The price of energy The DECC model includes energy prices for industry only when determining the shares of the different fuels; in contrast to all the other models analysed, it does not include energy prices in their industrial energy demand equations (on the grounds that the variable was found to be insignificant). The implication of this for over or under-prediction depends on what happens to prices. In a global recession, when energy prices typically fall, the implication is that the model would under-predict (because it would fail to capture the mitigating impact on demand of lower energy prices). Similarly, in recovery the model would over-predict because it would fail to capture the depressing impact on demand of higher energy prices. E3ME, E3MG and MDM-E3 have aggregate energy consumption equations for each sector and a corresponding series of fuel share equations, which include energy prices as a driver of energy demand and relative energy prices as a driver of the choice of fuel. This is also true of PRIMES, POLES and the WEM, such that prices affect both the aggregate energy consumption and the fuel mix. However, the DECC model does include the impact of price in the transport and domestic sectors (as do the other models).

Activity All models have a measure of industry output to represent the *activity* driver of energy demand. In most models the measure of output is gross value added (net output); in E3ME, E3MG and MDM-E3 the measure is gross output. Although there are certain theoretical reasons for preferring gross output[25], GVA data are more readily available and so this indicator is often used as a matter of convenience; in practice we doubt that it makes much difference to the forecasting properties. In the case of the DECC model, the choice of manufacturing subsector used as an activity driver is appropriate, but the assumptions for GVA by subsector had been updated by a simple scaling procedure which did not take account of the differences in the impact of the recession across subsectors.

Technology The treatment of *technology* varies considerably across the models, and especially between the top-down and bottom-up models. In the top-down models, technological progress is represented by an indicator which is either simply a time trend (as in the DECC model) or explained by a combination of fixed investment and investment in R&D (E3ME, E3MG and MDM-E3). In CE's suite of models (E3ME, E3MG and MDM-E3), technological progress is represented by a measure of accumulated investment which seeks to reflect technology as it is embodied in the capital stock. PRIMES follows a bottom-up approach for technology, where the technologies and their corresponding energy uses are listed explicitly[26]. It is not clear what the treatment of technology in WEM is for industrial sectors: WEM models energy intensity with econometric equations, but the drivers are not declared in the documentation.

With regards to improvements in energy efficiency due to technological change, the DECC model simply includes a time trend rather than a more explicit treatment of technology. In a recession, cutbacks in investment would normally curb the pace of energy-saving technological change, so ignoring this impact would cause the model to

[25] In principle the intermediate inputs, including energy, can be *substitutes* with respect to the labour and capital inputs included in value added, whereas using value added as the activity driver implies that they are complements.

[26] E3MLab, National Technical University of Athens (NTUA): An Interim report on Modelling Technology: PRIMES Model, European Consortium for Modelling of Air Pollution and Climate Strategies - EC4MACS

under-predict demand during recession and over-predict in recovery. POLES has a similar treatment of technology to the DECC Model, where the time trend represents energy efficiency due to technological changes.

All of the models reviewed employ a bottom-up treatment of power generation.

Peer review

We note here the conclusions of studies that have sought to compare or comment on the effectiveness of the models.

PRIMES is extensively used in-house by DG Energy and has also been applied in a number of research projects by DG Environment and DG Climate Action. It has been peer reviewed, in particular within the European Commission's (EC) framework in 1997[27].

Capros (2011)[28] notes that PRIMES is more detailed than POLES and WEM and claims that it has a more satisfactory micro-economic foundation (eg demanders maximize utility, suppliers maximize profits, and markets clear through prices).

However, a review by Helen ApSimon[29] points out that PRIMES is a complex model with many modules, making it difficult to understand the uncertainties and sensitivities of the model as a whole. It is easier to assess the relationship between energy demand and activity in other models, which have fewer interlinked sub-models than PRIMES. As a result it is difficult to conclude that PRIMES is a better model overall for including such a detailed treatment of sub-modules, although it certainly allows for a more comprehensive analysis.

POLES has been used for forecasting in a number of national and international projects. POLES has been scrutinised in the World Energy Technology Outlook (WETO), for the EC, as well as by the World Energy Council (WEC)[30]. POLES has been used to generate global energy scenarios eg the WETO-H2 study (EC, 2006) which developed a reference projection of the world energy system to test different scenarios for technologies and climate policies up to 2050[31].

A comparison study of the POLES reference case scenario with the IEA reference scenario and the US Department of Energy (DOE) reference case found that the POLES scenario was broadly consistent with IEA and DOE analysis[32], lending support to the POLES methodology.

Another study conducted by Peter Russ et al (2007) says that POLES is continuously being improved both in detail and by regional disaggregation. The latest developments in POLES include the addition of detailed modules for energy-intensive sectors (see

---

[27] E3Mlab: PRIMES Model, Version 2 Energy System Model-Design and features: http://www.e3mlab.ntua.gr/manuals/PRIMREFM.pdf

[28] A presentation by to Prof P. Capros (Jan 2011) on 'The E3MLab Models' http://www.e3mlab.ntua.gr/e3mlab/presentations/Capros-E3MLab%20Models.pdf

[29] The E3MLab Models': A review of PRIMES model

[30]http://www.enerdata.net/enerdatauk/solutions/energy-models/poles-model.php

[31]http://ec.europa.eu/research/energy/pdf/weto-h2_en.pdf

[32] Schade B, Wiesenthal T, Comparisons of Long-Term World Energy Studies: assumptions and results from four world energy models, JRC scientific and technical reports

eg Sazo et al., 2006) and coverage of non-greenhouse gases (see Criqui, 2002 and Criqui et al., 2006[33])

CE's suite of models has not been reviewed explicitly by peers. However, E3ME and E3MG have both been used extensively for scenario analysis research for the EC where the results are heavily scrutinised. E3ME and E3MG[34] are usually calibrated to match a set of projections that are published by the European Commission and so the test of the model lies in its internal consistency when drawing comparisons from a given baseline, rather than an assessment of the models' forecasting properties.

MDM-E3 is used to provide forecasts to DECC and other commercial organisations who regularly scrutinise the results. The MDM-E3 model has been used extensively in research projects for the Committee on Climate Change, DECC, Defra[35], commercial organisations in the energy sector and other NGOs such as Friends of the Earth. .

The results of the WEM are regularly published in the World Energy Outlook and used for the analysis of global energy prospects[36].

Adaptation in the light of the experience of the recession

Table 6.3 shows pre-recession and post-recession forecasts of final energy demand and GDP used in three of the models (DECC, MDM-E3 and PRIMES). The results show that the effect of downgrading long-term growth assumptions (reflected in the lower GDP growth) are greatest in the PRIMES model, and smallest in the DECC Energy Model, with MDM-E3 lying in the middle. This is most likely a result of the small (or small negative) responses to economic activity in road transport energy demand and household energy demand in the DECC model. In MDM-E3, energy demand (for road transport and household) responds moderately to changes in income. As a result, final energy demand will be lower in a recession due to a fall in income in MDM-E3 as compared to the DECC model (which has negative income elasticities for road transport and household energy demand). By contrast, the PRIMES model, which is informed by bottom-up sub-modules is the most reactive; this is likely to be a result of the tendency in bottom-up models to assume that cost-effective technology choices are taken up quickly, whereas the time-series parameters in MDM-E3 and the DECC Energy Model are likely to encompass real-world 'stickiness'. The response in MDM-E3 lies in the middle, it is more reactive than the DECC model because of stronger responses in the various economic sectors to slower economic growth, while the price effects and the effect of reduced investment (as a result of slower economic growth) also put upward pressure on final energy demand. Without undertaking a more consistent modelling exercise, in which the models are standardised as far as possible in terms of latest data and assumptions, it is difficult to draw more specific conclusions.

A further part of the explanation is the treatment of residual errors in the DECC model, which are regarded as transitory, rather than persistent. Consequently, any cases where the recession has produced an unexpectedly large reduction in energy

[33] Russ P, et al (2007): Global Climate Policy scenarios for 2030 and beyond – analysis of Greenhouse Gas Emission Reduction Pathway Scenarios with POLES and GEM-E3 models.

[34] A list of projects that involve E3MG:

http://www.camecon.com/ModellingTraining/suite_economic_models/E3MG.aspx

[35] A list of projects that involve MDM-E3:

http://www.camecon.com/ModellingTraining/suite_economic_models/MDM-E3/MDM-E3_overview.aspx

[36] http://www.worldenergyoutlook.org/model.asp

demand in the data are regarded as providing no information relevant to the long-term projection. In MDM-E3, it is assumed that such effects can be persistent: a partially (or fully) unexplained ratcheting down of energy demand. The documentation for PRIMES does not make clear how residuals are treated, but a common treatment in bottom-up models is to calibrate to the latest available data, which could be equivalent to treating a residual as persistent.

Table 6.3: Energy and GDP Growth Rates over 2005-20: Comparing DECC Model with MDM-E3 and PRIMES

ENERGY AND GDP GROWTH RATES OVER 2005-20: COMPARING DECC MODEL WITH MDM-E3 AND PRIMES

	Pre-recession		Post-recession	
	GDP growth rate (%) 2005-20	Final Energy Demand growth rate (%)	GDP growth rate (%) 2005-20	Final Energy Demand growth rate (%)
DECC	2.57	0.02	1.78	-0.09
MDM-E3	2.5	-0.04	1.57	-0.44
PRIMES	2.41	0.32	1.74	-0.35

Source(s): DECC Energy Model (2008 & 2010 run) , MDM-E3 (C081 & C111) and PRIMES (07 and 09 baseline projections)

Economy interactions

MDM-E3, E3ME and E3MG provide a detailed disaggregation of the economic side, which most models treat as aggregates (ie industries; commodities; household and government expenditures; foreign trade; and investment). The two-way flows of information between the economy and energy demand in MDM-E3 (E3MG and E3ME) consistently reflect the impact of changes on each other. The other models assume one-way flow of information from economic forecasts through to the energy demand projections.

The two-way interactions between the economy and the energy system are important because they not only allow for economic factors to alter the demand for energy, but also the prices of energy, and the energy intensity of sectors to affect economic growth. This was an important factor in the recent recession, since the collapse in fuel prices helped offset the collapse in global economic growth. The main benefit to modelling this way, with regard to energy demand, is that it forces a consistent economic picture as a result of changes to fossil fuel prices and carbon prices: economic growth will be constrained by high fossil fuel prices.

6.4 Concluding Remarks

In previous sections of the report we assessed the detail of the DECC Energy Model and made some comparisons with the MDM-E3 model. In this chapter we have more broadly compared a wide range of modelling approaches to contrast alternative designs and approaches.

Consider developing a supplementary bottom-up approach for certain energy-intensive sectors such as iron and steel and refineries….

We draw the following lessons from our comparison of modelling approaches. First, the models use either bottom-up approaches or top-down approaches, or some combination of the two (a top-down model with a bottom-up approach to the power sector). There are no grounds for concluding one or other approach is superior. Rather, the fact that both approaches are used and well-respected suggests that developing complementary bottom-up approaches for some sectors could be helpful. Certainly, it could be worth exploring this for the iron and steel sector, refineries, and perhaps the other energy-intensive sectors. Since the energy-intensive sectors consume the largest amount of energy relative to their economic size, economic growth might not be the main driving factor behind future changes in energy consumption. For example, oil refining is a sector with a small number of large plants, in which it may be feasible to identify explicitly the energy-using processes and take a view on how the technology may change over time. However, this requires investment of time to gather the necessary information on existing processes and potential changes in the future.

...although it is best used as a complement to more top-down analysis

One weakness of a bottom-up approach is the extent to which past trends are understood and, where it is appropriate, carried through into the projections, particularly where these do not relate to particular energy-using processes. For example, the bottom-up approach might not take account of differences in product quality and the economic composition of sub-sectors. Another criticism of bottom-up models is that as optimisation models (typically) they can over-estimate both the take-up and effectiveness of new technologies. Consequently, bottom-up approaches are best regarded as a complement to a top-down approach.

The DECC model has an adequate level of sectoral detail at the industry level

The DECC Energy Model has sufficient sector detail at the industry level. Broadly speaking, the more detailed the sector coverage the more accurate (or at least the more robust) the forecast is likely to be, since it allows for changes to the sector composition brought about by the economic drivers. For example, models which only represent industry as a whole are less likely to provide suitable forecasts, unless the trend in the composition of the subsectors continues unchanged into the forecast period.

Proposed amendments to the existing DECC model

Our detailed analysis provided in Chapter 4 suggested that the specification of prices, technology and income elasticity were potential weaknesses with the DECC model's treatment.

Include prices in the aggregate energy demand equations in the industrial sector

The absence of prices in the aggregate energy demand equations in the industrial sector means that there will probably be an over-prediction of energy demand during a recovery from recession (when world energy prices might be expected to pick up). Other models such as E3ME, E3MG, MDM-E3, POLES, PRIMES and WEM include prices in their energy demand equations.

A more explicit treatment of energy-efficiency

The DECC model currently includes a time trend, which does not explicitly capture improvements in capital stock and the movements in economic activity. Therefore, the DECC model will not be able to capture the impact of a recovery in investment post-recession, resulting in an over-prediction of energy demand. E3ME, E3MG, MDM-E3, WEM and PRIMES follow a more theory-based treatment of technology (as discussed in Section 6.3).

Re-assess the counterintuitive negative income elasticities for energy demand from road transport and households

As noted in the Oxford Economics review, the DECC model has negative income elasticities for energy demand from road transport and households, which is counterintuitive. E3ME, E3MG, MDM-E3, POLES, PRIMES and WEM have positive income elasticities for energy demand. The specification of these equations should be changed to allow the sign of parameter estimates to be consistent with theory.

Re-examine the drivers in the DECC model and re-specify the aggregate energy demand equation.

A comparison of the pre and post-recession forecasts of MDM-E3, PRIMES and the DECC Energy Model (see Table 6.3) showed the DECC model was least responsive to a recession, in part because of the low (or negative) activity parameters embodied in the domestic and road transport equations. We recommend that DECC considers re-specifying and re-estimating these equations to more closely scruitinse these counter-intuitive elasticities, particularly where there is evidence of endogeneity in the explanatory factors.

Assess the current treatment of forecast errors by re-estimating the energy demand equations

As discussed in Section 6.3, the DECC model and CE's suite of models (E3ME, E3MG, MDM-E3) differ in their treatment of the residual errors. While in the DECC model, residual errors are random and transitory, in the CE's suite of models they are persistent. If the impact of the recession has been to produce permanent reductions in energy demand (for example, due to the closure of energy-inefficient plant), the consequence of assuming that errors are transitory will be to over-estimate energy demand in the recovery. Our analysis in Section 4.2 proposed that the equations be re-estimated to investigate possible structural breaks and outliers, to inform a judgement about whether the existing treatment of residuals is justified.

Improve transparency through better documentation

All the models are well-used and either the models or their results are open to regular scrutiny. The PRIMES model is necessarily well documented, as are the POLES, E3ME, E3MG and, to a lesser extent, the MDM-E3 models. The public accessibility of documentation and reviews tends to increase depending on the various applications they have been applied to. The NEMS model, as an example of a public sector-owned model is very well documented and there is reasonable documentation of the IEA's World Energy Model. By contrast the documentation available on the DECC Energy Model is relatively poor, with the exception of the Oxford Economics reviews (December 2008).

7 Conclusion

After assessing the DECC Energy Model we have drawn a number of conclusions and made recommendations to improve the approach

The DECC Energy Model projections are used to inform the process by which carbon budgets are set, and it is therefore important that the application of the model is transparent and that the projections are robust. The scale of the recession has raised questions about the economy's long-term growth potential, which is a key driver of energy demand projections. The recession may also have caused a structural change in the energy-intensity of economic activity. This report examines the responses of the DECC Energy Model in light of the recession in order to make recommendations for improvements which could be made to the model and the modelling process. The work has involved analysis of the DECC Energy Model in three distinct and separate ways:

- the replication of key elements of the DECC Energy Model to analyse its structure and properties, including an assessment of the inputs to the model
- comparison of the DECC Energy Model projections with an alternative set of projection results, generated using CE's own MDM-E3 model, with the main input assumptions harmonised with those in the previous DECC Energy Model runs
- comparison between the DECC Energy Model and other models and modelling approaches as part of a wider energy modelling review

The DECC Energy Model is a sensible approach to projecting energy consumption and emissions, but improvements could be made

Based on this analysis our conclusions and recommendations are summarised in Table 7.1. The first important conclusion is that the top-down methodology employed by DECC to make projections of sector energy consumption and emissions is, by-and-large, a sensible approach, although there are a number of developments which could be incorporated. It is our view that these developments would improve the modelling approach, and we regard some of the recommended improvements as priorities for action in the short term. In the table, we therefore identify the developments that could be made, the relative priority of the development, and whether the development could be made in the short, medium or long term.

The sector structure of the model is adequate given the data and the approach

The DECC Energy Model distinguishes energy-using sectors that follow the same definitions as used by many of the similar models. To some extent this reflects the limitations of the data. DECC could go further than it presently does by disaggregating engineering and vehicles to its constituent sub-sectors, but this would only yield a small overall gain to the current top-down modelling approach, since this sector represents a small proportion of industry energy consumption. The bottom-up models that we have reviewed make use of additional data to estimate energy use at a sub-sector and process level. We do not think it necessary for DECC to prioritise this aspect in the short to medium term, but there are reasons why it may be a useful complementary approach and so we recommend it for consideration in the long term. The main benefit from developing a complementary bottom-up approach to understand some sectors, is that it forces the modeller/analyst to consider the technological characteristics alongside the top-down trends. For example, when considering the Iron and Steel sector, a bottom-up treatment would encompass information on specific plant efficiencies, and so the closure of a plant can be compared explicitly against the results of a top-down modelling approach in which the negative economic growth of the sector (as represented by a plant closure) is considered.

In the short term, we recommend that DECC re-assesses the economic inputs to the model…

The most important short-term development is to develop a new set of sub-sector industry economic growth forecasts. In Section 3, we identified that the differences between the various vintages of model projections, in terms of energy demand at least, reflected the differences between the various vintages of economic input assumptions for industry. Two main points emerged from our analysis. The first is that the sub-sector economic inputs had not been updated to account for the recent history, which would tend to increase forecast errors in the short term. DECC have now added up-to-date historic data which will be reflected in future projections.

…this is particularly pertinent following the recent recession

The second point is that the economic assumptions for industry sub-sectors were generated by using pre-recession growth rate differentials between sub-sectors. The implication is that the relative long-term growth rates of industries are assumed to have been unaffected by the recession.. In other words, DECC assumes that Iron and Steel, for example, has been as adversely affected by the recession as Chemicals. This is clearly not the case; different manufacturing sub-sectors have been affected in markedly different ways with different long-term prospects developing as a result of the recession.

The DECC model results show a discrepancy between energy projections and energy-based emissions which needs to be examined

The second pressing short-term issue relates to how the DECC Energy Model is linked to CO2 emissions for industry, and in particular how CHP is accounted for. In Section 4 we identified a large discrepancy in the DECC Energy Model projections from 2009, where energy consumption in 2020 is projected to be some 12% lower than 2007 (see Section 4.3), but CO2 emissions were unchanged in 2020 compared to the 2007 level. This also contrasted with projections made more recently in the 2010 run. It is not clear where the additional emissions are coming from, since the fuel mix is slightly cleaner by 2020, and both process and energy industry emissions (which also make up the industry emissions total) fall by 2020, relative to 2007. However, we assume that the additional emissions arise from CHP (which is attributed to industry), since CHP generation increases in this run.

…this is particularly pertinent following the recent recession
In the medium-term, we recommend more regular re-estimation…

In the medium term, we recommend re-estimation of the equations and an examination of systematic bias in the forecasting performance of the equations. We find some evidence of systematic bias in a number of industry sub-sectors, as shown by the out-of sample data compared to year-ahead forecasts (see Chapter 4 for further details). This has implications for the treatment of the residual error term. Regular re-estimation and an estimation strategy that includes outlier/break detection would be considered a suitable way of dealing with this bias. If, for whatever reason, the DECC Energy Model equations are not re-estimated but are found to include some systematic bias, then the residual between the projections and the data in the last year of data should not be treated simply as a transitory shock because the long-term equilibrium in the equation is no longer valid and nor is the correction to that equilibrium. Instead, the projection should account for the bias represented by the residual as a permanent change to the intercept. In Chapter 4 we put forward one method of adjusting for bias and show how it affects the projections for energy demand.

Table 7.1: Recommendations for the DECC Energy Model

RECOMMENDATIONS FOR THE DECC ENERGY MODEL			
Recommendation	**Time frame for implementation**	**Priority**	**Comments**
Apply a residual adjustment to sectors where there is evidence of systematic over or under-prediction	Short-term	Medium	Possibly requires development of clear criteria for deciding whether or not to apply the adjustment if not used as standard If the equations were more regularly re-estimated, the preferred alternative would be to test for outliers and structural breaks as part of the estimation procedure (see below)
Update GVA inputs with latest sub-sector data from the Blue Book	Short term	High	DECC has already indicated that it plans to do this.
Make use of more in-depth statistical information/soft data to account for known events not captured by the equations	Short-to-medium-term	Medium	To some extent already accounted for in DECC projections
Clarify method for deriving emissions projections from energy demand projections	Short term	Medium to high	While this should be relatively simple, there are a number of factors which could explain inconsistencies between energy and emissions projections in the various runs – particularly for industry sectors. These should be clarified.
Improve model documentation	Medium term	Low to medium	This would improve the transparency of the DECC model projections and, in turn, the transparency behind the proposed carbon budget levels.
Consider alternative methods and sources for sub-sectoral industry GVA forecasts	Medium term	Medium	Comprehensive treatment of inter-industry relationships and structural change potentially complex; may be difficult to bring in-house, if desired
Further analysis of the link between wholesale and retail energy prices (nature of margins and tax elements)	Medium-to-long-term	Low to medium	Implications for emissions of errors in this regard likely to be small relative to errors in actually forecasting wholesale prices

RECOMMENDATIONS FOR THE DECC ENERGY MODEL

Recommendation	Time frame for implementation	Priority	Comments
Re-estimation over the extended sample period/ more regular re-estimation of equations	Long-term	Medium	If the equations are still to project energy demand 'without policy', some (*ex-post*) assessment of the impacts of recent policy initiatives is required (involves an element of data construction to obtain the final dataset for estimation) Permits more statistics-based tests for outliers and structural breaks (residual adjustment above becomes unnecessary, although requires criteria to distinguish outliers from breaks) Clearly-specified (or appropriately automated) estimation strategy desirable
Possible re-specification of equations (including re-assessment of energy efficiency)	Long-term	Medium to High	Apparent insignificance of prices in aggregate energy demand equations worth revisiting Endogenous treatment of energy efficiency at least theoretically more appealing than a time trend term; introduces another variable that must be projected, however
Consider supplementing projections with more bottom-up treatment/analysis	Long-term	Medium	More holistic approach combines advantages of top-down and bottom-up analyses Potential coordination issues and/or greater complexities in reconciling differences in results

Source(s) : Cambridge Econometrics.

…but this has implications for how DECC accounts for forward-looking policy impacts

The opportunity for systematic bias is likely to be reduced by regular re-estimation of model parameters, including statistical tests for outliers and breaks. However, this represents a particular challenge for DECC (and indeed other modelling groups) with respect to separating the effects of policy from model parameters. The current set of DECC Model parameters were estimated over the period 1980-2004. Subsequent data have not been used in estimation on the grounds that all policy impacts thereafter can be treated as additional to the model-based projection. The weakness of this approach is that it does not allow for changes in the relationships between energy demand as a dependent variable, and economic activity and price (where it is included as an explanatory term) that have occurred in the post-2004 period for reasons other than policy.

Re-specification of the model should investigate the impact of energy prices and technological progress…

If re-estimation of the model parameters were to be undertaken more regularly, it would also be worth attempting to account for other drivers such as price and technology or investment-led technological change. These two factors are particularly interesting in the context of a recession, since the global recession of 2009 had (i) a substantial downward impact on global fossil fuel prices and the EU ETS allowance price, and (ii) a substantial downward impact on investment, with possible long-term implications for the capital stock and therefore energy efficiency.

…energy prices are likely to be increasingly important as pressure on fossil fuel supplies increases…

The lack of a price term in the industry aggregate energy demand equations is surprising. There are references in the literature to a significant price effect in determining energy demand and we also find this to be the case in the MDM-E3 model parameters. However, as the DECC Energy Model is estimated over a period of relatively low and stable energy prices this may explain why the term is mostly found to be insignificant. Moving into a world of higher and increasingly volatile energy prices suggests that it will become more important to account for the impact of prices. As the UK economy emerged from recession, the collapse of energy prices is thought to have offset in part the reductions in energy consumption which were estimated to come from reductions in economic activity alone.

…and technological progress is particularly important to account for; both in terms of the relationships between economic growth and technological progress, and to more explicitly capture efficiency trends

The treatment of technology is one of the main factors which distinguish the various models assessed as part of this research. Some of the models make use of bottom-up technology or process-driven approaches, while others include a top-down term for technological progress, either modelled endogenously or represented more as an exogenous time-trend. The disadvantage of including technological progress through an atheoretic time trend is that it decouples the forward-looking assumptions for the economy from those for technological progress, whereas the latter is in reality embodied in investment. This factor is increasingly important to account for during and following a recession, because, in this period, economic activity changes considerably with implications for investment and technological progress. Furthermore, a time trend proxy captures anything that is changing steadily over time, including, say, the effects of changing product quality and shifts in the sub-sector composition of economic growth. We recommend that DECC considers re-specifying the DECC Energy Model to account for changes in technological progress, but this does carry the implication that it will be necessary to ensure that assumptions for economic activity are consistent with those for technological progress.

For some sectors, bottom up modelling approaches would be suitable and necessary complements to the top-down approach currently used

There are clear benefits to developing bottom-up modelling treatments for some sectors: nearly all of the models identified have developed a bottom-up modelling treatment of the power sector, while other models go further still (eg NEMS and PRIMES) using bottom-up information and modelling for some sectors. The benefits are not that a bottom-up approach yields 'better' results, but rather that it provides a more complete explanation of technological change and it forces the modeller to consider the specific details of changes in energy consumption. For example, all modelling groups make use of a bottom-up approach for the power sector because it provides a more complete treatment of the sector and of potential changes which are beyond those encompassed in a top-down approach. We recommend, in the longer term, the development of bottom-up approaches to complement the top-down approach currently used by DECC. This is most suited to sectors of the economy where energy use (and future energy use) is potentially easier to decouple from economic growth, and where the data are sufficient to inform a bottom-up approach; the iron and steel manufacturing sector and petroleum refining could be looked at in this way. The downside of bottom-up approaches is that future technologies and future processes must be specified and well-understood, and such models are rarely tested against historical data on energy consumption. As a result, while we advocate the development of bottom-up methods, on a sector-by-sector basis, we recommend that they are complements, rather than substitutes, to a top-down approach.

The documentation of the DECC Energy Model could be considerably improved, with benefits to DECC

The final recommendation is on documentation. The DECC Energy Model is not sufficiently well documented beyond the Oxford Economics reports produced in 2008 and some elements of the model have in fact changed since then. Given the importance of the projections of the model in setting carbon budgets and informing the requirements for policy action, the approach needs to be made more transparent. This would help external advisors, academics and government-related groups such as the Committee on Climate Change and the National Audit Office, make recommendations to improve the modelling approaches, while also providing sufficient information to underpin the credibility of the projections.

The DECC Energy Model is broadly fit for purpose, but a number of improvements could be made

Overall, the assessment of the DECC Energy Model has highlighted some weaknesses of the approach, some of which are already known to DECC and are under internal review, and others which are intended to inform the debate as to how the modelling approach used by DECC could be improved. The model, for the most part, is a suitable tool for producing energy projections and emissions projections in the medium term, but there is certainly scope for further developments.

8 References

Adeyemi, O. I., Broadstock, D. C., Chitnis, M., Hunt, L. C., Judge, G. (2008), 'Asymmetric Price Responses and the Underlying Energy Demand Trend: Are they Substitutes or Complements? Evidence from Modelling OECD Aggregate Energy Demand', *Surrey Energy Economics Discussion paper Series*, **121** http://www.seec.surrey.ac.uk/research/SEEDS/SEEDS121.pdf

Anderson, D., Winne, S. (2004), 'Modelling Innovation and Threshold Effects In Climate Change Mitigation', *Tyndall Centre Working Paper*, **59** http://www.tyndall.ac.uk/content/modelling-innovation-and-threshold-effects-climate-change-mitigation

Barker, T. S., Ekins, P., Johnstone, N. (1995), *Global Warming and Energy Demand*, Routledge, London

Barker, T. S., Ekins, P. & Strachan, N. (2005), 'Energy-Economy-Engineering-Environment: An E4 Representation of the UK Energy System', UKERC Working paper

Bowen, A., Forster, P. M., Gouldson, A., Hubacek, K., Martin, R., O'Neill, D. W., Rap, A., Rydge, J. (2009), 'The implications of the economic slowdown for greenhouse gas emissions and targets', Policy paper, Centre for Climate Change Economics and Policy http://www.cccep.ac.uk/Publications/Policy/docs/PPBowenetc-economic-slowdown-emissions.pdf

Cambridge Econometrics (2009), 'An Impact Assessment of the Current Economic Downturn on UK CO_2 Emissions' http://downloads.theccc.org.uk/docs/CE%20Final%20Report_110809.pdf

Cambridge Econometrics; Department of Applied Economics, University of Cambridge; Policy Studies Institute (2005), 'Modelling the Initial Effects of the Climate Change Levy'

Chamberlin, G. (2010) 'Output and expenditure in the last three UK recessions', *Economic & Labour Market Review*, Volume 4, Number 8 (August)

Committee on Climate Change (2008), 'Building a low-carbon economy – the UK's contribution to tackling climate change' http://www.theccc.org.uk/reports/building-a-low-carbon-economy

Committee on Climate Change (2009), 'Meeting Carbon Budgets – the need for a step change' http://www.theccc.org.uk/reports/1st-progress-report

Department of Energy & Climate Change (2010), *Digest of UK Energy Statistics 2010* http://www.decc.gov.uk/en/content/cms/statistics/publications/dukes/dukes.aspx

Department of Energy & Climate Change, *Climate Change Statistics* http://www.decc.gov.uk/en/content/cms/statistics/climate_stats/climate_stats.aspx

Department of Energy & Climate Change, *Energy Trends* http://www.decc.gov.uk/en/content/cms/statistics/publications/trends/trends.aspx

Dimitropoulos, J., Hunt, L. C. and Judge, G. (2005) ‘Estimating underlying energy demand trends using UK annual data’, *Applied Economics Letters*, **12(4)**, 239-244

Ekins, P. (2005), ‘Emissions trading: impacts on electricity consumers’ http://www.ofgem.gov.uk/Pages/MoreInformation.aspx?docid=4&refer=Sustainability/Environment/Policy

European Climate Foundation (2010), *Roadmap 2050* http://www.roadmap2050.eu/

HM Treasury, Budget archive website http://www.hm-treasury.gov.uk/budget_archive.htm

International Energy Agency (2010), *World Energy Outlook 2010* http://www.worldenergyoutlook.org/2010.asp

International Monetary Fund (2011), *World Economic Outlook April 2011: Tensions from the Two-Speed Recovery - Unemployment, Commodities, and Capital Flows* http://www.imf.org/external/pubs/ft/weo/2011/01/

Johnstone, N. (1995), ‘Modelling Passenger Demand, Energy Consumption and Pollution Emissions in the Transport Sector’, *Cambridge Working Papers in Economics*, **9527**, Faculty of Economics, University of Cambridge

Koehler, J., Barker, T., Pan, H., Agnolucci, P., Ekins, P., Foxon, T. J., Anderson, D.,Winne, S., Dewick, P., Green, K. (2005), ‘New Lessons for Technology Policy and Climate Change - Investment for Innovation: A briefing document for policy makers’, *Tyndall Briefing Note*, **13**, Tyndall Centre for Climate Change Research http://www.tyndall.ac.uk/content/new-lessons-technology-policy-and-climate-change-investment-innovation-briefing-document-pol

Lee, K., Pesaran, M. H., Pierse, R. G. (1990), ‘Aggregation Bias in Labour Demand Equations for the UK Economy’ Chapter 6 in Barker, T. S. & Pesaran, M. H. (eds), *Disaggregation in Econometric Modelling*, Routledge

McFarland, J. R., Reilly, J. M., Herzog, H. J. (2004), ‘Representing energy technologies in top-down models using bottom-up information’. *Energy Economics*, **26**, 685-707

Office for Budget Responsibility, Economic forecasts website http://budgetresponsibility.independent.gov.uk/category/topics/economic-forecasts/

Oxford Economics (2008a), ‘Review of the BERR Energy Demand Model’ http://www.theccc.org.uk/pdfs/Final_Report_Dec_2008.pdf

Oxford Economics (2008b), ‘Estimation of households demand for gas and electricity’ http://www.theccc.org.uk/pdfs/Final%20BERR%20domestic%20report%20December%202008.pdf

Oxford Economics (2008c), ‘Re-estimation of the BERR Energy Demand Model industry equations’ http://www.theccc.org.uk/pdfs/Final%20report%20December%202008.pdf

Pindyck, R. S. (1979) ‘Interfuel substitution and the industrial demand for energy: an international comparison’, *Review of Economics and Statistics*, 169–179 (May)

Reinhart, C. M., Rogoff, K. S. (2009) *This Time is Different: Eight Centuries of Financial Folly*, Oxford, UK: Princeton University Press

Roy, J., Sanstad, A. H., Sathaye, J. A., Khaddaria, R. (2006) 'Substitution and price elasticity estimates using inter-country pooled data in a translog cost model', Lawrence Berkeley National Laboratory, LBNL-55306 http://escholarship.org/uc/item/4g89926w

Appendices

Appendix A: Additional DECC Model Equation Analysis

This appendix provides additional information in support of the analysis in the main report

This appendix provides additional analysis of the DECC Model to support the conclusions of the assessment in the main report (see Chapters 3 and 4).

The first section in this appendix presents an overview of the assumptions for industry in the DECC model (for more detail, see Section 3.3 of the main report). The sections that follow examine in turn energy demand from each of the industry sub-sectors. The appendix concludes with some commentary on the treatment of energy demand from the non-road transport sectors and a comparison with the treatment in MDM-E3.

A.1 Industry energy demand equations

GVA forecasts drive industrial energy demand in the DECC Model

Appendix Figure A.1 shows the manufacturing GVA assumptions in the three DECC Model runs provided to the CCC. The runs are summarised as follows:

- 2008 run – steady, 'business as usual' GVA growth
- 2009 run – sharp decline in GVA followed by trend growth; a permanent loss in industrial output
- 2010 run – sharp decline in GVA, followed by a period of recovery (higher growth) and then a return to trend; some, but not all, of the lost output is regained in the medium term

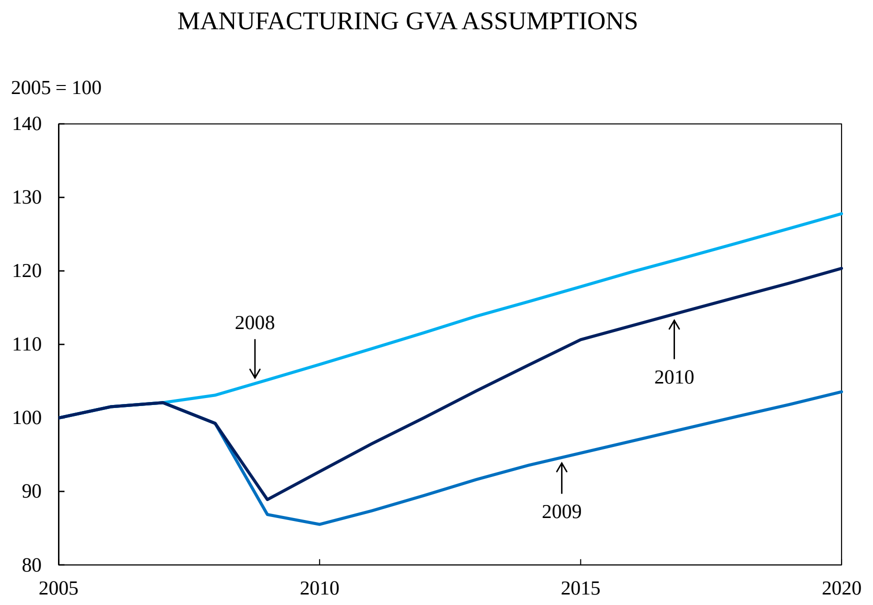
As mentioned in the main report, the permanent loss of manufacturing GVA in the 2009 run and the recovery in the 2010 run contrasts with a recovery in UK GDP in the 2009 run and a permanent loss of GDP in the 2010 run (see Appendix Figure A.2), suggesting 'rebalancing' in the 2010 run.

Aggregate manufacturing GVA assumptions from HM Treasury/OBR must be disaggregated to the industry sub-sector level

The forecasts of manufacturing GVA are only provided at this aggregate level and must be disaggregated to the sub-sector detail defined in the DECC Model. Oxford Economics produced sub-sectoral GVA projections consistent with HMT projections for the CCC's inaugural report, which were included in the 2008 DECC Model run. Manufacturing GVA assumptions for the two later runs were constructed by applying the growth differentials in the original Oxford Economics projections to the updated HM Treasury/OBR forecasts.

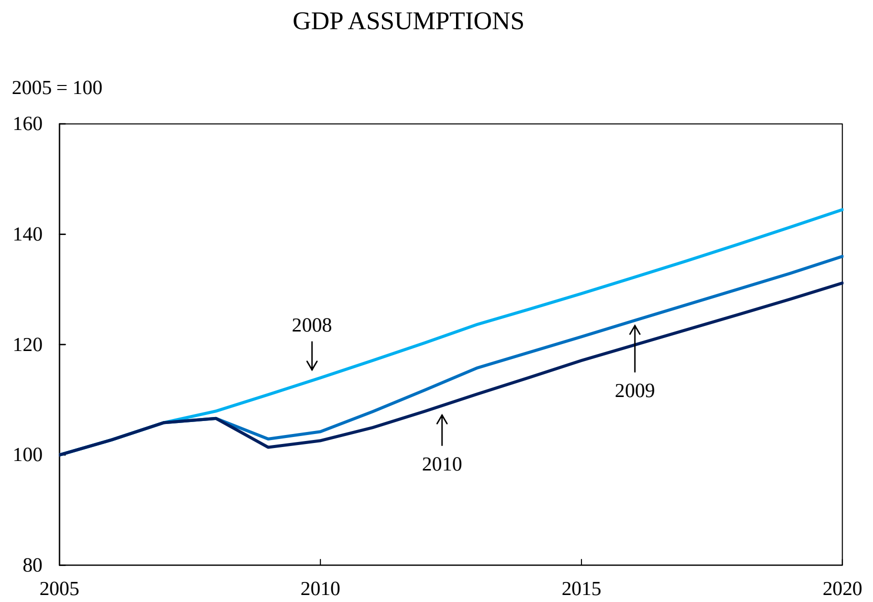
The method for constructing sub-sectoral GVA forecasts is assessed in Section 4.3 of the main report. For the most part, the focus of the industry analysis in this appendix is on how these inputs (irrespective of how they are formed) drive energy demand in the DECC Model. The charts and analysis that follow examine each of the industry sub-sectors in the DECC Model in turn. Where it has been possible, this analysis draws on our work to replicate the DECC Model equations, in order to decompose a change in energy demand into the contributions of the individual drivers (ie how much of the change comes from GVA, how much from the trend in energy efficiency etc).

Appendix Figure A.1: Manufacturing GVA Assumptions



Source(s): DECC.

Appendix Figure A.2: GDP Assumptions



Source(s): HM Treasury, DECC.

A.2 Chemicals

The Chemicals aggregate energy demand equation is specified as an error-correction model

The DECC Model aggregate energy demand equation for Chemicals is specified as an error-correction model with industry output and a time trend as its drivers. The equation does not include terms to account for energy prices. As with all the industry aggregate demand equations, the coefficient on output in the long run is imposed, with a value of one; in the long run, energy demand grows one-for-one with output. The time trend coefficient is negative, with a value of -0.037.

The Chemicals GVA assumptions mirror those for manufacturing as a whole

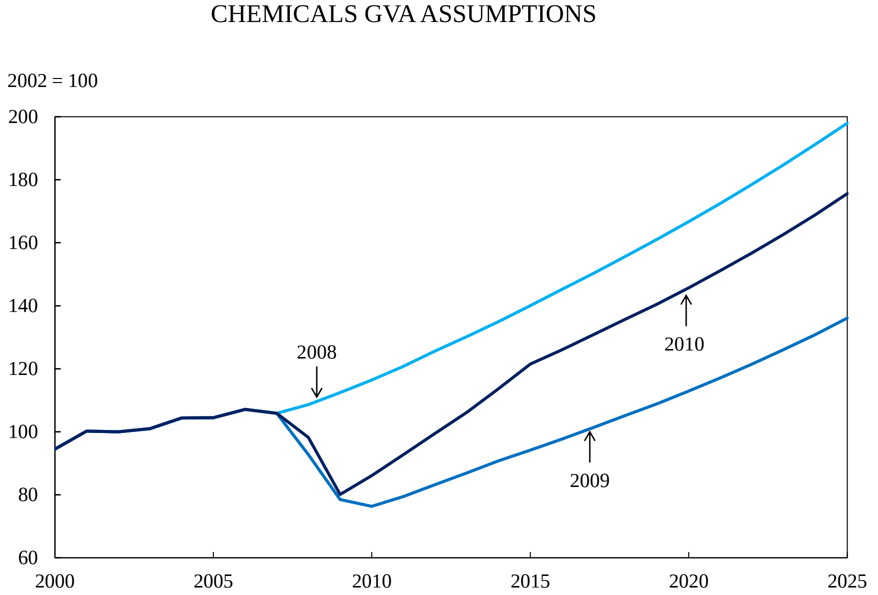
Over the projection period, the growth profiles of the Chemicals GVA assumptions are similar to that of manufacturing as a whole (see Appendix Figure A.3). In the 2008 run, Chemicals GVA growth is steady, at 3½-4% pa. This same rate of growth prevails in the 2009 run, post-recession, with a permanent loss of output. In contrast, a recovery is seen in the 2010 run. The recession is followed by a period of above-trend growth to 2015 before long-run growth returns to 3½-4% pa, as seen in the previous two runs. In the long-run, the GVA assumptions differ in their level, rather than their growth.

Long-run energy demand depends on GVA growth and the effect of the time trend

In the 2008 run, a sustained decline in energy demand is projected over the entire projection period, in contrast to the steady growth in GVA in the output assumptions for this sector. While long-run energy demand from this sector grows one-for-one with output, all other things being equal, this effect is outweighed by the increasing energy efficiency represented by the negative coefficient on the time trend in the equation. This is confirmed in a formal decomposition of the changes.

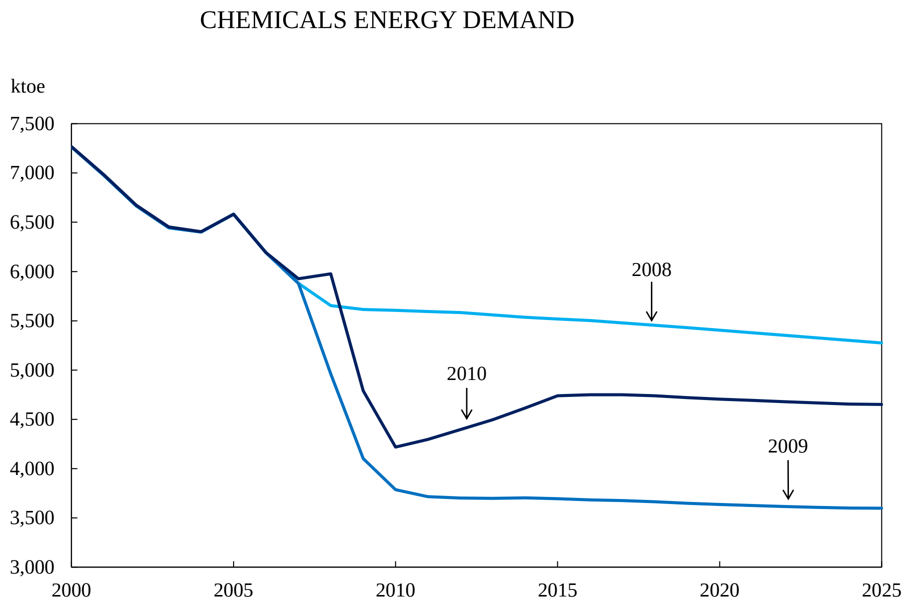
The time trend coefficient's value exceeds the output growth in the GVA assumptions for this run, leading to an overall reduction in energy demand over time. The rate of (assumed) output growth relative to the size of the time-trend coefficient is the sole determinant of long-run aggregate energy demand for all but one of the industry sub-sectors.

Appendix Figure A.3: Chemicals GVA Assumptions



Source(s): DECC.

Appendix Figure A.4: Chemicals Energy Demand



Source(s): DECC.

The 2009 run includes a recession in its output assumptions; GVA falls sharply in 2008 and 2009, with a further fall in 2010. This leads to corresponding falls in energy demand in those years in the 2009 run. In 2011 the sector returns to its long-run output-growth trend of 3¾-4% pa and energy demand similarly returns to the long-run trend of a gentle, sustained decline.

The 2008 and 2009 runs incorporate largely the same economic data, to 2007, differing only in the forward looking assumptions; the 2009 run includes a recession. The revised economic outlook in the 2009 run would be expected to lead to a revised short-term forecast for energy demand more in line with the outturn data embodied in the 2010 run (which contains updated energy data up to and including 2009). The 2009 run shows a reduction in energy demand in the short run compared to the 2008 run as a result of the decline in output in the updated GVA forecast.

In contrast to the short-run projections in the 2008 and 2009 runs, energy demand from Chemicals increased in 2008

However, the outturn data in the 2010 run shows an increase in energy demand from Chemicals in 2008, compared to the projected decrease in the 2008 run and an even larger decrease in the 2009 run. The effect of the updated GVA figures, to incorporate a recession, led to a larger forecast error.

The increase in the forecast discrepancy is a surprising result, especially on further examination. The Chemicals sector defined in DUKES covers both chemicals and pharmaceuticals. The former is typically more energy-intensive than the latter. While GVA fell in 2008, the shift in the share between chemicals and pharmaceuticals favoured pharmaceuticals. The *increase* seen in energy demand cannot be explained by this, although the change in fuel *mix* is consistent with the change in the GVA shares within the Chemicals sub-sector.

Post-recession, Chemicals GVA recovers with a period of above-trend output growth. Trend growth resumes in the long term. This output growth profile is evident in the energy demand projection. Energy demand falls sharply in 2009 and 2010, the years in which the largest output declines are seen. The higher output growth to 2015 outweighs the time trend effect, leading to an increase in energy demand in this period. Following the return to trend growth, the effect of output growth on energy demand is again outweighed by the trend efficiency term, leading to a long-run decline in energy demand at a rate similar to the declines in the previous two runs' long terms.

The majority of the industry aggregate energy demand equations shares the characteristics of the Chemicals equation outlined above. Output growth drives increases in energy demand, and the time trend either reinforces or counteracts this effect, depending on its sign and its size relative to the projection of GVA growth.

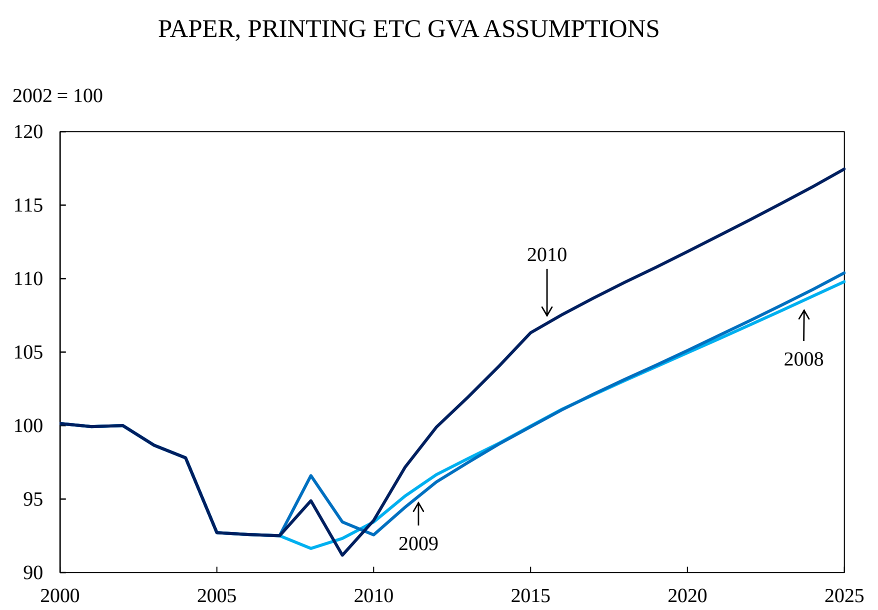
A.3 Paper, Printing etc (PPP)

The Paper, printing etc aggregate energy demand equation is specified as an error-correction model

As for Chemicals, the drivers of aggregate energy demand from Paper, Printing etc (PPP) are output and a time trend[37]. The equation is specified as an error-correction model. In contrast to the Chemicals equation, the coefficient on the time trend is positive (albeit small) at 0.010.

One feature of the equation, which is not common to all the aggregate energy demand equations, is the inclusion of a lagged dependent variable in the equation. This term introduces further dynamics into the projection, because changes in energy demand in

Appendix Figure A.5: Paper, Printing etc GVA Assumptions



Source(s): DECC.

[37] There is a second time trend included in this equation to capture a structural break in energy efficiency trends. A number of industry aggregate energy demand equations include a second time trend, but the variables' values are all constant over the projection period; the effect of the second time trend term is constant and only the 'main' time trend is of any interest.

previous periods have current-period impacts. The coefficient on this term has a (positive) value of 0.578. The implication is that a 1% increase in energy demand in the previous year leads to a 0.578% increase in energy demand in the current year, all other things being equal.

The long-run levels of GVA in the 2008 and 2009 runs are similar

The GVA assumptions for the DECC Model PPP sector do not mirror the growth profiles of the assumptions on manufacturing GVA as a whole as closely as the other industry sub-sectors. Appendix Figure A.5 shows that the long-run level of GVA is very similar in the 2008 and 2009 runs. These two runs differ mainly in their short-term profiles.

In the short run, GVA in the 2008 run falls and then rises steadily…

In the 2008 run (which uses industry sub-sector projections produced by Oxford Economics), PPP GVA falls by around 1% in 2008, continuing the trend of decreasing output seen in the previous five years. A period of faster growth to 2013 follows, of 1¼-2% pa. In the long run, GVA in PPP grows by 1% pa.

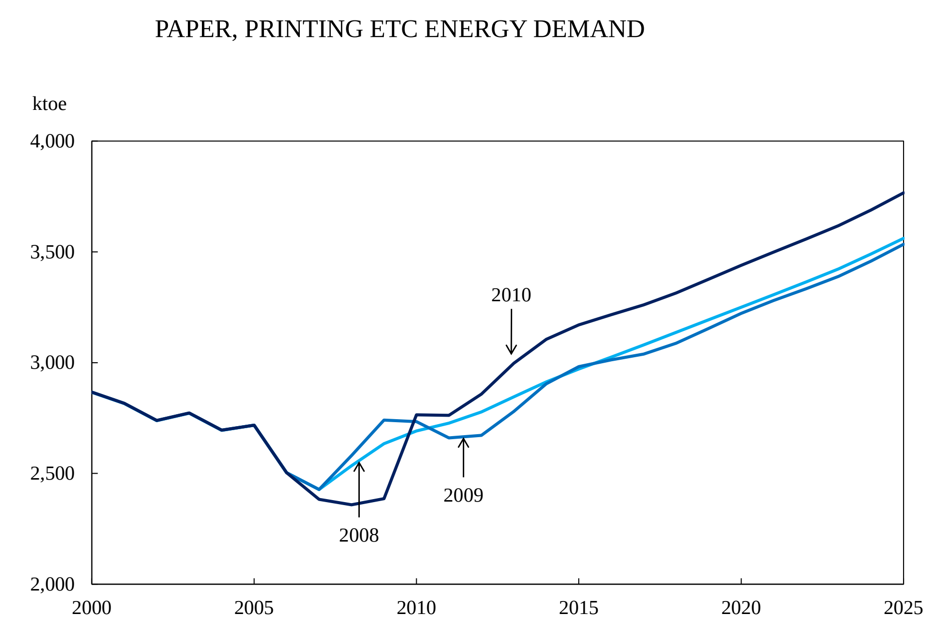
…whereas in the 2009 run a strong rise and a sharp fall is seen

In contrast, the updated GVA assumptions in the 2009 run show strong growth in GVA in 2008, of 4.4%. A sharp decline of 3.3% follows in 2009, in the recession, with a further decrease of 0.9% in 2010. The percentage difference in the projected level of GVA in 2010 between the two runs is less than 1% and similar medium and long-run growth profiles lead to very similar levels of GVA by 2020.

The short-run growth profile of PPP GVA in the 2010 run resembles the 2009 run more closely than the 2008 run. An increase in output is seen in 2008 (2.6% compared to 4.4% in the 2009 run) followed by a decrease in 2009 (3.9% compared to 3.3%). GVA returns to growth in 2010 (2.6%) bringing GVA in 2010, in the 2010 run, to a similar level as in the previous two runs.

The recovery and rebalancing in the 2010-run manufacturing assumptions is reflected in higher growth in PPP GVA over 2010-15 and long-run growth returns to 1% pa thereafter.

Appendix Figure A.6: Paper, Printing etc Energy Demand



Source(s): DECC.

The level of GVA in 2010 is similar in all three DECC Model runs (although the profiles in the years before differ markedly) and the growth profiles determine the differences in the long-run levels. The recovery in the 2010 run before a return to long-run growth leads to a higher level of output in this run compared to the previous two.

In the first year of projection in the 2008 run, output falls and energy demand rises

In the 2008 run, GVA in PPP is projected to fall by 1% in 2008 (the first year of projection). However, energy demand increases in that year, by 4.4%, in contrast to the general trend of falling output and falling energy demand seen in the recent history (see Appendix Figure A.6).

For PPP, the time trend coefficient is positive, reinforcing the effect of output growth

The strong growth in energy demand in 2008 in the 2008 run is followed by further growth in 2009, of 3.9%. Growth begins to settle from 2010 onwards, at around 2% pa. This growth in energy demand is driven by the 1% pa growth in output and reinforced by the positive coefficient on the time trend (which adds, approximately, a further 1 pp growth). In PPP, the time trend appears to represent a decrease in energy efficiency (possibly from more energy-intensive production technologies and practices), rather than an increase. The conclusion from the analysis is the same; long-run energy demand is driven by industry sub-sector output and the time trend.

The 2009 run shows strong GVA growth in 2008, in contrast to the 2008 run, in which a continued decline is seen. The 2009 run then has a sharp fall in GVA in 2009. In the 2009 run, the GVA growth in 2008 is reflected in a strong increase in energy demand in that year (6.3%). A similarly strong increase is seen in 2009, an increase at odds with the fall in GVA in that year. A formal decomposition of this equation result shows that the effect of the fall in output in 2009 is outweighed by:

- the error-correction mechanism
  - energy demand in the previous year is below the level implied by the long-run equilibrium relationships; the correction mechanism drives an increase in energy demand
- the effect of the lagged dependent variable
  - the large increase in energy demand in the previous year is carried through, in part, to current energy demand

Notably, the increase in energy demand from the lagged dependent variable is greater than the effect of the decline in current-period output.

The level of long-run energy demand in the 2009 run is similar to that in 2008 run

The error-correction mechanism and the lagged dependent variable are reinforcing effects in 2008 and 2009 (both contribute to the increases in energy demand). In 2010, the lagged dependent variable continues to drive an increase in energy demand, but this is tempered by the error-correction term which is now correcting for an above-equilibrium level of energy demand brought about by the equation's strong response to the lagged dependent variable. The error-correction mechanism continues to counteract the lagged dependent variable's effect in 2011, leading to a decline in energy demand in that year. The dynamics of the projection then begin to settle on the long-term growth path. The similarity in the long-run levels of GVA between the 2008 and 2009 runs is reflected in similar levels of energy demand by the end of the projection period.

In the long run, PPP GVA in the 2010 run is higher than in the other two runs

In the short run, the growth profile of PPP GVA in the 2010 run resembles the profile in the 2009 run. Output increases in 2008 and falls in 2009 before a return to growth. There is a period of higher growth over 2010-15 before a return to trend growth; the overall effect is to raise the long-run level of output in the 2010 run above the levels seen in the 2008 and 2009 runs.

The more up-to-date outturn data in the 2010 run indicate flat energy demand in 2008 and 2009, in contrast to the strong growth projected in the two earlier DECC Model runs. Energy demand rises sharply, by almost 16%, in 2010, the first year of forecast. This result is driven by the error correction term in the equation which suggests that energy demand in 2009 was below the long-run equilibrium implied by the equation. The strong growth caused by the error-correction term's effect is quite visible in Appendix Figure A.6.

The projection stabilises over the medium term in a similar fashion to the 2009 run, as the combined effect of the lagged dependent variable and the error-correction term settles. The long-run growth profile mirrors the previous two runs, although the level of energy demand is higher owing to a higher level of GVA in the 2010 run.

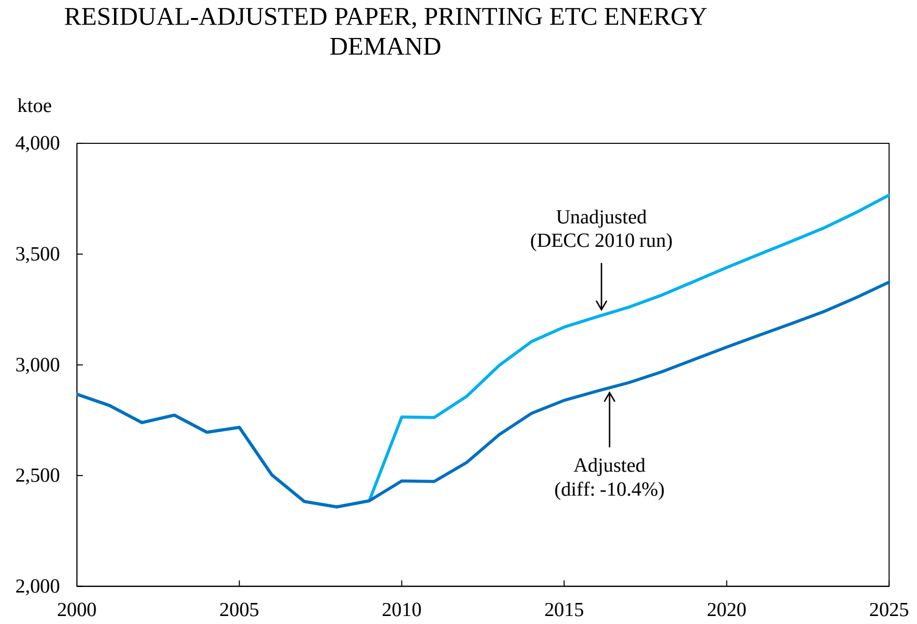
The PPP results from the 2010 run show a strong error-correction response

The results from the PPP aggregate energy demand equation in the 2010 run illustrate two findings from the main report (see Chapter 4) particularly well:

- a strong error-correction response in the early years of the forecast, which dominates the other drivers' effects
- the failure to account for new historical GVA data at the industry sub-sector level

Appendix Figure A.6 shows a sharp increase in energy demand at the start of the forecast period, driven by the error-correction response in the equation. The equation is correcting for a large deviation in the actual energy demand from the implied long-run equilibrium. If the discrepancy is indeed a one-off random shock, allowing the

Appendix Figure A.7: Residual-Adjusted Paper, Printing etc Energy Demand



Source(s): DECC.

equation to correct for the residual is acceptable. However, if there are reasons to think that the deviation is systematic or persistent, then the long-run equilibrium for energy demand is no longer valid and allowing the equation to correct to this relationship risks biasing the projection results.

Appendix Table A.1 lists the industry aggregate energy demand equations we were able to replicate. These equations' projections can be decomposed into the contributions of the individual drivers to the overall changes in energy demand and can also be examined over the historical period to assess the nature of the forecast errors. The forecast errors in the 2010 run over 2007-09 are listed in Appendix Table A.1.

The forecast error in the PPP aggregate energy demand equation widens over 2007-09

The majority of the equations listed in Appendix Table A.1 have tended to over-predict energy demand; the projected energy demands are persistently higher than the outturn figures. In the case of PPP, the forecast error also widens over time. The predicted level of demand in 2009 is more than 10% higher than the outturn figure. There appears to be some evidence of bias in the equation and thus a possible case for accounting for the forecast error in the projection period.

If the percentage difference between the equation result and the outturn figure in the last year of data were applied to the forecast over the projection period, energy demand from PPP would be 10.4% lower in the 2010 run than the published figures (see Appendix Figure A.7).

The energy demand projections with and without the residual adjustments give an indication as to the range of the projection results, depending on whether the forecast error in the last year of data is treated as completely transitory (the current DECC Model treatment) or completely persistent (the residual-adjusted forecast, which would also account for systematic biases). Particularly in a recession, the forecast error might be expected to arise from a combination of a transitory shocks as well as a persistent effect.

For PPP, the residual-adjusted forecast gives an indication of the lower bound on long-run energy demand in the 2010 run

Forecast errors could be separated into transitory (outliers) and persistent (structural breaks) effects by re-estimating the equation over the extended sample period and testing for the significance of outliers and breaks. We were unable to undertake re-estimation because we could not obtain the necessary dataset. Without re-estimation, the decision as to whether or not to apply a persistent residual adjustment is an issue of judgement, made on a pragmatic basis to guard against systematic bias in the projections over recent history. Unless the residual adjustment were applied to all DECC Model equations, it would be necessary to set clear criteria for its use.

Appendix Table A.1: Estimated Size of Industry Residual Adjustments

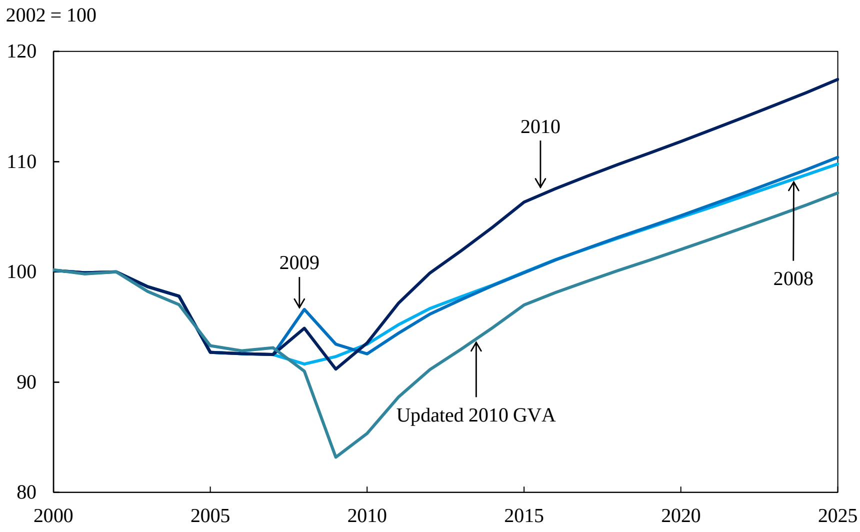
ESTIMATED SIZE OF INDUSTRY RESIDUAL ADJUSTMENTS

	2007	**2008**	**2009**	**2009 (ktoe)**	**Comment**
Non-ferrous metals	+4.6%	+1.3%	-8.9%	-103	Equation over-predicts in 2009, but under-predicts in 2007 and 2008 – evidence of bias is weaker
Chemicals	+1.6%	+12.4%	+6.7%	+215	Equation shows signs of under-prediction
Engineering & vehicles	-3.7%	-1.3%	-5.8%	-160	Equation shows signs of over-prediction
Food, drink & tobacco	-5.9%	-4.8%	-10.6%	-260	Equation shows signs of over-prediction
Textiles, leather, etc	-2.9%	-6.6%	-16.2%	-85	Equation shows signs of over-prediction
Paper, printing, etc	-3.0%	-6.8%	-10.4%	-29	Equation shows signs of over-prediction

Note(s) : Residual adjustments are calculated from the raw DECC Model results, which are expressed in 'useful' units of energy.
Source(s) : DECC, Cambridge Econometrics.

Appendix Figure A.8: ONS-Updated Paper, Printing etc GVA Assumptions

ONS-UPDATED PAPER, PRINTING ETC GVA ASSUMPTIONS



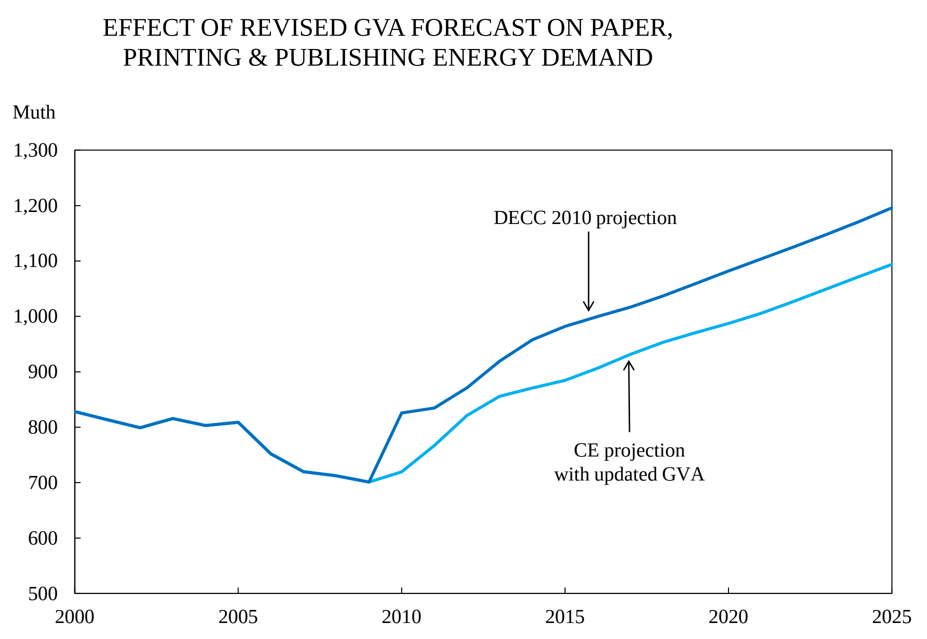
Source(s): DECC, ONS.

The most recent historical GVA data for the industry sub-sectors were not incorporated into the 2010 run

Another aspect of the PPP aggregate energy demand equation pointed out in the main report was the failure to update the historical GVA figures for the industry sub-sectors with more recent historical data. Appendix Figure A.9 shows the effect of including the updated GVA figures in the 2010 run, assuming that the growth rates in the projection period are unchanged. In 2009, the last year of industry sub-sector data in the DECC 2010 run, the level of PPP GVA in the assumptions is 9.6% higher than in the outturn GVA data. Moreover, the growth and decline in GVA in the 2010 run assumptions, in 2008 and 2009, respectively, is not seen in the actual outturn data for these years. Both the profile and the last year of data for PPP GVA are incorrect. This has implications for the energy demand projections.

Appendix Figure A.9 shows the PPP aggregate energy demand projection from the 2010 run alongside a modified version of that projection, which includes the updated GVA assumptions shown in Appendix Figure A.8. In the short run, the updated (lower) GVA figures in the modified projection implies a lower equilibrium level of long-run energy demand and, consequently, a smaller error-correcting response from the equation in 2010, the first year of projection.

Appendix Figure A.9: Effect of Revised GVA Forecast on Paper, Printing & Publishing Energy Demand



Source(s): DECC, ONS, CE calculations.

The updated GVA figures for PPP lead to a smaller disequilibrium term in the first year of forecast, reducing the size of the error-correction response

A smaller error-correction response in the short term leads to a smoother trajectory for energy demand because the reinforcing effects of the lagged dependent variable, and the subsequent compensation by the error-correction mechanism, are smaller. The long-run level of energy demand is lower in the adjusted projection because the long-run levels of GVA are lower as a result of the updated historical data. The long-run difference in energy demand mirrors the difference in the levels of GVA, by around 10%.

Discrepancies between the DECC assumptions and the most recent historical data are seen for all the industry sub-sectors, to varying degrees. Appendix Table A.2 compares the GVA assumptions in the DECC Model 2010 run for the industry sub-sectors against the historical GVA data in the ONS Blue Book over 2000-09. The final percentage difference between the assumptions and the outturn data for each sub-sector listed, in 2009, give an indication as to the long-run impact on the aggregate energy demand projection of using more up-to-date GVA series.

Discrepancies in the disaggregation of manufacturing GVA to the industry sub-sectors are potentially significant because different industries have different energy intensities, fuel mixes and rates of growth in energy efficiency. Allocating GVA growth to PPP over another sector can lead to potentially different outcomes for emissions in the aggregate.

Appendix Table A.2: Comparison of DECC Model and ONS Historical GVA

COMPARISON OF DECC MODEL AND ONS HISTORICAL GVA

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Food, beverages, tobacco										
DECC Model (2002 = 100)	96.7	98.0	100.0	99.9	101.5	102.4	101.6	100.8	99.6	88.0
Blue Book 2010 (2002 = 100)	96.8	97.3	100.0	98.3	99.9	101.9	101.2	101.2	99.5	97.6
% difference	0.0%	-0.7%	0.0%	-1.7%	-1.6%	-0.5%	-0.3%	0.4%	-0.1%	9.9%
Textiles Production										
DECC Model (2002 = 100)	121.3	108.1	100.0	98.2	88.5	86.7	88.0	86.0	84.2	82.0
Blue Book 2010 (2002 = 100)	122.1	106.7	100.0	98.2	87.4	85.5	85.4	84.1	83.8	76.7
% difference	0.6%	-1.3%	0.0%	-0.1%	-1.3%	-1.4%	-3.1%	-2.3%	-0.5%	-6.9%
Paper, printing, publishing & Pulp										
DECC Model (2002 = 100)	100.1	99.9	100.0	98.7	97.8	92.7	92.6	92.5	94.9	91.2
Blue Book 2010 (2002 = 100)	100.2	99.8	100.0	98.2	97.0	93.3	92.9	93.1	91.0	83.2
% difference	0.0%	-0.1%	0.0%	-0.4%	-0.8%	0.6%	0.3%	0.7%	-4.3%	-9.6%
Chemicals										
DECC Model (2002 = 100)	94.5	100.2	100.0	101.0	104.4	104.5	107.1	105.9	98.2	80.1
Blue Book 2010 (2002 = 100)	94.1	99.2	100.0	100.9	104.8	107.5	110.9	109.9	109.8	104.4
% difference	-0.4%	-1.0%	0.0%	-0.1%	0.4%	2.9%	3.4%	3.7%	10.5%	23.3%
Non-metallic mineral products										
DECC Model (2002 = 100)	101.2	101.7	100.0	105.9	112.0	111.5	113.5	114.7	109.0	92.0
Blue Book 2010 (2002 = 100)	100.2	101.1	100.0	104.4	110.7	110.8	113.9	113.9	107.6	92.5
% difference	-1.0%	-0.5%	0.0%	-1.4%	-1.2%	-0.7%	0.3%	-0.7%	-1.2%	0.6%

COMPARISON OF DECC MODEL AND ONS HISTORICAL GVA

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Non-Ferrous Metals										
DECC Model (2002 = 100)	115.0	113.5	100.0	87.2	93.1	96.9	97.9	103.4	100.1	87.4
Blue Book 2010 (2002 = 100)	101.7	98.9	100.0	98.7	101.3	102.2	103.7	104.5	100.3	81.1
% difference	-13.1%	-14.8%	0.0%	11.6%	8.1%	5.2%	5.7%	1.0%	0.2%	-7.7%
Iron & Steel										
DECC Model (2002 = 100)	129.9	116.1	100.0	113.7	118.0	113.5	119.2	122.7	115.9	84.0
Blue Book 2010 (2002 = 100)	101.7	98.9	100.0	98.7	101.3	102.2	103.7	104.5	100.3	81.1
% difference	-27.8%	-17.4%	0.0%	-15.3%	-16.4%	-11.1%	-14.9%	-17.4%	-15.5%	-3.5%
Vehicle Engineering										
DECC Model (2002 = 100)	110.8	106.5	100.0	100.3	104.6	103.5	107.0	108.4	104.5	91.8
Blue Book 2010 (2002 = 100)	104.7	103.2	100.0	104.8	110.7	110.3	115.3	116.4	113.5	97.1
% difference	-5.8%	-3.2%	0.0%	4.3%	5.5%	6.1%	7.2%	6.9%	7.9%	5.4%
Other Manufacturing										
DECC Model (2002 = 100)	103.1	101.1	100.0	100.3	99.7	97.8	98.4	99.8	94.7	86.8
Blue Book 2010 (2002 = 100)	110.4	107.2	100.0	98.6	101.2	100.3	102.2	103.5	99.1	86.1
% difference	6.6%	5.6%	0.0%	-1.7%	1.5%	2.5%	3.7%	3.5%	4.4%	-0.8%
Total manufacturing										
DECC Model (2002 = 100)	104.0	102.7	100.0	100.2	102.2	101.0	102.6	103.1	100.3	89.8
Blue Book 2010 (2002 = 100)	103.6	102.2	100.0	99.7	101.9	101.8	103.3	103.8	100.8	90.2
% difference	-0.4%	-0.5%	0.0%	-0.5%	-0.4%	0.7%	0.7%	0.7%	0.5%	0.4%
Construction										
DECC Model (2002 = 100)	94.4	96.5	100.0	104.7	108.9	110.5	111.7	114.4	105.9	103.2

COMPARISON OF DECC MODEL AND ONS HISTORICAL GVA

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
Blue Book 2010 (2002 = 100)	94.0	96.2	100.0	105.1	108.6	109.8	110.9	113.9	113.0	100.6
% difference	-0.4%	-0.3%	0.0%	0.4%	-0.2%	-0.7%	-0.8%	-0.5%	6.2%	-2.7%

Note(s) : The DECC Model GVA series are taken from the 2010 run.
The ONS *Blue Book* does not separately identify Iron & Steel and Non-Ferrous Metals as sectors; only Basic Metals as a whole is defined (and reported above).

Source(s) : DECC, ONS.

A.4 Engineering & vehicles

The Engineering & vehicles aggregate energy demand equation is specified as an error-correction model

The aggregate energy demand equation for Engineering & vehicles is specified as an error-correction model with industry output and a time trend as its drivers. The coefficient on the time trend in the equation has a value of -0.008. The coefficient is negative, indicating an increase in energy efficiency over time.

The GVA assumptions mirror the growth profiles of manufacturing output as a whole seen in Appendix Figure A.1. Engineering & vehicles GVA in the 2008 run grows by 1¾-2% pa in the long run. This long-run growth is also seen in the 2009 and 2010 runs although the short-term output profiles in these two runs differ because they include the recession.

The output assumptions in the 2009 and 2010 runs show falls in GVA in 2008 and 2009, to similar levels of output. The 2010 run has a relatively smaller decline in 2008 and a sharper decline in 2009, when compared against the growth profile in the 2009 run. In contrast to PPP, Appendix Table A.2 shows that the GVA figures for Engineering & vehicles tend to be lower than the actual data in the historical period.

The 2009 run assumes a permanent loss of output from the recession…

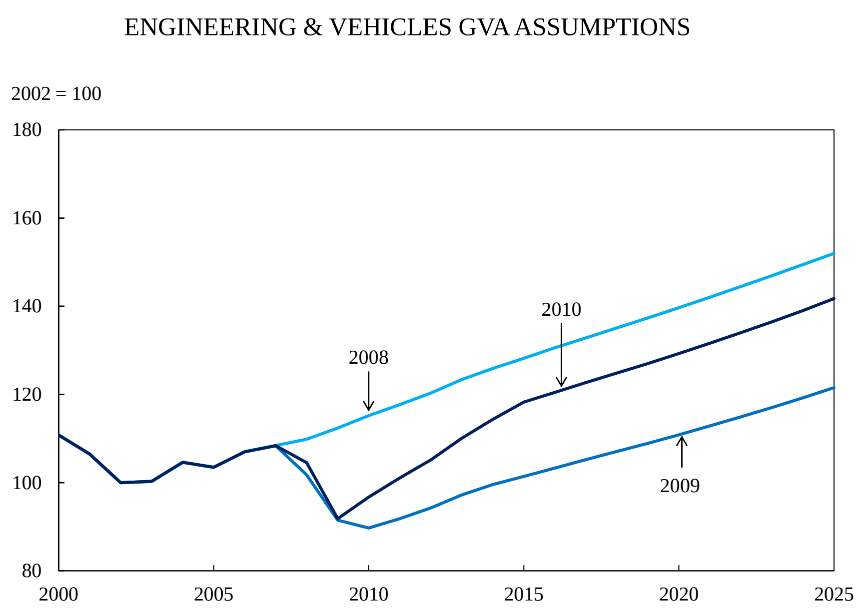
The assumptions in the two most recent runs diverge in 2010. While the 2009 run has a further year of decline in output (consistent with the assumptions for manufacturing GVA in aggregate), the 2010 run assumes strong growth of more than 5% in 2010.

After 2010, the output growth profile in the 2009 run is very similar to that of the 2008 run. The three years in which output falls lead to a permanent loss of output, of around 20%, when the levels of output in the two runs are compared.

…while the 2010 run includes a period of recovery

In contrast to the permanent loss of output in the recession assumed in the 2009 run, the 2010 run embodies a period of recovery. The GVA assumptions are for higher growth of 3½-4½% pa over 2011-15 and the long-run trend of 1¾-2% prevails

Appendix Figure A.10: Engineering & Vehicles GVA Assumptions



Source(s): DECC.

thereafter. By 2020, GVA in the 2010 run is around 7½% below the level in the 2008 run.

The historical data show a general fall in energy demand

In recent history, energy demand from Engineering & vehicles has generally been falling. There is a particularly large fall in 2007 (the last year of data in the 2008 and 2009 runs), of almost 4%.

In the 2008 run, energy demand in the long run increases by ½-1% pa

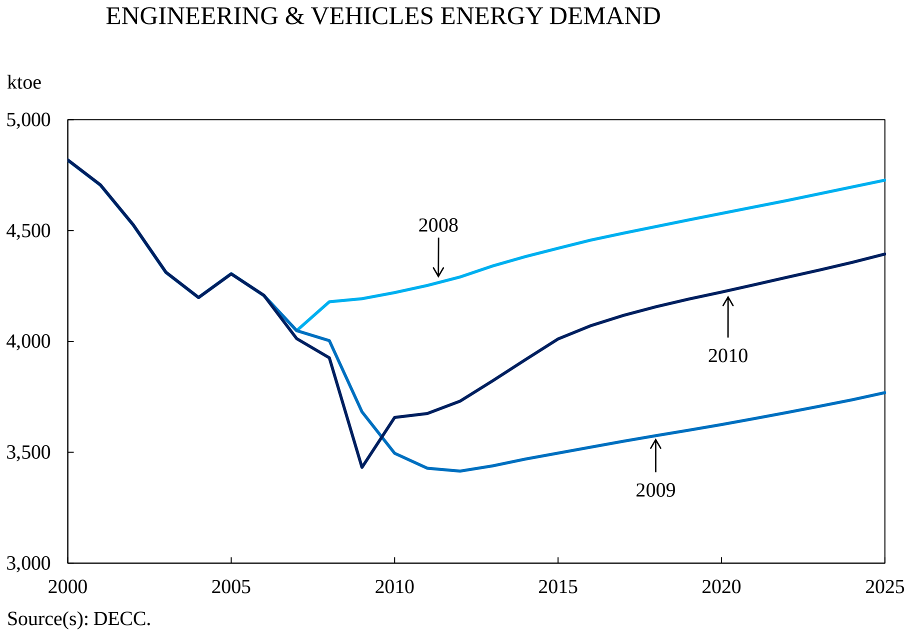
In the 2008 run, there is a 3.2% increase in energy demand in 2008, the first year of projection. This growth is driven by the sustained increase in output in the GVA assumptions and the error-correction response; energy demand in the previous year was below the level implied by the long-run equilibrium of the equation. After the strong growth in 2008, to bring energy demand back to the long-run path, growth is steady to 2020, at ½-1% pa. This trajectory is consistent with output growth of 1¾%-2% pa (long-run energy demand grows one-for-one with output) and the increase in energy efficiency over time (the time trend reduces energy demand growth by approximately ¾ pp each year).

Engineering & vehicles energy demand fell in the recession

In contrast to the immediate increase in energy demand seen in the 2008 run in the first year of projection, energy demand in the 2009 run falls by 1.1% in 2008 owing to the fall in output in this set of assumptions.

In the early part of the projection, energy demand in the 2009 run continues to fall. A sharp fall in output in 2009 (-10.1%) drives a similarly sharp fall in energy demand (-8%). A more modest fall in output in 2010 leads to a further fall in energy demand. From 2011 onwards, the 2009-run output profile for Engineering & vehicles is similar to the profile in the 2008 run and energy demand in the 2009 run returns quickly to the long-run path, growing at ½-1% pa.

Appendix Figure A.11: Engineering & Vehicles Energy Demand



Source(s): DECC.

Updated economic assumptions did reduce the short-run forecast errors for Engineering & vehicles energy demand

The outturn data in the DECC Model 2010 run show falls in energy demand in 2008 and 2009. Appendix Figure A.11 shows that the updated GVA assumptions in the 2009 run move the short-term forecast in that run closer to the outturn data, when compared against the 'no-recession' 2008 run; the forecast errors have been reduced.

Appendix Figure A.11 also shows a sharp increase in energy demand in the 2010 run, in the first year of projection (2010), of 6.6%. This increase in demand is driven by a combination of the increase in GVA in the 2010 run assumptions, in 2010, and the error-correction mechanism compensating for below-equilibrium energy demand. Energy demand grows steadily over the medium term, reflecting the higher output growth in the recovery period. In the long run, energy demand grows at a similar rate to the long runs of the other DECC projections, at ½-1% pa.

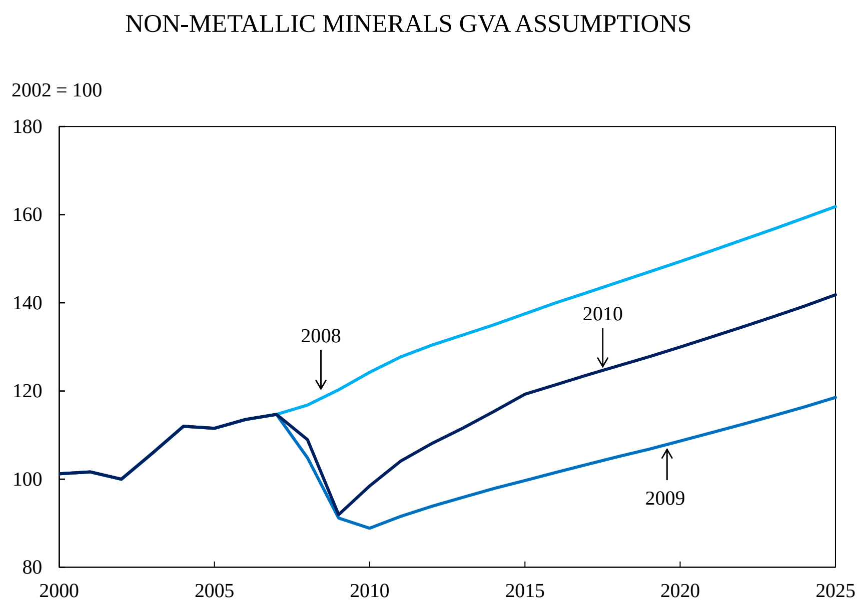
A.5 Non-metallic minerals

The Non-metallic minerals aggregate energy demand equation is specified as an error-correction model

The DECC Model equation for Non-metallic minerals aggregate energy demand is a cointegrating equation with output and a time trend as the main drivers. The time trend coefficient is negative, with a value of -0.020; energy efficiency increases at approximately 2 pp pa. As with the PPP aggregate energy demand equation, the Non-metallic minerals equation includes a lagged dependent variable term. The coefficient on this term is positive and relatively modest in size, taking a value of 0.202.

While the other industry equations have one, and at most two, dummy variables, the Non-metallic minerals equation has four, to account for events that cannot be explained by the other explanatory variables. This is possibly unusual, given that the sample period for this equation is 1980-2004. Once lags and first differences in the equation are accounted for, the more than one-sixth of the observations are associated with dummy variables.

Appendix Figure A.12: Non-Metallic Minerals GVA Assumptions



Source(s): DECC.

The GVA profiles for Non-metallic minerals are similar to those for manufacturing as a whole, with long-run output growth of 1½-1¾% pa (see Appendix Figure A.12). In the 2009 run, industry output is around 27% level in 2020 than in the 2008 run. The recovery in the 2010 run closes the gap in output to the 2009 run, to 13%.

For this industry sub-sector, the discrepancies between the GVA assumptions in the 2010 run and the official UK statistics are small. GVA in this sector in 2009, according to *Blue Book 2010*, was around ½% higher than the corresponding DECC Model assumption (see Appendix Table A.2).

In the 2008 run, energy demand first rises…

There is a clear downward trend in energy demand from Non-metallic minerals over 2000-07 (see Appendix Figure A.13). Despite this downward trend, energy demand increases in the 2008 run, in 2008, by 1%. This growth is driven by the growth in output (in the short term, energy demand grows almost one-for-one with output) and the error-correction term (to compensate for below-equilibrium energy demand in the recent history). A further year of energy demand growth follows in 2009, bolstered by the effect of the lagged dependent variable and strong growth in the previous year.

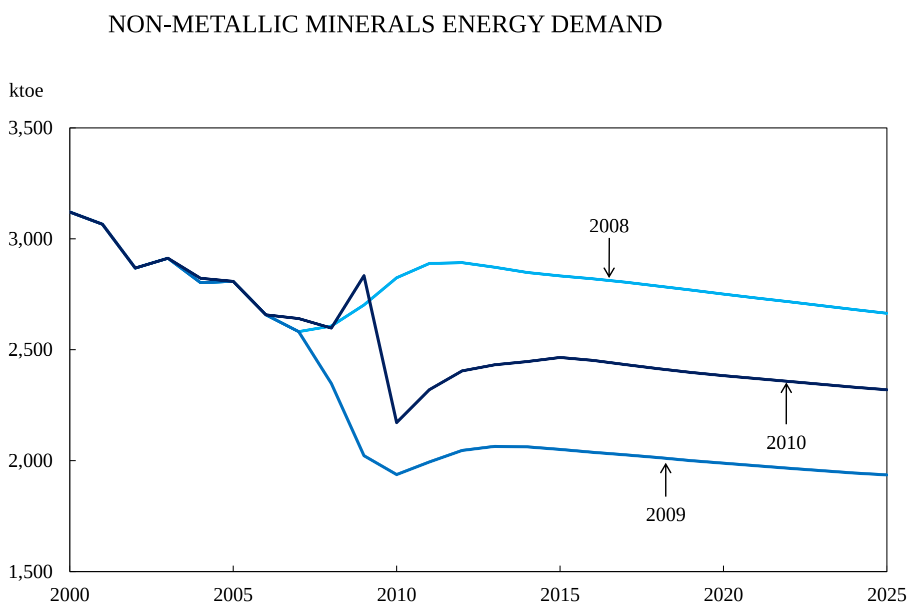
…and then falls in the long run, by ½% pa

Energy demand growth slows over 2010-12 as the error-correction term compensates for the lagged dependent variable's effect. Thereafter, the long-run trend is for a sustained decline in energy demand, by around ½% pa; output growth is outweighed by increases in energy efficiency.

In contrast to the continual growth in output in the 2008 run, in the 2009 run the recession leads to a fall in output of 8.6% in 2008 and a further decline of 13% in 2009. A more modest decline, of 2.5%, is seen in 2010.

The sharp fall in output in the 2009 run is mirrored in sharp reductions in energy demand. The fall in 2010 is smaller than in the previous two years owing to a smaller decline in output.

Appendix Figure A.13: Non-Metallic Minerals Energy Demand



Source(s): DECC.

After the recession, energy demand from Non-metallic minerals grows by 2½-3% pa, driven mainly by the recovery in output. Output growth slows in the medium-to-long term, and the long-run equilibrium returns, with energy demand gradually falling by ½% pa.

The data in the 2010 run suggest substantial forecast errors in the 2009 run projection…

The 2010 run, which incorporates new outturn data for 2008 and 2009, shows a slight fall in energy demand in 2008 (much smaller than the reduction projected in the 2009 run) followed by a strong increase in demand in 2009 (in contrast to a sharp fall projected in the 2009 run in the recession). When the runs are compared, the updated economic assumptions in the 2009 run appear to have led to a larger forecast error than the 2008 run, which does not include a recession. However, we were unable to reconcile the outturn data in the 2010 run with the officially-published data in *DUKES 2010*.

…but we are unable to reconcile the 2010-run figures with those in DUKES 2010

The energy-demand figures in the DECC Model database (for historical data) and from the equations (for demand in the projection period) are expressed in units of 'useful' energy. This measure of energy consumption excludes the energy contained in the fuels that is not captured and used in production ie the energy lost in combustion. Moreover, different fuels have different conversion efficiencies, potentially leading to different growth profiles when comparing the DECC Model energy demand figures to those in *DUKES*.

However, even accounting for the conversion efficiencies, we are unable to reconcile the historical data embodied in the DECC 2010 run with the figures in *DUKES 2010*. The 2010 run has a fall in aggregate energy demand in 2008, followed by an increase. In contrast *DUKES 2010* suggests that energy demand rose in 2008 before falling in 2009. We were unable to resolve this discrepancy in the project.

The profile of short-run energy demand in the 2010 run in 2008 and 2009 is also surprising when considered in the light of the output assumptions. Output in 2008 falls by 5% (energy demand falls by 1.6%) and a sharper fall of 15.6% is seen in 2009 (but energy demand *increases* by 9.1%).

We are also unable to explain the sharp fall in energy demand in 2010 in the DECC projection

The data discrepancy aside, our replication of this equation appears incomplete. We were unable to produce an equation that mimicked the short-term dynamics seen in Appendix Figure A.13; in particular, the sharp fall in demand in 2010 (of more than 23%) is greater than the fall predicted by our version of the equation (which suggests a fall of around 8%).

Nevertheless, the long-run characteristics of the replicated equation appear sound and we are able to reproduce the medium-term dynamics and return to the long-run trend. In the post-recession period, energy demand grows, much as it does in the medium terms of the 2008 and 2009 runs, driven by output growth over this period. Growth in energy demand slows to 2015 before the long-run trend re-asserts itself. The reason for the different long-run levels is explained by the differences in the long-run levels of output.

A.6 Non-ferrous metals (NFM)

The Non-ferrous metals aggregate energy demand equation is specified as an error-correction model

The Non-ferrous metals (NFM) aggregate energy demand equation in the DECC Model is specified as an error-correction model. The time trend (with a value of -0.026) only applies before 1994[38], leaving output as the only driver in the equation over the projection period. The only source of dynamics in the equation is the error-correction mechanism.

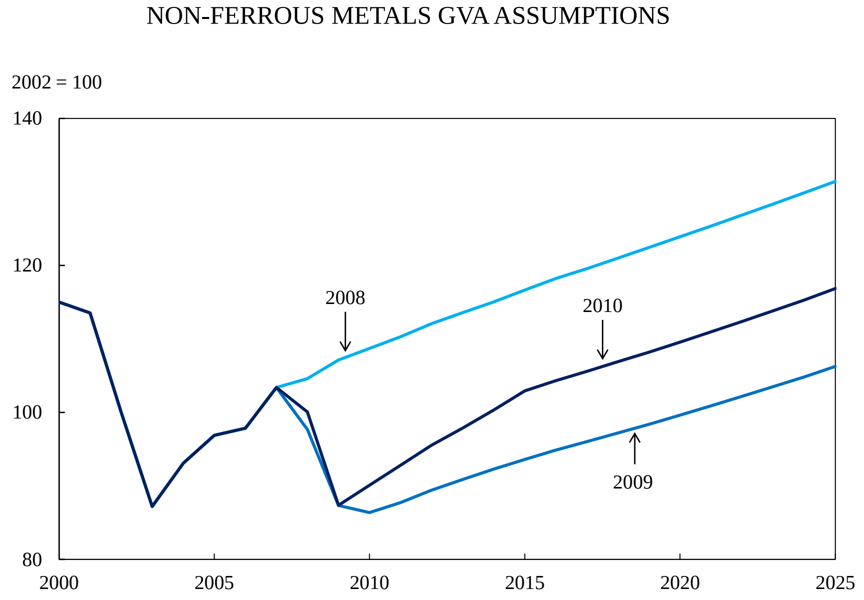
The GVA assumptions for NFM follow the same pattern as for manufacturing as a whole. Long-term growth in all three runs is around 1¼% pa (see Appendix Figure A.14). It is difficult to gauge the nature of the discrepancy in the GVA figures between the DECC Model runs and official statistics because Iron and steel and NFM are not separately distinguished as economic sectors in the ONS *Blue Book*. In the 2009 run, GVA is around 19½% lower than in the 2008 run, in the long run. The gap between long-run GVA in the 2008 and 2010 runs is smaller, owing to the economic recovery; energy demand in the 2010 run is around 12½% lower.

The NFM equation does not allow for a change in energy efficiency over the projection period

The only terms of note in the aggregate energy demand equation are output (which drives the long-term trend) and the error-correction term (which determines the path to the long-run relationship). As previously mentioned, there is no change in energy efficiency explicitly represented in the equation over the projection period.

The data in the DECC Model runs show an increase in NFM energy demand over 2005-07 and the 2008 run shows a further increase in 2008, the first year of projection. As with the Non-metallic minerals equation, our replication of the NFM aggregate energy demand equation appears incomplete. We were unable to reproduce the short-

Appendix Figure A.14: Non-Ferrous Metals GVA Assumptions



Source(s): DECC.

[38] The value of the time trend term is constant after 1994, indicating a permanent energy saving but no further increases in efficiency.

term dynamics of the equation, which show an increase in energy demand in the first year of forecast. However, we were able to reproduce the longer-term dynamics which show the return to equilibrium depicted in Appendix Figure A.15.

The DECC projections show clearly the correction to the long-run equilibrium

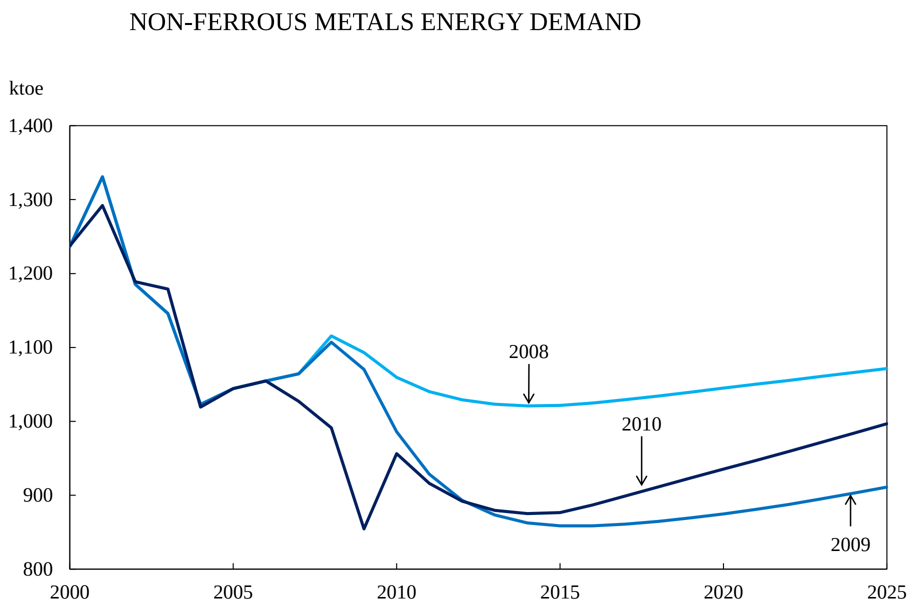
Appendix Figure A.13 shows clearly that the long-run relationship in the equation implies a lower level of energy demand than that seen in the recent history. This prompts a strong error-correction response from the equation, driving energy demand down. The rate of decline slows over the medium term as the projected energy demand returns to the long-run relationship and the long-run trend re-asserts itself from around 2015 onwards. In the 2008 run energy demand grows at around ½% pa. This growth is consistent with the level of energy savings 'locked in' before 1994.

Energy demand in the 2009 run also increases in the first year of projection. Again, this is a result we were unable to replicate and occurs despite the fall in GVA in 2008 in this run. The 2009 run assumptions for output suggest a much lower level of GVA than in the 2008 run. Energy demand in the recent history and the short run is much further away from the long-run equilibrium than in the 2008 run, leading to a much stronger error-correction response. This is seen in larger falls in energy demand before the long-run trend of increasing energy demand takes over.

There were difficulties in reproducing the dynamics and long-run trend in the 2010 run

The outturn data in the 2010 run for 2008 and 2009 show decreases in energy demand, in contrast to the increase projected in 2008 in the earlier two runs. The 2010 run shows a particularly sharp fall in energy demand in the recession in 2009. Appendix Figure A.15 shows a clear forecast error that is not reduced when the GVA assumptions are updated in the 2009 run. Without being able to replicate the short-term dynamics, the reasons for the forecast errors are not clear.

Appendix Figure A.15: Non-Ferrous Metals Energy Demand



Source(s): DECC.

The sharp increase in energy demand in 2010 was not reflected in our own replication of the equation although the general profile of the return to the long-run equilibrium is similar to the energy demand projection in Appendix Figure A.15.

However, another feature of the 2010 projection we were unable to reproduce is the higher long-run growth in the 2010 run; 1¼% pa compared to around ½% pa in the 2008 and 2009 runs. We are unable to relate this higher growth in energy demand with the output growth in the assumptions (which is similar to the growth in the 2008 and 2009 runs, at around 1¼% pa).

A.7 Food, drink etc

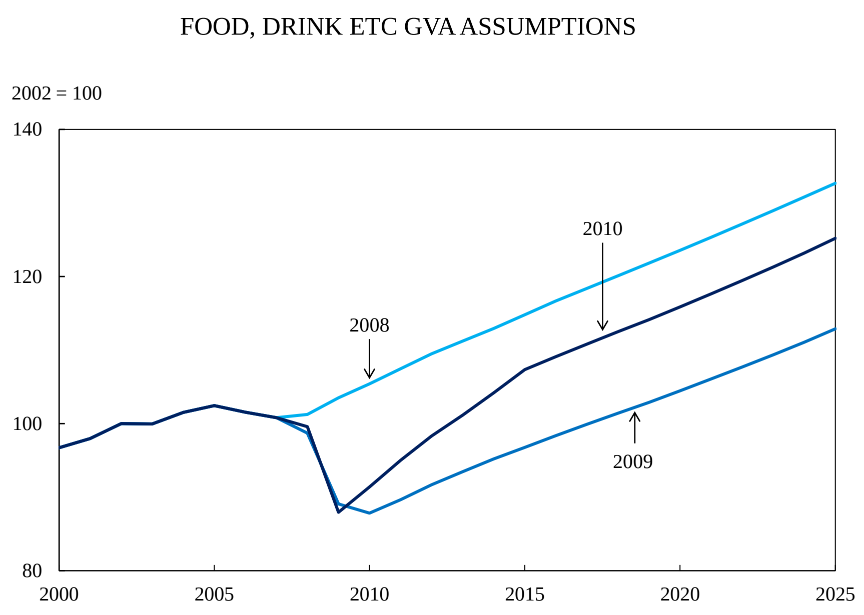
The Food, drink etc aggregate energy demand equation is a levels equation, rather than one specified as an error-correction model

The DECC Model equation for Food, drink etc is specified in levels, rather than as an error-correction model. As such, there are no dynamics and energy demand grows in line with output, accounting for the effect of the time trend. The value of the coefficient on the time trend is negative (-0.003); increasing energy efficiency reduces energy demand by approximately 0.3 pp pa.

The output assumptions for Food, drink etc again mirror those for manufacturing as a whole. In the long run, output grows at around 1½% pa. In the long run, GVA in the 2009 run is around 15½% lower than in the 2008 run projection. The gap between the 2008 and 2010 runs is smaller, at around 6¼% (see Appendix Figure A.16).

Appendix Table A.2 shows that the discrepancy between the DECC Model assumptions and ONS figures is small over 2005-08 (less than ½%) but increases substantially in 2009. Output in 2009, in the 2010-run data, is almost 10% lower than the official figures.

Appendix Figure A.16: Food, Drink etc GVA Assumptions



Source(s): DECC.

The Food, drink etc equation is a levels equation with no dynamics…

As a levels equation with no dynamics, we would not expect the incorporation of new outturn energy demand data to affect the projections; only changes in the output assumptions are expected to have an effect (accounting for the effect of the time trend on energy efficiency). This is borne out in the projections of energy demand themselves (see Appendix Figure A.17).

…and the return to the long-run trend is instantaneous

In the 2008 run, strong growth in energy demand at the start of the projection period (in contrast to the general downward trend over 2000-07) arises from a jump from the actual outturn data to the equation result. The transition from history to forecast does not take account of results in previous periods; the 'error-correction' is effectively instantaneous. Long-run growth resumes almost immediately, at around 1¼% pa. The growth in energy demand is slightly lower than the growth in long-run output owing to the negative coefficient on the time trend term; energy efficiency is increasing over time.

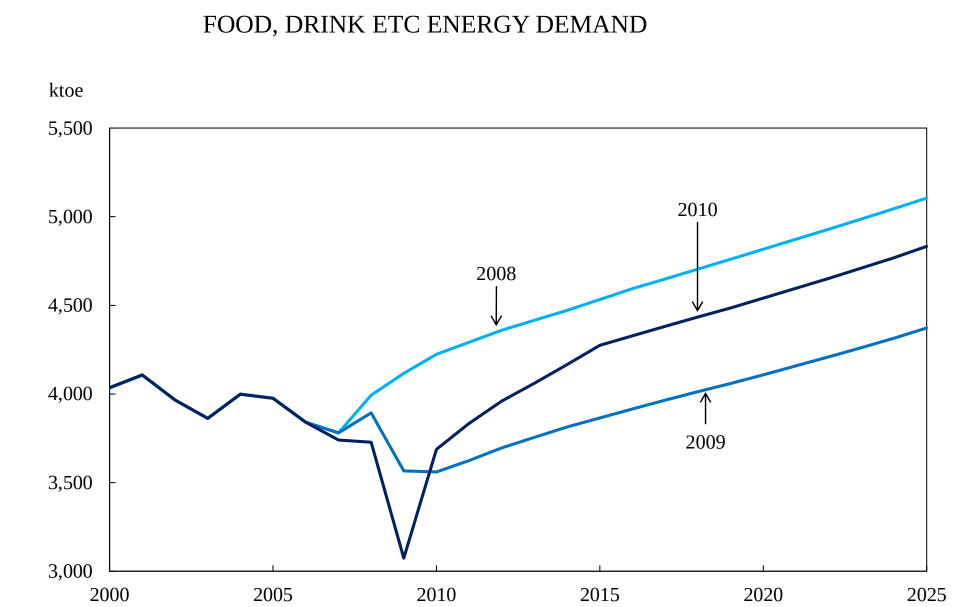
The 2009 run is similar to the 2008 run in the immediate return to the long-run equilibrium. Long-run energy demand is lower than in the 2008 run owing to the lower level of output in the assumptions.

The updated assumptions in the 2009 run do reduce the forecast errors in energy demand

Appendix Figure A.17 shows that the updated output assumptions in the 2009 run, to include a recession, do lead to a short-term forecast for energy demand that is closer to the outturn data in the 2010 run. The 2009 figure in the 2009 run would have been closer still if the assumptions had included a sharper fall in output, as seen in the 2010-run outturn data.

As in the previous two runs, there is a clear return to trend after the last year of data in the 2010 run. Energy demand fell sharply in 2009 and in 2010 increases strongly, reflecting both the growth in output, but also a higher level of energy demand projected by the equation compared to the outturn figure.

Appendix Figure A.17: Food, Drink etc Energy Demand



Source(s): DECC.

The equation persistently over-predicts energy demand…

The pronounced shifts in demand in the transition from history to forecast raise the possibility that there are quite large differences between the outturn data and the levels of energy demand predicted by the equation. The formal decomposition of the equation into its components confirms this. Over 2002-09, the Food, drink etc equation over-predicted energy demand, by 1-3% over 2002-05 and by around 5% over 2006-08. The period of over-prediction in the recent historical period is possible evidence of systematic bias in the equation and presents a case for either applying a residual adjustment or re-estimating the equation and possibly including a structural break, to account for the bias.

…and the forecast error increases substantially in the recession

Appendix Table A.1 shows the forecast errors over 2007-09. The error in the Food, drink etc equation increases markedly in 2009; it is more than twice as large as the error in 2008. It seems reasonable to expect that at least some of the error is related to the tendency for over-prediction in previous years of history (justifying either a residual adjustment or a structural break in a re-estimated equation, as mentioned above). The increase in the error in 2009 (which is likely to show up as an outlier in an econometric analysis) could be a combination of

- a persistent change in the long-run relationship
  - this may either increase or decrease the equation's tendency to over-predict energy demand and should be carried forward into the projection period
- a transitory shock in the recession
  - this portion of the error should not be carried forward into the projection period

It is difficult to identify the relative contributions of the above from the last data point in the series and, as mentioned previously, accounting for the discrepancy is a matter of judgement. The current DECC treatment (as a transitory shock) and a residual adjustment to account completely for the forecast error (as a persistent change) are two extremes for dealing with the error.

A.8 Textiles, leather etc

The Textiles, leather etc aggregate energy demand equation is specified as an error-correction model

The Textiles, leather etc aggregate energy demand equation is specified as an error correction model with output and the time trend as the key drivers. The time trend coefficient takes a positive value, of 0.033; other things being equal, energy demand increases by 3.3% pa (energy consumption per unit of output increases over time).

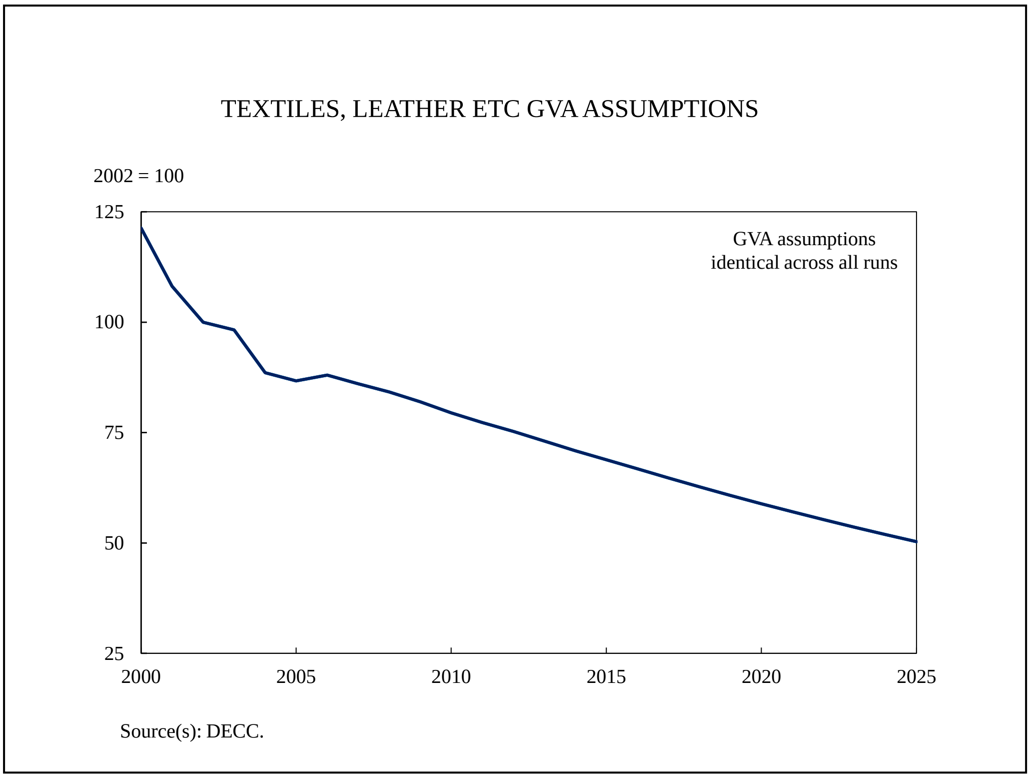
The output assumptions for this sector are identical in all three DECC Model runs; the recession in the 2009 and 2010 runs is not reflected in the GVA projections for this industry sub-sector. In the long run, GVA falls steadily, by 3% pa (see Appendix Figure A.18). This continues the trend of decline in UK textiles.

The output assumptions are identical across the DECC Model runs

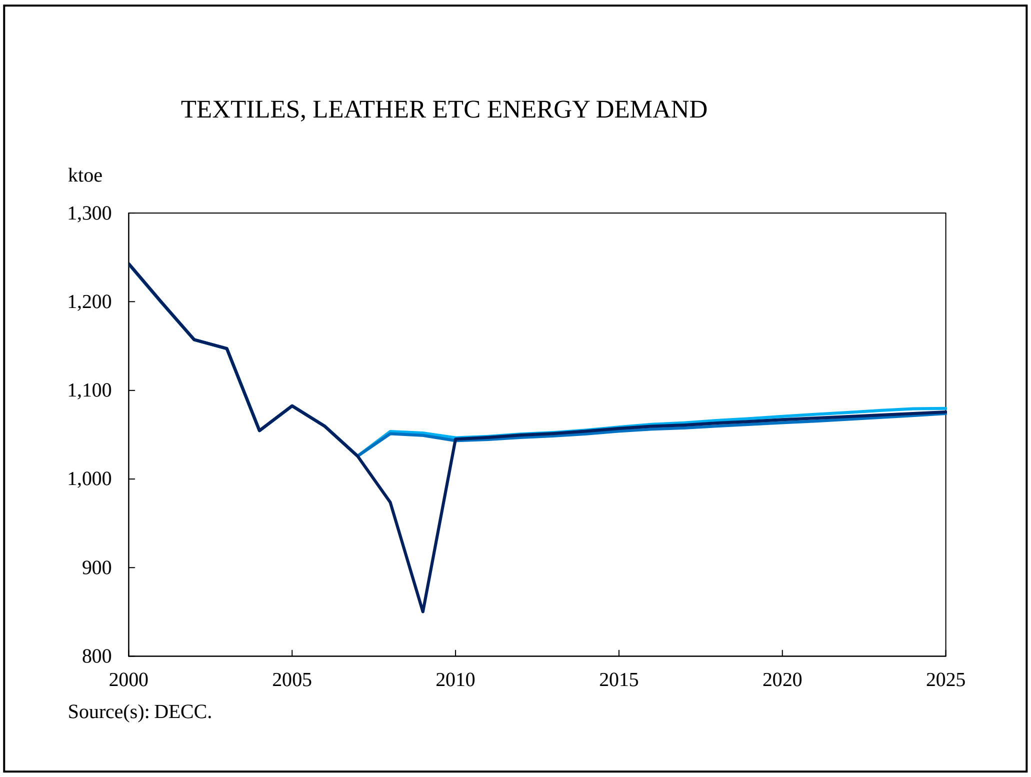
The failure to update the historical GVA figures to account for the recession can be seen in the widening gap between the DECC Model GVA assumptions and the ONS outturn data (see Appendix Table A.2). By 2009, the DECC Model assumptions (which do not account for a change in economic circumstances as a result of the recession) assume output to be almost 7% higher than the actual outturn.

Because the GVA assumptions are unchanged between runs, the only new data in the projections are the updated outturn energy demand data in the 2010 run. The energy demand projections in the 2008 and 2009 runs are identical (see Appendix Figure A.19).

Appendix Figure A.19: Textiles, Leather etc GVA Assumptions



Appendix Figure A.18: Textiles, Leather etc Energy Demand



Appendix Figure A.19 shows a general decrease in energy demand over 2000-07, but this trend reverses over the projection period.

In the long run, lower output leads to lower energy demand (from the one-for-one relationship between output and energy demand), but this is offset by increases in energy intensity from the time trend; energy demand grows by around ¼% pa.

Energy demand fell sharply in the recession

The 2010 run includes outturn energy demand data for 2008 and 2009. In contrast to the increase and slight decrease projected in the 2008 and 2009 runs, energy demand fell sharply in the recession, by 5% in 2008 and almost 13% in 2009. The 2009 run was not updated to include a recession in its economic assumptions for this sector so the forecast errors are identical when the 2008 and 2009 runs are compared against the 2010 run.

We were unable to replicate the rapid return to the long-run trend in the DECC projection

In the 2010 run, in the first year of forecast, energy demand returns immediately to the long-run trend in the 2008 and 2009 runs. This is surprising given the dynamic nature of the equation specification. Moreover, our own replication of the equation suggests the return to the long-run trend is slower than the error-correction mechanism evident in Appendix Figure A.19.

The projected increase in energy demand over time, despite the downward trend in output, is unusual, implying an increase in energy intensity over time. The atheoretic nature of the energy efficiency term makes this difficult to interpret, although it is possible that UK production is increasingly high value-added in nature.

A.9 Construction and Other industry

DECC report energy demand from an aggregate sector comprising Construction and Other manufacturing

Aggregate energy demand from Construction and Other industry (also known as Other manufacturing) is projected separately in the DECC Model, but aggregated for reporting. Construction accounts for a relatively large share of UK output and is larger than Other industry in output terms. Conversely, Construction accounts for a relatively small share of UK final energy demand; Other industry demand was more than ten times larger in 2009. As such, we would expect the energy demand projections from the Other industry equation to have a greater bearing on the aggregate figure reported by DECC than Construction.

The Construction equation is a levels equation with an elasticity of one imposed on output (energy demand grows one-for-one with output) and a negative coefficient (-0.052) on the time trend term, indicating an increase in energy efficiency over time.

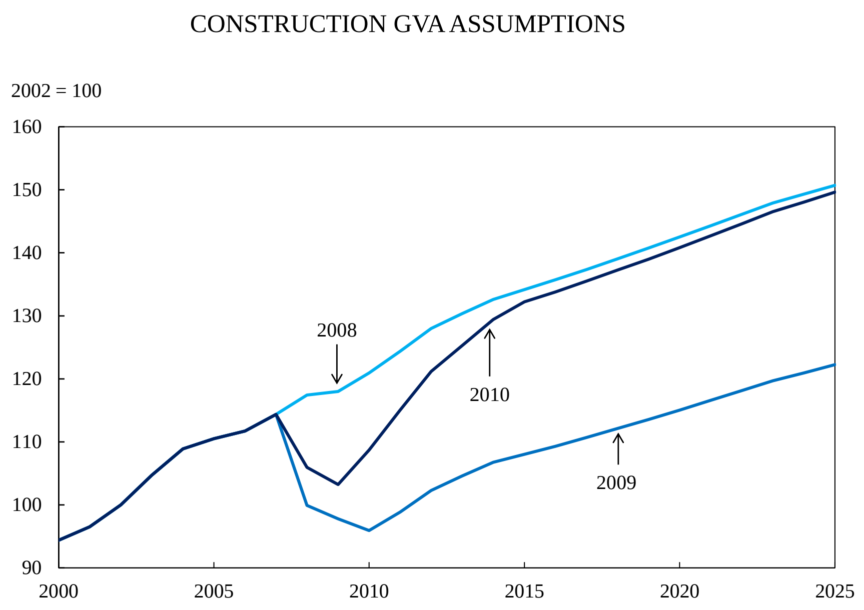
The Other industry equation is the only aggregate energy demand equation to include a price term

The equation for Other industry is specified as an error correction model. In contrast to the majority of the industry equations, the Other industry equation does not include a time trend but does include a price term, a weighted average of the price of individual fuels. The price elasticity is negative (as would be expected) and relatively small, with a value of -0.145.

Construction GVA grew strongly over 2000-07 and is projected to continue to grow in the 2008 run. Growth remains strong (1¾-3% pa) over the medium term, slowing to 1¼% pa in the long run.

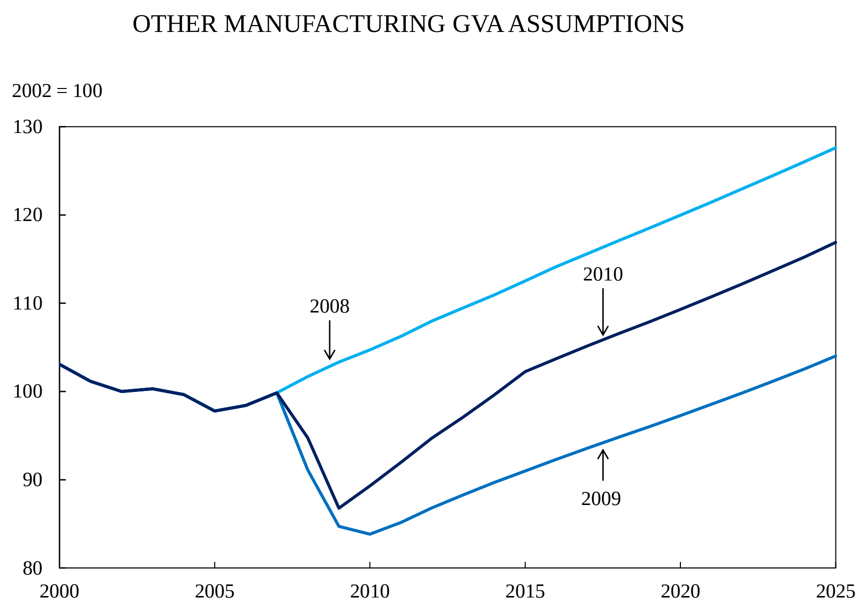
In the 2009 run, Construction GVA falls sharply in the recession, by 12½% in 2008 and 2% in both 2009 and 2010 (see Appendix Figure A.20). There is a small recovery in output in the medium term but, for the most part, Construction sees a permanent loss of output in the 2009 run. In the long run, output is more than 19% lower in the 2009 run than in the 2008 run.

Appendix Figure A.20: Construction GVA Assumptions



Source(s): DECC.

Appendix Figure A.21: Other Manufacturing GVA Assumptions



Source(s): DECC.

In the 2010 run, Construction output recovers to almost the same levels as in the 2008 run

The assumptions in the 2010 run show a less severe fall in Construction output in 2008 than was included in the 2009 run, a decline of 7½% instead of 12½%. There is a further decline in 2009, of 2½%. In the recovery, output grows strongly, by more than 5% pa over 2010-12 and by over 3% pa for the two years after. Trend long-run growth follows. The strong growth in the medium term leads Construction GVA to return to almost the same levels as in the 2008 run. Long-run output in the 2010 run is around 1% lower than in the 2008 run.

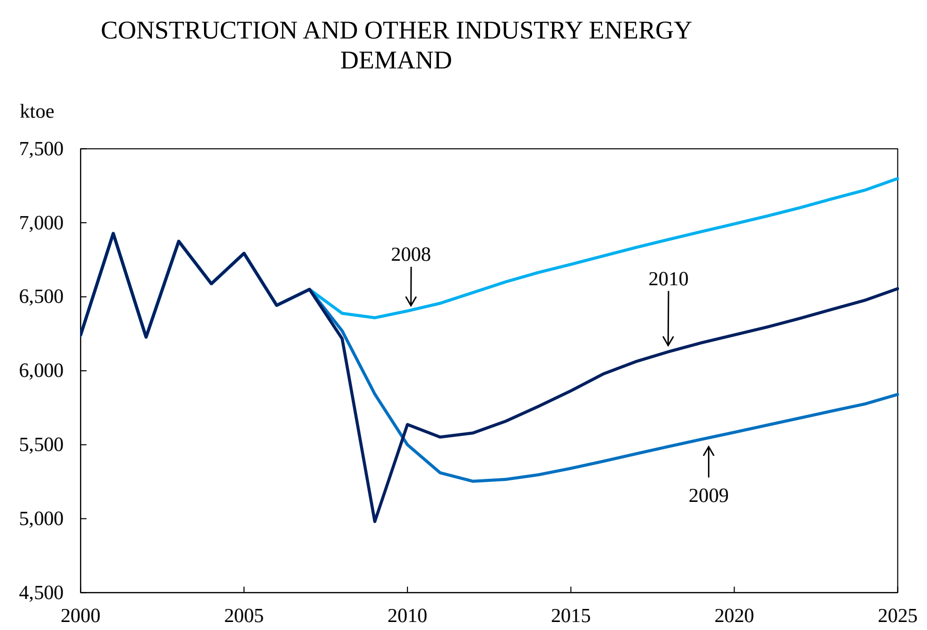
The output assumptions for Other manufacturing mirror the manufacturing GVA assumptions more closely. In the long run, output grows by 1¼ -1½% pa. Long-run output in the 2009 run is 19% lower than in the 2008 run. The recovery in the 2010 run closes the gap in long-run output to 9% below the 2008 run.

In the 2008 run, energy demand from Other manufacturing increases while energy demand from Construction falls

Energy demand from Construction and Other industry fluctuated over 2000-07 and there is no clear upward or downward trend in the data. In the 2008 run, energy demand is projected to fall in 2008 and 2009 before growing steadily by ¾-1% pa thereafter. The long-run growth in energy demand is driven by output growth in Other manufacturing but slowed somewhat by falling energy demand in Construction (the increase in efficiency outweighs the growth in output in this sub-sector).

The updated output assumptions in the 2009 run, which include a sharp decline in the recession, lead to a sharp decline in energy demand and further smaller falls in the following years (see Appendix Figure A.22). Construction is a small fuel user relative to Other manufacturing; the mild recovery in Construction output in the short term does little to counteract the permanent loss in Other manufacturing output. Energy demand returns to the long-run trend from 2013 onwards. Long-run energy demand in the 2009 run is around 20% lower than in the 2008 run.

Appendix Figure A.22: Construction and Other Industry Energy Demand



Source(s): DECC.

The new outturn data in the 2010 run show a sharper decline in energy demand in the recession than that projected in the 2009 run. However, the updated assumptions in the 2009 run do bring the short-term energy demand projection closer to the outturn, when compared against the 2008 run.

We were unable to replicate the strong increase in energy demand in 2010; instead, our reproduction of the equation suggests a gentler return to the long-run trend. The long-run levels appear similar in the DECC results and our own. Long-run energy demand from Construction and Other industry in the 2010 run is around 11% lower than in the 2008 run. The difference comes from Other manufacturing, rather than Construction. Energy demand from the latter sub-sector is similar in the 2008 and 2010 runs, a result consistent with the output assumptions.

A.10 Industry summary

For the industry sector equations we were able to replicate, the residual adjustments suggest that energy demand could have been 3.7% lower in 2020 in the 2010 run

Our estimates of the size of the residual adjustments in the 2010 run, for industry (for the equations we were able to replicate) are shown in Table 4.1. Excluding 'Unclassified', these sectors accounted for 68% of industry energy demand in 2009. Industry energy demand accounted for 17% of UK final energy consumption and around one-third of final-user combustion emissions in 2009. From our analysis, the aggregate energy demand equations for these sectors over-predicted energy demand by 422 ktoe units of 'useful' energy. Energy demand would have been around 3.7% lower in the long run with these residual adjustments. Converted back to total energy the gap remains at around 3.7%.

The direction and sign of the residuals adjustments in Table 4.1 does identify evidence of systematic bias in the equations we were able to replicate. In general the bias suggests over-prediction in the DECC Model equations (negative residual adjustments). However, the size of the implied adjustment is appreciably larger in 2009 than in 2007 or 2008. While it is not possible to assess this increase statistically, these figures do point to the possibility that the residual is a combination of systematic bias (or a structural break, if the equation is well specified) in the equations and a shock (an outlier). It is valid to apply the residual treatment to compensate for the systematic bias/structural break, but not a transitory shock. A transitory shock must either be treated as an outlier in the equation or the equation must be allowed to correct for it in the dynamic solution.

Appendix Table A.3: Estimated Size of the Industry Residual Adjustments

ESTIMATED SIZE OF INDUSTRY RESIDUAL ADJUSTMENTS					
	2007	**2008**	**2009**	**2009 (ktoe)**	**Comment**
Non-ferrous metals	+4.6%	+1.3%	-8.9%	-103	Equation over-predicts in 2009, but under-predicts in 2007 and 2008 – evidence of bias is weaker
Chemicals	+1.6%	+12.4%	+6.7%	+215	Equation shows signs of under-prediction
Engineering & vehicles	-3.7%	-1.3%	-5.8%	-160	Equation shows signs of over-prediction
Food, drink & tobacco	-5.9%	-4.8%	-10.6%	-260	Equation shows signs of over-prediction
Textiles, leather, etc	-2.9%	-6.6%	-16.2%	-85	Equation shows signs of over-prediction
Paper, printing, etc	-3.0%	-6.8%	-10.4%	-29	Equation shows signs of over-prediction

Note(s) : Residual adjustments are calculated from the raw DECC Model results, which are expressed in 'useful' units of energy.
Source(s) : DECC, Cambridge Econometrics.

A.11 Non-road transport energy demand

This section focuses on non-road transport energy demand

In this section, we summarise the treatment of energy demand from non-road transport sectors in the DECC Model. The treatment of these sectors is simpler than for industry, road transport and households and the levels of energy demand are also relatively small in comparison. We then contrast the DECC Model treatment to the treatment in CE's own MDM-E3 model.

The DECC Model identifies three non-road transport sectors, which correspond to the three non-road transport fuel users distinguished in *DUKES*:

- air transport
- rail transport
- water transport

Air transport and water transport are assumed to use just one type of fuel (petroleum products) and rail transport demand is divided into petroleum products and electricity.

Air transport fuel demand is driven by activity and prices

In the DECC Model, fuel demand from air transport is driven by assumptions on:

- OECD GDP
- the real price of fuel

No terms are included to allow for improvements in energy efficiency, and none are applied off-model, according to the Oxford Economics (2008a) report. Emissions grow in line with fuel demand.

As an equation, the economic rationale appears sound and the use of OECD GDP as the activity driver is justified by the fact that the air transport sector defined in DUKES covers fuel consumption for both domestic and international. It is not clear if the domestic/international split is assumed explicitly or if UK emissions are simply linked to the projected total fuel demand under the implicit assumption that the share of fuel consumption for domestic aviation is constant. If the latter, it may be worth introducing a set of assumptions. In recent history, growth in international aviation has outpaced growth in domestic aviation; UK emissions from this sector may be overstated.

Rail transport energy demand is driven by assumptions on track length

Rail transport demand for fuel is driven by the assumed length of track, differentiated by electrified track and track for petroleum-powered trains. These variables implicitly capture a stock/infrastructure effect, although track utilisation is implicitly constant (an increase in track length leads to a corresponding increase in energy demand).

There are no terms in the equations to capture activity or price effects. As the Oxford Economics review (2008a) notes, the importance of this depends on how rail services respond to changes in demand. If the supply is largely fixed, then an increase in demand is leads to higher transport costs (whether monetary or in the form of overcrowding and delays) and the exclusion of activity and price effects is justified. Alternatively, if the supply of services does respond to demand, then activity and prices should feature in the equation. The nature of the supply of rail services is relevant because projections of economic activity differ in the DECC runs with and without a recession. How supply responds is an issue that should probably be resolved empirically.

The aggregate energy demand equation in MDM-E3 includes both activity and prices in a cointegrating equation. The most recent parameter estimates (used in the projections generated for this project) suggest that rail transport energy demand is relatively unresponsive to activity and moderately responsive to price in the short run. In the long run, there is a modest activity response but little in the way of a price response. The MDM-E3 equation does suggest some responsiveness of supply to demand.

The track-length elasticities differ, such that for a given increase in track length, electrified track leads to a larger increase in rail-transport electricity demand than the increase in petroleum demand brought about by the same increase in track length for petroleum-powered trains. The Oxford Economics (ibid) report also notes an unusual lag structure in this equation, which leads to energy demand actually falling two years after a track extension. The unusual lag structure is worth reviewing if these are equations are re-estimated.

Water transport fuel demand is set exogenously

Demand for fuel from water transport is not projected by an equation. Instead, the demand is set exogenously, by assumption ie off-model. As a small fuel user, this seems a reasonable approach.

The presence of an investment term is the main difference between the DECC and MDM-E3 equations

In MDM-E3, for air, rail and water transport, energy demand is determined in the same way as most other final users, with an aggregate energy demand equation driven by:

- activity (gross output in the relevant transport industry sectors)
- fuel prices
- investment (to capture energy efficiency effects)

The presence of an investment term to account for changes in energy efficiency over time is the most notable difference between the DECC Model and MDM-E3 equation specifications for air transport. The treatment of rail transport energy demand is quite different and the nature of the UK's physical rail infrastructure is not captured in the MDM-E3 equations, whereas it is in the DECC Model. However, the DECC Model treatment fails to capture the effects of activity and price that will have contributed to the decrease in rail transport energy demand in 2009.

MDM-E3 projects energy demand from water transport endogenously, in contrast to the exogenous assumptions made in the DECC Model.

Appendix B: Detailed MDM-E3 Projections

This appendix contains tables of more detailed model results from the MDM-E3 projections. The following tables are provided for each of the three runs, to 2020:

- Economic activity by fuel user
- Aggregate energy demand by fuel user
- Energy demand by fuel user and fuel
- CO_2 emissions by fuel user
- Capacity and generation by station type

The final table in this appendix presents the Central fossil fuel price assumptions from the three DECC Model runs, which were used in the MDM-E3 projections.

Appendix Table B.1: Economic Activity by Fuel User – 2008 Run

ECONOMIC ACTIVITY BY FUEL USER (% PA) – 2008 RUN														
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2005-10	2010-15	2015-20
Iron & steel	0.4	-1.48	0.24	0.97	3.10	2.46	1.26	1.20	0.90	0.85	0.96	1.05	1.03	0.78
Non-ferrous metals	0.4	-1.48	0.24	1.17	2.43	1.46	1.48	1.61	1.33	1.29	1.40	0.75	1.42	1.21
Mineral products	0.1	2.77	0.44	1.82	2.98	3.30	2.80	2.08	1.78	1.74	1.84	2.26	2.05	1.67
Chemicals	-0.53	1.59	1.88	2.62	3.53	3.51	3.79	3.98	3.68	3.63	3.73	2.62	3.76	3.55
Mechanical engineering	2.18	4.63	3.01	1.30	2.32	2.49	2.19	2.22	2.56	2.01	1.86	2.74	2.17	1.73
Electrical Engineering	-4.15	-0.56	-2.10	1.30	2.32	2.49	2.19	2.22	2.56	2.01	1.86	0.67	2.17	1.73
Vehicles	-0.98	3.34	1.70	1.30	2.32	2.49	2.19	2.22	2.56	2.01	1.86	2.23	2.17	1.73
Food, drink & tobacco	2.03	-0.70	0.44	0.44	2.24	1.83	1.93	1.91	1.58	1.54	1.64	0.84	1.72	1.48
Tex., cloth. & leath.	-2.12	-0.13	-1.03	-2.16	-2.65	-3.03	-2.76	-2.62	-2.91	-2.97	-2.88	-1.81	-2.83	-3.08
Paper, print. & pub.	-3.62	-0.45	0.94	-0.94	0.75	1.22	1.89	1.53	1.12	1.08	1.18	0.30	1.36	0.98
Other industries	-0.56	1.48	1.62	1.85	1.61	1.35	1.46	1.64	1.37	1.33	1.44	1.58	1.45	1.29
Construction	1.02	1.01	3.15	2.68	0.49	2.48	2.86	2.91	1.86	1.71	1.17	1.96	2.10	1.22
Air	6.4	5.49	7.17	1.08	1.80	1.88	1.85	1.82	1.51	1.42	1.44	3.46	1.61	1.35
Rail	2.54	3.80	3.62	1.08	1.80	1.88	1.85	1.82	1.51	1.42	1.44	2.43	1.61	1.35

ECONOMIC ACTIVITY BY FUEL USER (% PA) – 2008 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2005-10	2010-15	2015-20
Water	5.24	-12.66	-3.78	1.08	1.80	1.88	1.85	1.82	1.51	1.42	1.44	-2.50	1.61	1.35
Domestic	2.17	1.84	2.20	1.50	2.25	2.50	2.62	2.51	2.75	2.75	2.75	2.06	2.68	2.50
Public administration	1.66	1.23	1.74	1.08	1.80	1.88	1.85	1.82	1.51	1.42	1.44	1.54	1.61	1.35
Commercial	3.16	5.21	4.39	1.08	1.80	1.88	1.85	1.82	1.51	1.42	1.44	2.86	1.61	1.35
Agriculture	7.59	0.81	-4.38	1.08	1.80	1.88	1.85	1.82	1.51	1.42	1.44	0.21	1.61	1.35
Miscellaneous	1.51	1.51	1.72	1.08	1.80	1.88	1.85	1.82	1.51	1.42	1.44	1.60	1.61	1.35

Source(s) : MDM-E3, Cambridge Econometrics.

Appendix Table B.2: Aggregate Energy Demand – 2008 Run

AGGREGATE ENERGY DEMAND (KTOE) – 2008 RUN																
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Iron & steel	1,758	1,863	1,775	1,759	2,168	2,252	2,248	2,250	2,256	2,260	2,248	2,259	2,268	2,279	2,278	2,270
Non-ferrous metals	1,011	1,003	952	931	887	807	848	815	798	791	745	749	747	764	750	754
Mineral products	3,214	3,098	3,120	3,063	3,082	3,117	3,146	3,135	3,096	3,066	3,045	3,029	3,015	2,976	2,925	2,869
Chemicals	5,588	5,348	5,076	5,207	5,118	5,298	5,320	5,561	5,797	6,040	6,148	6,153	6,174	6,223	6,286	6,362
Mechanical engineering	1,609	1,550	1,504	1,513	1,492	1,470	1,431	1,419	1,413	1,406	1,379	1,378	1,377	1,379	1,370	1,364
Electrical engineering	1,032	1,057	987	1,066	985	1,025	1,035	1,027	1,018	998	967	934	902	873	848	825
Vehicles	1,532	1,466	1,381	1,364	1,360	1,380	1,381	1,377	1,373	1,371	1,370	1,384	1,397	1,408	1,418	1,426
Food, drink & tobacco	3,540	3,381	3,329	3,569	3,463	3,565	3,677	3,712	3,674	3,578	3,452	3,400	3,351	3,321	3,291	3,278
Tex., cloth. & leath.	1,056	1,042	981	976	932	995	914	865	820	781	746	715	692	674	662	650
Paper, print. & pub.	2,873	2,711	2,596	2,940	3,075	3,141	2,955	2,543	2,153	1,898	1,729	1,635	1,591	1,611	1,660	1,753
Other industries	5,698	5,441	5,641	5,607	5,673	5,664	5,733	5,798	5,792	5,753	5,719	5,676	5,630	5,584	5,569	5,570
Construction	586	552	528	544	549	517	487	485	468	448	430	426	428	436	441	446
Unclassified	3,096	3,300	3,158	3,018	3,093	3,314	3,314	3,314	3,314	3,314	3,314	3,314	3,314	3,314	3,314	3,314
Air	13,856	13,999	13,906	14,198	13,568	14,517	13,853	13,495	13,915	14,355	14,783	15,267	15,697	16,098	16,478	16,836
Rail	1,468	1,437	1,443	1,518	1,478	1,529	1,560	1,587	1,615	1,646	1,658	1,686	1,710	1,742	1,762	1,787
Road	42,464	42,696	43,207	42,226	42,238	41,515	41,560	41,054	40,817	40,497	40,091	39,702	39,322	38,995	38,725	38,484
Water	1,372	1,814	1,618	1,734	1,338	1,238	1,441	1,443	1,433	1,443	1,459	1,491	1,521	1,548	1,570	1,592

AGGREGATE ENERGY DEMAND (KTOE) – 2008 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Domestic	47,780	46,527	44,889	44,501	42,212	41,669	41,763	41,925	41,700	41,564	41,229	41,080	40,956	40,998	40,963	40,967
Public administration	7,097	6,646	6,347	6,321	6,214	6,143	5,968	5,694	5,645	5,592	5,562	5,502	5,452	5,420	5,412	53,97
Commercial	10,077	9,682	9,565	9,359	9,371	9,224	9,387	9,535	9,712	9,931	9,956	10,174	10,339	10,611	10,733	10,988
Agriculture	988	918	908	916	1,092	765	770	749	731	723	682	682	670	673	651	650
Miscellaneous	2,183	1,940	1,798	1,736	1,736	1,586	1,679	1,653	1,635	1,606	1,568	1,518	1,473	1,434	1,402	1,376
Total energy demand	159,879	157,471	154,709	154,068	151,124	150,731	150,472	149,436	149,175	149,061	148,280	148,154	148,024	148,360	148,507	148,957

Source(s) : MDM-E3, Cambridge Econometrics.

Appendix Table B.3: Energy Demand by Fuel – 2008 Run

ENERGY DEMAND BY FUEL (KTOE) - 2008 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Iron & steel																
Coal	479	435	506	473	654	576	563	549	536	523	507	496	484	472	458	443
Oil	14	20	67	67	82	47	42	39	36	34	31	29	27	26	24	23
Gas	833	905	779	785	943	1,244	1,275	1,322	1,369	1,411	1,439	1,481	1,519	1,557	1,585	1,606
Electricity	432	504	423	435	489	384	368	340	315	293	270	253	237	224	210	198
Non-ferrous metals																
Coal	24	36	22	19	19	19	18	16	15	13	12	11	10	9	8	8
Oil	53	53	48	47	48	38	39	37	35	35	32	32	32	32	32	31
Gas	272	267	246	256	210	214	250	253	262	264	254	261	266	279	281	289
Electricity	661	647	635	609	610	536	541	509	486	478	447	445	439	443	429	425
Mineral products																
Coal	738	690	758	711	734	625	617	578	542	509	479	449	421	389	359	329
Oil	216	200	239	229	289	281	287	299	292	287	283	280	277	272	265	259
Gas	1,574	1,531	1,451	1,478	1,248	1,419	1,516	1,490	1,502	1,510	1,522	1,536	1,551	1,551	1,544	1,532
Electricity	686	677	672	645	812	791	726	768	760	760	761	764	767	764	757	749
Chemicals																
Coal	84	84	76	66	62	54	48	43	39	36	33	29	26	23	21	20
Oil	194	188	192	183	214	193	195	209	217	225	228	227	226	226	228	229
Gas	3,102	2,952	2,592	2,661	2,264	2,505	2,675	2,724	2,885	3,034	3,110	3,125	3,145	3,179	3,222	3,272
Electricity	1,816	1,753	1,737	1,706	2,097	2,066	1,920	2,102	2,174	2,263	2,296	2,291	2,296	2,312	2,334	2,360
Other	392	371	480	592	482	482	482	482	482	482	482	482	482	482	482	482

ENERGY DEMAND BY FUEL (KTOE) - 2008 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Mechanical engineering																
Coal	9	9	7	10	8	6	6	6	7	7	6	6	6	6	6	6
Oil	118	106	107	109	104	109	104	103	102	101	99	99	99	99	99	98
Gas	737	703	659	668	638	669	638	625	617	609	595	591	588	585	579	573
Electricity	742	730	727	722	743	685	682	684	687	688	678	681	684	688	686	687
Other	3	2	3	4	0	0	0	0	0	0	0	0	0	0	0	0
Electrical engineering																
Coal	3	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3
Oil	35	85	36	51	39	35	37	38	38	38	37	35	34	33	31	30
Gas	355	337	321	351	313	337	333	327	321	314	303	291	279	269	260	251
Electricity	638	631	627	660	630	648	661	658	655	643	624	604	585	568	554	541
Vehicles																
Coal	35	34	32	31	34	29	29	28	28	27	27	27	27	26	26	26
Oil	139	124	123	116	121	108	108	108	108	109	110	111	112	113	114	115
Gas	856	814	734	744	681	758	780	811	846	886	930	985	1,041	1,090	1,137	1,178
Electricity	502	494	492	474	524	484	465	430	391	349	304	261	217	178	141	107
Food, drink & tobacco																
Coal	19	17	30	29	46	39	46	49	54	58	61	66	71	77	84	92
Oil	323	282	283	304	293	290	316	314	321	319	315	319	326	336	350	369
Gas	2,143	2,039	1,975	2,150	1,524	1,785	2,071	1,901	1,929	1,850	1,763	1,707	1,652	1,603	1,551	1,504
Electricity	1,055	1,042	1,039	1,078	1,599	1,450	1,243	1,446	1,368	1,350	1,312	1,306	1,302	1,304	1,305	1,312
Other	1	1	2	8	1	1	1	1	1	1	1	1	1	1	1	1

ENERGY DEMAND BY FUEL (KTOE) - 2008 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Tex., cloth. & leath.																
Coal	50	49	52	52	49	53	48	46	43	41	39	38	37	36	35	34
Oil	110	131	119	118	113	121	111	105	100	95	90	87	84	82	80	79
Gas	605	571	523	520	496	530	487	460	437	416	397	381	368	359	352	346
Electricity	292	291	288	286	274	292	268	254	241	229	219	210	203	198	194	191
Paper, print. & pub.																
Coal	98	99	101	120	102	120	107	87	69	58	50	45	41	40	40	41
Oil	86	59	65	74	95	77	77	66	54	45	38	34	31	29	28	28
Gas	1,521	1,420	1,334	1,557	1,526	1,654	1,547	1,332	1,131	1,001	916	870	850	865	894	948
Electricity	1,137	1,110	1,096	1,188	1,353	1,291	1,225	1,059	899	794	725	686	669	677	698	736
Other	31	22	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Other industries																
Coal	113	130	135	139	157	169	185	198	206	211	216	218	220	221	223	226
Oil	2,437	2,205	2,386	2,401	2,234	2,163	2,176	2,178	2,155	2,121	2,092	2,058	2,025	1,993	1,975	1,965
Gas	894	848	794	827	764	854	870	887	894	895	896	895	895	893	897	903
Electricity	1,848	1,844	1,916	1,835	2,103	2,064	2,087	2,120	2,123	2,111	2,101	2,089	2,076	2,062	2,059	2,060
Other	405	414	411	406	415	415	415	415	415	415	415	415	415	415	415	415
Construction																
Oil	190	174	169	177	180	179	170	169	163	156	150	149	149	152	154	155
Gas	230	220	204	216	202	192	176	172	162	152	143	138	135	134	132	130
Electricity	166	158	155	151	167	146	142	144	142	140	137	139	143	149	155	160
Unclassified																
Coal	56	53	62	59	61	65	65	65	65	65	65	65	65	65	65	65

ENERGY DEMAND BY FUEL (KTOE) - 2008 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Oil	2,814	3,013	2,797	2,673	2,739	2,935	2,935	2,935	2,935	2,935	2,935	2,935	2,935	2,935	2,935	2,935
Gas	39	34	36	34	35	38	38	38	38	38	38	38	38	38	38	38
Other	187	200	263	251	257	276	276	276	276	276	276	276	276	276	276	276
Air																
Oil	13,856	13,999	13,906	14,198	13,568	14,517	13,853	13,495	13,915	14,355	14,783	15,267	15,697	16,098	16,478	16,836
Rail																
Coal	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4
Oil	707	726	700	744	725	747	756	764	771	780	781	787	792	801	804	809
Electricity	758	708	740	771	750	779	801	820	840	863	875	895	914	938	954	974
Road																
Oil	42,390	42,508	42,845	41,406	41,229	40,260	40,157	39,373	38,856	38,559	38,180	37,816	37,459	37,151	36,898	36,672
Other	74	188	362	821	1,009	1,256	1,403	1,682	1,961	1,937	1,911	1,886	1,863	1,844	1,827	1,812
Water																
Oil	1,372	1,814	1,618	1,734	1,338	1,238	1,441	1,443	1,433	1,443	1,459	1,491	1,521	1,548	1,570	1,592
Domestic																
Coal	673	623	665	721	662	664	672	682	687	692	695	699	703	709	715	720
Oil	3,092	3,250	2,876	2,856	2,718	2,733	2,671	2,674	2,676	2,656	2,627	2,607	2,592	2,586	2,579	2,573
Gas	32,836	31,550	30,341	29,974	28,132	28,927	29,388	29,714	29,459	29,275	28,969	28,776	28,603	28,529	28,409	28,306
Electricity	10,809	10,695	10,555	10,502	10,272	8,922	8,608	8,429	8,456	8,519	8,519	8,580	8,642	8,757	8,843	8,950
Other	370	410	452	448	428	423	424	425	423	422	419	418	417	417	417	417
Public administration																
Coal	27	14	10	10	18	8	8	8	8	8	8	8	8	8	8	8

ENERGY DEMAND BY FUEL (KTOE) - 2008 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Oil	541	489	487	479	408	384	363	338	329	318	307	294	281	270	260	250
Gas	4,380	3,983	3,700	3,691	3,196	3,085	3,009	2,831	2,792	2,755	2,639	2,533	2,423	2,319	2,184	2,046
Electricity	1,722	1,745	1,727	1,716	2,165	2,242	2,165	2,094	2,095	2,089	2,186	2,246	2,318	2,402	2,538	2,671
Other	427	415	422	425	426	425	424	423	422	422	422	421	421	421	421	421
Commercial																
Coal	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5
Oil	388	394	409	422	397	380	386	392	399	406	406	413	419	429	434	443
Gas	3,284	2,947	2,846	2,773	2,611	2,768	2,793	2,817	2,853	2,899	2,890	2,934	2,963	3,022	3,040	3,094
Electricity	6,371	6,309	6,280	6,133	6,331	6,044	6,177	6,293	6,427	6,592	6,626	6,792	6,922	7,124	7,223	7,414
Other	29	28	27	27	28	28	28	29	29	29	30	30	30	31	31	32
Agriculture																
Coal	6	3	3	7	0	0	0	0	0	0	0	0	0	0	0	0
Oil	363	306	294	307	366	249	252	245	240	237	223	223	218	219	212	211
Gas	194	173	172	174	203	135	143	141	139	137	130	130	127	127	123	123
Electricity	344	347	355	342	421	309	303	292	284	282	265	266	261	263	255	255
Other	81	90	85	86	103	72	72	70	69	68	64	64	63	63	61	61
Miscellaneous																
Coal	1	3	1	1	1	0	0	0	0	0	0	0	0	0	0	0
Oil	461	340	310	295	326	278	301	296	292	286	278	268	260	252	246	242
Gas	1,721	1,596	1,486	1,440	1,409	1,308	1,378	1,357	1,343	1,320	1,289	1,250	1,213	1,182	1,156	1,134

Source(s) : MDM-E3, Cambridge Econometrics.

Appendix Table B.4: CO2 Emissions – 2008 Run

CO2 EMISSIONS (MTCO2) – 2008 RUN																
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Power Generation	183.4	192.4	188.4	184.9	192.0	196.8	188.8	185.2	185.9	183.7	175.4	176.9	184.2	177.9	179.6	172.2
Transformation/own use	43.6	37.3	38.0	40.3	39.1	42.8	42.4	42.3	42.3	42.3	42.4	42.5	42.6	42.7	42.8	42.9
Iron & steel	6.6	6.9	6.8	6.7	8.3	9.0	9.0	9.1	9.2	9.3	9.4	9.5	9.6	9.6	9.7	9.7
Non-ferrous metals	2.4	2.4	2.2	2.3	2.1	2.1	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.4	2.4	2.5
Mineral products	17.7	17.4	18.0	18.0	17.6	18.0	18.5	18.5	18.5	18.5	18.5	18.6	18.6	18.6	18.6	18.5
Chemicals	12.3	11.8	11.0	11.1	9.7	10.5	11.1	11.3	12.0	12.5	12.8	12.8	12.9	13.0	13.2	13.4
Mechanical engineering	3.1	2.9	2.9	2.9	2.8	2.9	2.8	2.7	2.7	2.7	2.6	2.6	2.6	2.6	2.5	2.5
Electrical engineering	1.4	1.5	1.4	1.5	1.3	1.4	1.4	1.4	1.4	1.3	1.3	1.2	1.2	1.1	1.1	1.1
Vehicles	3.7	3.5	3.3	3.4	3.2	3.4	3.5	3.6	3.7	3.9	4.0	4.2	4.5	4.7	4.8	5.0
Food, drink & tobacco	8.8	8.3	8.6	9.3	7.0	7.9	9.1	8.5	8.6	8.4	8.0	7.8	7.7	7.6	7.4	7.3
Tex., cloth. & leath.	2.8	2.7	2.6	2.6	2.5	2.7	2.4	2.3	2.2	2.1	2.0	1.9	1.8	1.8	1.8	1.7
Paper, print. & pub.	6.3	5.9	5.9	6.8	6.7	7.2	6.7	5.8	4.9	4.3	3.9	3.7	3.6	3.6	3.7	3.9
Other industries	10.6	10.1	10.7	10.8	10.3	10.5	10.6	10.8	10.8	10.7	10.7	10.6	10.5	10.4	10.4	10.4
Construction	1.4	1.3	1.3	1.4	1.3	1.3	1.2	1.2	1.1	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Unclassified	8.9	8.8	8.3	7.9	8.1	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7	8.7

CO2 EMISSIONS (MTCO2) – 2008 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Air	4.9	4.9	4.8	4.4	4.2	4.5	4.3	4.2	4.3	4.4	4.6	4.7	4.8	5.0	5.1	5.2
Rail	2.2	2.2	2.2	2.3	2.3	2.3	2.4	2.4	2.4	2.4	2.4	2.5	2.5	2.5	2.5	2.5
Road	120.4	120.8	122.0	118.0	117.6	114.9	114.7	112.5	111.1	110.2	109.2	108.2	107.2	106.3	105.6	104.9
Water	5.0	6.3	5.8	6.1	4.7	4.4	5.1	5.1	5.0	5.1	5.1	5.2	5.3	5.4	5.5	5.6
Domestic	84.9	81.8	78.4	77.5	72.9	74.7	75.6	76.4	76.0	75.6	74.9	74.5	74.2	74.1	73.9	73.7
Public administration	11.2	10.7	9.8	9.9	8.9	8.2	8.0	7.6	7.5	7.4	7.2	6.9	6.6	6.4	6.0	5.7
Commercial	11.6	10.9	11.0	10.8	10.1	10.6	10.7	10.8	11.0	11.1	11.1	11.3	11.4	11.6	11.7	11.9
Agriculture	4.6	4.3	4.2	4.1	5.4	3.7	3.6	3.5	3.4	3.3	3.1	3.1	3.1	3.1	3.0	2.9
Total CO2 emissions	557.7	555.1	547.5	543.1	538.0	548.4	543.0	536.0	534.8	531.4	520.5	520.7	526.8	520.0	521.0	513.3

Source(s) : MDM-E3, Cambridge Econometrics.

Appendix Table B.5: Capacity and Generation by Station Type – 2008 Run

CAPACITY AND GENERATION BY STATION TYPE - 2008 RUN

Capacity (TW)	2005	2010	2015	2020
Coal	23	24	22	20
Oil/mixed	10	10	5	0
Gas	24	29	35	37
Nuclear	12	11	7	8
CHP	6	6	7	9
Hydro	2	2	2	2
Other renewables	3	5	11	15
Autogenerators (non-CHP)	1	1	1	1
Pumped storage	3	3	3	3
Imports	2	2	3	3
Total	85	93	96	97
Generation (TWh)				
Coal	110	110	97	101
Oil/mixed	26	14	5	0
Gas	128	138	147	144
Nuclear	82	63	38	46
CHP	29	29	36	42
Hydro	5	6	6	7
Other renewables	11	19	39	54
Autogenerators (non-CHP)	6	8	8	8
Pumped storage	3	5	5	5
Imports	8	3	5	5
Total	407	395	385	412

Source(s) : MDM-E3, Cambridge Econometrics.

Appendix Table B.6: Economic Activity by Fuel User – 2009 Run

ECONOMIC ACTIVITY BY FUEL USER (% PA) – 2009 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2005-10	2010-15	2015-20
Iron & steel	0.4	-1.48	0.24	-4.26	-6.85	-0.28	0.30	0.39	0.36	0.30	0.21	-2.56	0.31	0.09
Non-ferrous metals	0.4	-1.48	0.24	-4.26	-10.58	-1.12	1.58	1.92	1.63	1.56	1.42	-3.52	1.62	1.26
Mineral products	0.1	2.77	0.44	-5.45	-13.02	-2.54	3.01	2.48	2.18	2.09	1.86	-3.72	2.32	1.73
Chemicals	-0.53	1.59	1.88	-0.89	-15.40	-2.70	4.07	4.74	4.49	4.37	3.77	-3.33	4.29	3.69
Mechanical engineering	2.18	4.63	3.01	-2.53	-10.12	-1.92	2.35	2.64	3.13	2.42	1.88	-1.52	2.48	1.79
Electrical engineering	-4.15	-0.56	-2.10	-6.81	-10.12	-1.92	2.35	2.64	3.13	2.42	1.88	-4.37	2.48	1.79
Vehicles	-0.98	3.34	1.70	-2.77	-10.12	-1.92	2.35	2.64	3.13	2.42	1.88	-2.07	2.48	1.79
Food, drink & tobacco	2.03	-0.70	0.44	-1.65	-9.75	-1.41	2.07	2.28	1.93	1.85	1.66	-2.68	1.96	1.54
Tex., cloth. & leath.	-2.12	-0.13	-1.03	-0.37	-2.65	-3.03	-2.76	-2.62	-2.91	-2.97	-2.88	-1.45	-2.83	-3.08
Paper, print. & pub.	-3.62	-0.45	0.94	-2.21	-3.26	-0.94	2.02	1.83	1.37	1.30	1.19	-1.19	1.54	1.02
Other industries	-0.56	1.48	1.62	-4.02	-7.01	-1.04	1.57	1.96	1.67	1.60	1.45	-1.85	1.65	1.34
Construction	1.02	1.01	3.15	-0.73	-2.13	-1.91	3.07	3.47	2.27	2.06	1.18	-0.14	2.41	1.27
Air	6.4	5.49	7.17	-1.17	-8.14	-1.64	1.73	1.93	1.66	1.53	1.26	0.19	1.62	1.21
Rail	2.54	3.80	3.62	0.24	-8.14	-1.64	1.73	1.93	1.66	1.53	1.26	-0.52	1.62	1.21
Water	5.24	-12.66	-3.78	7.15	-8.14	-1.64	1.73	1.93	1.66	1.53	1.26	-4.04	1.62	1.21
Domestic	2.17	1.84	2.20	0.43	-3.00	0.25	3.25	3.35	3.90	2.75	2.41	0.33	3.13	2.29
Public administration	1.66	1.23	1.74	0.34	-8.14	-1.64	1.73	1.93	1.66	1.53	1.26	-1.36	1.62	1.21
Commercial	3.16	5.21	4.39	0.68	-8.14	-1.64	1.73	1.93	1.66	1.53	1.26	-0.02	1.62	1.21
Agriculture	7.59	0.81	-4.38	-0.16	-8.14	-1.64	1.73	1.93	1.66	1.53	1.26	-2.76	1.62	1.21

ECONOMIC ACTIVITY BY FUEL USER (% PA) – 2009 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2005-10	2010-15	2015-20
Miscellaneous	1.51	1.51	1.72	-0.27	-8.14	-1.64	1.73	1.93	1.66	1.53	1.26	-1.43	1.62	1.21

Source(s): MDM-E3, Cambridge Econometrics.

Appendix Table B.7: Aggregate Energy Demand – 2009 Run

AGGREGATE ENERGY DEMAND (KTOE) - 2009 RUN																
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Iron & steel	1,758	1,863	1,775	1,613	1,485	1,489	1,520	1,544	1,586	1,614	1,628	1,649	1,663	1,667	1,657	1,639
Non-ferrous metals	1,011	1,003	952	934	886	857	846	806	800	790	754	755	749	753	738	732
Mineral products	3,214	3,098	3,120	3,216	2,839	2,576	2,551	2,602	2,645	2,672	2,689	2,699	2,704	2,680	2,637	2,589
Chemicals	5,588	5,348	5,076	5,147	4,287	5,054	4,940	5,150	5,376	5,593	5,660	5,628	5,626	5,662	5,723	5,803
Mechanical engineering	1,609	1,550	1,504	1,472	1,338	1,404	1,374	1,359	1,358	1,351	1,330	1,330	1,328	1,325	1,314	1,306
Electrical engineering	1,032	1,057	987	987	888	968	970	975	980	974	954	926	895	863	831	802
Vehicles	1,532	1,466	1,381	1,361	1,191	1,470	1,429	1,396	1,377	1,370	1,366	1,376	1,384	1,390	1,394	1,397
Food, drink & tobacco	3,540	3,381	3,329	3,426	2,738	2,769	2,917	3,013	3,080	3,094	3,075	3,106	3,129	3,146	3,148	3,152
Tex., cloth. & leath.	1,056	1,042	981	956	849	905	872	855	828	794	759	727	701	677	657	640
Paper, print. & pub.	2,873	2,711	2,596	2,627	2,817	3,043	2,913	2,706	2,448	2,229	2,040	1,887	1,765	1,691	1,652	1,661
Other industries	5,698	5,441	5,641	5,440	4,835	5,398	5,685	5,802	5,795	5,740	5,677	5,607	5,528	5,442	5,371	5,318
Construction	586	552	528	548	452	616	561	512	459	431	423	431	443	453	457	458
Unclassified	3,096	3,300	3,158	3,018	2,956	3,167	3,167	3,167	3,167	3,167	3,167	3,167	3,167	3,167	3,167	3,167
Air	13,856	13,999	13,906	13,426	12,133	13,221	12,666	12,603	13,140	13,592	13,989	14,452	14,868	15,233	15,565	15,922
Rail	1,468	1,437	1,443	1,531	1,558	1,580	1,588	1,590	1,600	1,612	1,613	1,625	1,635	1,648	1,654	1,661

AGGREGATE ENERGY DEMAND (KTOE) - 2009 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Road	42,464	42,696	43,207	42,151	40,367	40,445	40,380	40,012	39,982	39,714	39,261	38,809	38,389	38,026	37,715	37,484
Water	1,372	1,814	1,618	1,764	1,618	1,516	1,533	1,484	1,454	1,450	1,454	1,479	1,506	1,531	1,553	1,575
Domestic	47,780	46,527	44,889	45,985	44,633	43,856	43,915	44,026	44,059	43,931	43,602	43,419	43,292	43,266	43,226	43,189
Public administration	7,097	6,646	6,347	6,344	5,532	6,161	5,721	5,711	5,643	5,596	5,568	5,514	5,474	5,452	5,449	54,38
Commercial	10,077	9,682	9,565	9,621	9,519	9,184	9,329	9,423	9,606	9,796	9,861	10,049	10,199	10,416	10,556	10,750
Agriculture	988	918	908	981	1,065	790	806	776	763	744	708	703	687	681	661	652
Miscellaneous	2,183	1,940	1,798	1,753	1,582	1,442	1,537	1,534	1,543	1,535	1,519	1,484	1,448	1,415	1,390	1,366
Total energy demand	159,879	157,471	154,709	154,300	145,569	147,912	147,220	147,047	147,690	147,789	147,096	146,822	146,581	146,585	146,517	146,703

Source(s) : MDM-E3, Cambridge Econometrics.

Appendix Table B.8: Energy Demand by Fuel – 2009 Run

ENERGY DEMAND BY FUEL (KTOE) - 2009 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Iron & steel																
Coal	479	435	506	428	412	349	350	347	349	348	343	340	334	326	316	304
Oil	14	20	67	62	65	37	34	31	29	27	25	24	22	21	19	18
Gas	833	905	779	722	628	821	859	904	959	1,003	1,037	1,076	1,109	1,133	1,147	1,154
Electricity	432	504	423	401	379	281	277	261	249	236	222	210	198	187	175	164
Non-ferrous metals																
Coal	24	36	22	20	18	19	17	16	15	13	12	11	10	10	9	8
Oil	53	53	48	47	47	42	40	38	37	36	34	34	33	33	32	32
Gas	272	267	246	257	229	240	253	247	253	249	239	242	243	248	248	251
Electricity	661	647	635	610	591	556	535	507	495	491	469	468	462	462	449	441
Mineral products																
Coal	738	690	758	758	733	525	511	490	473	453	431	408	384	356	327	300
Oil	216	200	239	223	199	210	208	224	225	226	226	226	225	222	217	211
Gas	1,574	1,531	1,451	1,579	1,325	1,223	1,282	1,288	1,334	1,368	1,397	1,423	1,446	1,452	1,448	1,439
Electricity	686	677	672	656	583	618	550	601	613	625	635	643	650	650	645	639
Chemicals																
Coal	84	84	76	65	57	53	45	39	36	33	29	25	22	20	18	17
Oil	194	188	192	176	154	171	166	179	186	193	194	192	190	190	192	194
Gas	3,102	2,952	2,592	2,681	2,189	2,514	2,622	2,659	2,821	2,961	3,014	3,003	3,008	3,035	3,078	3,131
Electricity	1,816	1,753	1,737	1,633	1,405	1,835	1,626	1,790	1,852	1,925	1,941	1,927	1,924	1,935	1,954	1,980
Other	392	371	480	592	482	482	482	482	482	482	482	482	482	482	482	482

ENERGY DEMAND BY FUEL (KTOE) - 2009 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Mechanical engineering																
Coal	9	9	7	10	10	9	9	9	9	8	8	8	8	8	8	7
Oil	118	106	107	98	87	97	94	92	91	91	89	89	89	89	88	88
Gas	737	703	659	662	588	656	628	613	607	599	587	584	580	576	568	562
Electricity	742	730	727	698	654	642	644	646	651	653	645	649	651	653	650	649
Other	3	2	3	4	0	0	0	0	0	0	0	0	0	0	0	0
Electrical engineering																
Coal	3	4	4	4	3	4	4	4	4	4	4	4	4	3	3	3
Oil	35	85	36	47	42	40	42	43	44	44	43	41	39	37	35	33
Gas	355	337	321	335	295	333	329	329	328	324	315	305	293	280	268	257
Electricity	638	631	627	601	547	591	595	599	604	603	592	576	560	542	524	509
Vehicles																
Coal	35	34	32	31	30	32	31	30	29	29	28	28	28	27	27	26
Oil	139	124	123	116	104	113	110	108	106	106	106	107	107	107	107	107
Gas	856	814	734	741	620	831	830	844	869	905	946	997	1,047	1,091	1,131	1,165
Electricity	502	494	492	474	438	493	458	414	372	330	286	245	203	165	130	98
Food, drink & tobacco																
Coal	19	17	30	28	32	23	29	31	35	38	41	44	48	52	57	61
Oil	323	282	283	293	238	207	240	246	262	269	275	284	294	304	314	327
Gas	2,143	2,039	1,975	2,095	1,631	1,421	1,784	1,670	1,756	1,743	1,717	1,712	1,702	1,685	1,659	1,631
Electricity	1,055	1,042	1,039	1,002	836	1,117	863	1,065	1,025	1,042	1,042	1,064	1,085	1,104	1,117	1,132
Other	1	1	2	8	1	1	1	1	1	1	1	1	1	1	1	1

ENERGY DEMAND BY FUEL (KTOE) - 2009 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Tex., cloth. & leath.																
Coal	50	49	52	53	47	51	49	48	46	44	42	41	39	38	37	36
Oil	110	131	119	104	92	99	95	93	90	86	83	79	76	74	72	70
Gas	605	571	523	524	466	497	478	469	454	436	416	399	384	371	360	351
Electricity	292	291	288	274	243	260	250	245	238	228	218	208	201	194	188	184
Paper, print. & pub.																
Coal	98	99	101	105	91	117	107	95	81	70	61	53	47	43	40	39
Oil	86	59	65	65	78	70	76	74	68	60	53	46	41	36	32	30
Gas	1,521	1,420	1,334	1,427	1,501	1,698	1,611	1,495	1,357	1,240	1,140	1,060	996	959	941	950
Electricity	1,137	1,110	1,096	1,028	1,147	1,159	1,118	1,042	943	859	786	728	681	653	638	642
Other	31	22	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Other industries																
Coal	113	130	135	136	128	154	177	192	202	208	213	215	216	216	216	216
Oil	2,437	2,205	2,386	2,209	1,939	2,013	2,104	2,119	2,095	2,054	2,012	1,966	1,918	1,869	1,827	1,794
Gas	894	848	794	815	700	835	874	896	901	898	894	889	882	874	870	867
Electricity	1,848	1,844	1,916	1,874	1,653	1,981	2,116	2,180	2,183	2,165	2,143	2,122	2,097	2,068	2,044	2,027
Other	405	414	411	406	415	415	415	415	415	415	415	415	415	415	415	415
Construction																
Coal	0	0	0	28	22	33	31	28	25	24	23	24	25	25	25	25
Oil	190	174	169	159	127	190	176	162	146	137	134	137	141	144	145	145
Gas	230	220	204	213	176	238	209	187	165	152	147	147	148	148	146	143

ENERGY DEMAND BY FUEL (KTOE) - 2009 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Electricity	166	158	155	148	127	155	144	134	123	118	118	124	130	136	141	144
Unclassified																
Coal	56	53	62	65	64	68	68	68	68	68	68	68	68	68	68	68
Oil	2,814	3,013	2,797	2,541	2,489	26,67	2,667	2,667	26,67	2,667	2,667	26,67	2,667	2,667	2,667	2,667
Gas	39	34	36	34	34	36	36	36	36	36	36	36	36	36	36	36
Other	187	200	263	377	369	396	396	396	396	396	396	396	396	396	396	396
Air																
Oil	13,856	13,999	13,906	13,426	12,133	13,221	12,666	12,603	13,140	13,592	13,989	14,452	14,868	15,233	15,565	15,922
Rail																
Coal	3	3	3	5	5	5	5	5	5	5	5	5	6	6	6	6
Oil	707	726	700	747	771	787	789	788	790	792	789	790	791	792	791	789
Electricity	758	708	740	779	782	788	793	797	805	815	819	829	839	850	858	866
Road																
Oil	42,390	42,508	428,45	41,331	39,359	39,190	38,977	38,331	38,022	37,776	37,350	36,923	36,526	36,182	35,889	35,672
Other	74	188	362	821	1,009	12,56	1,403	1,682	1,961	1,937	1,911	1,886	1,863	1,844	1,827	1,812
Water																
Oil	1,372	1,814	1,618	1,764	1,618	1,516	1,533	1,484	1,454	1,450	1,454	1,479	1,506	1,531	1,553	1,575
Domestic																
Coal	673	623	665	737	741	731	740	749	758	765	768	771	774	779	783	788
Oil	3,092	3,250	2,876	3,032	2,915	2,973	2,920	2,918	2,935	2,916	2,882	2,861	2,844	2,833	2,823	2,816
Gas	32,836	31,550	30,341	30,916	29,603	30,369	30,804	31,101	31,010	30,832	30,539	30,325	30,150	30,031	29,913	29,778
Electricity	10,809	10,695	10,555	10,818	10,905	9,320	8,988	8,794	8,892	8,957	8,953	9,004	9,068	9,166	9,251	9,352

ENERGY DEMAND BY FUEL (KTOE) - 2009 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Other	370	410	452	482	469	462	463	464	464	463	460	458	457	457	456	456
Public administration																
Coal	27	14	10	9	16	7	7	7	8	8	8	8	8	8	8	8
Oil	541	489	487	472	364	394	352	343	330	317	305	290	276	263	252	241
Gas	4,380	3,983	3,700	3,712	3,167	3,402	3,207	3,212	3,203	3,217	3,164	3,126	3,100	3,093	3,071	3,061
Electricity	1,722	1,745	1,727	1,724	1,563	1,932	1,731	1,726	1,680	1,632	1,669	1,668	1,669	1,666	1,695	1,707
Other	427	415	422	426	422	426	423	423	423	423	422	422	422	422	422	422
Commercial																
Coal	4	4	4	7	7	7	7	7	7	7	7	7	7	8	8	8
Oil	388	394	409	402	378	355	364	366	371	376	377	382	387	394	399	406
Gas	3,284	2,947	2,846	2,868	2,695	2,810	2,828	2,836	2,871	2,906	2,907	2,940	2,962	3,003	3,024	3,059
Electricity	6,371	6,309	6,280	6,325	6,419	5,992	6,109	6,194	6,336	6,487	6,549	6,699	6,822	6,990	7,103	7,255
Other	29	28	27	19	21	20	20	20	21	21	21	21	21	22	22	22
Agriculture																
Coal	6	3	3	7	0	0	0	0	0	0	0	0	0	0	0	0
Oil	363	306	294	304	343	253	258	248	243	236	224	222	217	214	208	205
Gas	194	173	172	186	197	138	150	147	146	142	136	135	131	130	126	124
Electricity	344	347	355	350	379	291	288	274	270	264	251	250	245	243	237	234
Other	81	90	85	134	146	108	111	106	105	102	97	96	94	93	91	89
Miscellaneous																
Coal	1	3	1	1	2	0	0	0	0	0	0	0	0	0	0	0
Oil	461	340	310	243	216	200	219	217	218	216	213	207	201	196	192	188

ENERGY DEMAND BY FUEL (KTOE) - 2009 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Gas	1,721	1,596	1,486	1,509	1,365	1,242	1,318	1,316	1,324	13,19	1,307	1,277	1,247	1,219	1,198	1,177

Source(s) : MDM-E3, Cambridge Econometrics.

Appendix Table B.9: CO2 Emissions – 2009 Run

CO2 EMISSIONS (MTCO2) – 2009 RUN																
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Power Generation	183.4	192.4	188.4	183.9	182.3	198.4	187.4	186.5	186.9	185.3	175.3	173.2	178.3	175.8	177.6	168.4
Transformation/own use	43.6	37.3	38.0	36.2	36.9	40.1	39.6	39.5	39.4	39.4	39.4	39.5	39.5	39.6	39.7	39.7
Iron & steel	6.6	6.9	6.8	5.9	5.4	5.7	5.9	6.0	6.2	6.4	6.5	6.6	6.7	6.7	6.7	6.7
Non-ferrous metals	2.4	2.4	2.2	2.1	1.9	1.9	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Mineral products	17.7	17.4	18.0	17.1	15.0	13.5	13.8	14.0	14.2	14.4	14.5	14.6	14.7	14.7	14.6	14.5
Chemicals	12.3	11.8	11.0	10.7	8.8	10.0	10.3	10.5	11.0	11.6	11.7	11.7	11.7	11.8	11.9	12.1
Mechanical engineering	3.1	2.9	2.9	2.7	2.4	2.7	2.6	2.5	2.5	2.5	2.4	2.4	2.4	2.4	2.4	2.3
Electrical engineering	1.4	1.5	1.4	1.4	1.2	1.3	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.1	1.1	1.0
Vehicles	3.7	3.5	3.3	3.2	2.7	3.5	3.5	3.5	3.6	3.7	3.9	4.1	4.3	4.4	4.6	4.7
Food, drink & tobacco	8.8	8.3	8.6	8.6	6.8	5.9	7.3	7.0	7.3	7.3	7.2	7.3	7.3	7.3	7.2	7.2
Tex., cloth. & leath.	2.8	2.7	2.6	2.5	2.2	2.3	2.2	2.2	2.1	2.0	2.0	1.9	1.8	1.7	1.7	1.6
Paper, print. & pub.	6.3	5.9	5.9	5.9	6.2	7.0	6.6	6.2	5.6	5.1	4.6	4.3	4.0	3.8	3.7	3.8
Other industries	10.6	10.1	10.7	9.5	8.3	9.2	9.6	9.8	9.8	9.8	9.7	9.5	9.4	9.2	9.1	9.0
Construction	1.4	1.3	1.3	1.4	1.1	1.6	1.4	1.3	1.1	1.0	1.0	1.0	1.0	1.1	1.1	1.0
Unclassified	8.9	8.8	8.3	7.7	7.5	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Air	4.9	4.9	4.8	4.7	3.8	4.2	4.0	4.0	4.1	4.3	4.4	4.6	4.7	4.8	4.9	5.0
Rail	2.2	2.2	2.2	2.2	2.2	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Road	120.4	120.8	122.0	117.7	112.1	111.8	111.2	109.4	108.6	107.9	106.7	105.5	104.4	103.4	102.6	102.0

CO2 EMISSIONS (MTCO2) – 2009 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Water	5.0	6.3	5.8	6.2	5.7	5.3	5.4	5.2	5.1	5.0	5.1	5.1	5.2	5.3	5.4	5.4
Domestic	84.9	81.8	78.4	81.0	77.4	79.2	80.1	80.8	80.7	80.4	79.7	79.2	78.9	78.6	78.4	78.2
Public administration	11.2	10.7	9.8	10.4	9.1	9.5	8.9	9.0	8.9	9.0	8.8	8.7	8.7	8.6	8.6	8.5
Commercial	11.6	10.9	11.0	11.6	10.9	11.3	11.4	11.4	11.5	11.7	11.7	11.8	11.9	12.0	12.1	12.3
Agriculture	4.6	4.3	4.2	4.2	5.1	3.7	3.7	3.5	3.4	3.3	3.1	3.1	3.0	3.0	2.9	2.9
Total CO2 emissions	557.7	555.1	547.5	536.8	515.1	538.3	528.7	525.7	525.9	523.6	511.4	507.6	511.3	507.9	508.6	498.9

Source(s) : MDM-E3, Cambridge Econometrics.

Appendix Table B.10: Capacity and Generation by Station Type – 2009 Run

CAPACITY AND GENERATION BY STATION TYPE - 2009 RUN

Capacity (TW)	2005	2010	2015	2020
Coal	23	24	22	19
Oil/mixed	10	9	5	0
Gas	24	29	36	38
Nuclear	12	11	7	8
CHP	6	6	8	9
Hydro	2	2	2	2
Other renewables	3	6	12	16
Autogenerators (non-CHP)	1	1	1	1
Pumped storage	3	3	3	3
Imports	2	2	3	3
Total	85	92	97	99
Generation (TWh)				
Coal	110	104	91	97
Oil/mixed	26	16	6	0
Gas	128	140	150	135
Nuclear	82	53	32	39
CHP	29	29	38	44
Hydro	5	6	6	7
Other renewables	11	22	39	53
Autogenerators (non-CHP)	6	6	6	6
Pumped storage	3	4	4	4
Imports	8	3	5	5
Total	407	383	377	391

Source(s) : MDM-E3, Cambridge Econometrics.

Appendix Table B.11: Economic Activity by Fuel User – 2010 Run

ECONOMIC ACTIVITY BY FUEL USER (% PA) – 2010 RUN														
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2005-10	2010-15	2015-20
Iron & steel	0.4	-1.48	0.24	-4.26	-25.49	-22.87	0.57	0.60	0.54	0.49	0.39	-11.48	0.52	0.09
Non-ferrous metals	0.4	-1.48	0.24	-4.26	-25.49	3.12	3.03	2.94	2.43	2.51	2.60	-6.19	2.70	1.26
Mineral products	0.1	2.77	0.44	-5.45	-14.71	7.06	5.75	3.80	3.26	3.37	3.41	-2.28	3.91	1.73
Chemicals	-0.53	1.59	1.88	-0.89	-13.92	7.51	7.77	7.26	6.71	7.03	6.91	-1.04	7.13	3.69
Mechanical engineering	2.18	4.63	3.01	-2.53	-19.51	5.32	4.49	4.04	4.67	3.89	3.44	-2.29	4.11	1.79
Electrical engineering	-4.15	-0.56	-2.10	-6.81	-11.30	5.32	4.49	4.04	4.67	3.89	3.44	-3.25	4.11	1.79
Vehicles	-0.98	3.34	1.70	-2.77	-17.31	5.32	4.49	4.04	4.67	3.89	3.44	-2.30	4.11	1.79
Food, drink & tobacco	2.03	-0.70	0.44	-1.65	-2.63	3.92	3.96	3.48	2.88	2.98	3.04	-0.15	3.27	1.54
Tex., cloth. & leath.	-2.12	-0.13	-1.03	-0.37	-9.11	-3.03	-2.76	-2.62	-2.91	-2.97	-2.88	-2.79	-2.83	-3.08
Paper, print. & pub.	-3.62	-0.45	0.94	-2.21	-9.17	2.60	3.87	2.80	2.04	2.09	2.17	-1.74	2.59	1.02
Other industries	-0.56	1.48	1.62	-4.02	-9.70	2.89	3.00	3.00	2.50	2.58	2.66	-1.66	2.75	1.34
Construction	1.02	1.01	3.15	-0.73	-11.05	5.29	5.86	5.31	3.38	3.31	2.16	-0.63	4.00	1.27
Air	6.4	5.49	7.17	-1.17	-5.23	1.38	3.77	3.30	2.80	2.82	2.69	1.43	3.07	1.35
Rail	2.54	3.80	3.62	0.24	-10.23	1.38	3.77	3.30	2.80	2.82	2.69	-0.38	3.07	1.35
Water	5.24	-12.66	-3.78	7.15	-8.27	1.38	3.77	3.30	2.80	2.82	2.69	-3.49	3.07	1.35
	2.17	1.84	2.20	0.43	-3.31	0.20	1.30	1.70	2.10	2.20	2.20	0.25	1.90	2.29

ECONOMIC ACTIVITY BY FUEL USER (% PA) – 2010 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2005-10	2010-15	2015-20
Domestic														
Public administration	1.66	1.23	1.74	0.34	1.61	1.38	3.77	3.30	2.80	2.82	2.69	1.26	3.07	1.35
Commercial	3.16	5.21	4.39	0.68	-4.09	1.38	3.77	3.30	2.80	2.82	2.69	1.46	3.07	1.35
Agriculture	7.59	0.81	-4.38	-0.16	-5.53	1.38	3.77	3.30	2.80	2.82	2.69	-1.62	3.07	1.35
Miscellaneous	1.51	1.51	1.72	-0.27	-8.23	1.38	3.77	3.30	2.80	2.82	2.69	-0.85	3.07	1.35

Source(s) : MDM-E3, Cambridge Econometrics.

Appendix Table B.12: Aggregate Energy Demand – 2010 Run

AGGREGATE ENERGY DEMAND (KTOE) - 2010 RUN																
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Iron & steel	1,758	1,863	1,775	1,613	1,199	648	662	682	706	728	741	772	798	819	832	841
Non-ferrous metals	1,011	1,003	952	934	822	600	639	647	660	666	642	662	668	673	667	666
Mineral products	3,214	3,098	3,120	3,216	2,788	2,913	2,983	3,084	3,142	3,176	3,201	3,204	3,192	3,143	3,074	3,003
Chemicals	5,588	5,348	5,076	5,147	4,388	4,717	4,793	5,100	5,396	5,699	5,878	5,917	5,970	6,044	6,131	6,227
Mechanical engineering	1,609	1,550	1,504	1,472	1,289	1,254	1,249	1,257	1,274	1,288	1,288	1,313	1,328	1,334	1,331	1,327
Electrical engineering	1,032	1,057	987	987	871	906	931	955	976	985	976	958	933	905	877	851
Vehicles	1,532	1,466	1,381	1,361	1,188	1,262	1,278	1,312	1,346	1,372	1,388	1,411	1,426	1,435	1,441	1,446
Food, drink & tobacco	3,540	3,381	3,329	3,426	2,937	2,927	3,110	3,296	3,422	3,501	3,540	3,577	3,584	3,565	3,523	3,477
Tex., cloth. & leath.	1,056	1,042	981	956	832	871	781	718	664	620	582	559	542	527	513	502
Paper, print. & pub.	2,873	2,711	2,596	2,627	2,254	2,006	1,869	1,785	1,679	1,591	1,503	1,421	1,349	1,304	1,289	1,317
Other industries	5,698	5,441	5,641	5,440	4,739	4,993	5,414	5,569	5,544	5,450	5,346	5,229	5,104	4,987	4,896	4,839
Construction	586	552	528	548	449	409	430	461	452	428	404	393	393	400	407	413
Unclassified	3,096	3,300	3,158	3,018	2,956	3,102	3,102	3,102	3,102	3,102	3,102	3,102	3,102	3,102	3,102	3,102
Air	13,856	13,999	13,906	13,426	12,730	13,347	12,867	12,860	13,482	14,072	14,590	15,076	15,544	15,961	16,334	16,720
Rail	1,468	1,437	1,443	1,531	1,507	1,436	1,443	1,451	1,467	1,488	1,499	1,527	1,553	1,580	1,601	16,23
Road	42,464	42,696	43,207	42,151	40,704	40,617	40,362	39,658	39,219	38,718	38,152	37,686	37,269	36,908	36,600	36,370
Water	1,372	1,814	1,618	1,764	1,570	1,462	1,479	1,431	1,407	1,412	1,424	1,448	1,484	1,520	1,552	1,582

AGGREGATE ENERGY DEMAND (KTOE) - 2010 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Domestic	47,780	46,527	44,889	45,985	43,567	41,933	41,179	40,752	40,409	40,203	39,900	39,902	39,988	40,122	40,237	40,379
Public administration	7,097	6,646	6,347	6,344	5,712	5,910	5,811	5,728	5,550	5,483	5,480	5,399	5,347	5,328	5,326	53,15
Commercial	10,077	9,682	9,565	9,621	8,963	7,994	8,598	8,819	9,020	9,218	9,292	9,517	9,673	9,858	10,009	10,202
Agriculture	988	918	908	981	909	610	650	634	619	606	574	580	568	561	548	541
Miscellaneous	2,183	1,940	1,798	1,753	1,522	1,308	1,371	1,351	1,337	1,314	1,283	1,238	1,194	1,155	1,121	1,094
Total energy demand	159,879	157,471	154,709	154,300	143,898	141,226	141,002	140,651	140,873	141,121	140,785	140,895	141,010	141,232	141,409	141,837

Source(s) : MDM-E3, Cambridge Econometrics.

Appendix Table B.13: Energy Demand by Fuel – 2010 Run

ENERGY DEMAND BY FUEL (KTOE) - 2010 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Iron & steel																
Coal	479	435	506	428	321	152	153	155	158	160	160	163	164	164	162	159
Oil	14	20	67	62	54	21	19	17	16	15	14	13	12	12	11	10
Gas	833	905	779	722	515	323	344	369	395	421	440	472	500	525	544	562
Electricity	432	504	423	401	310	152	146	141	137	133	127	125	122	118	114	110
Non-ferrous metals																
Coal	24	36	22	20	17	12	13	12	12	11	10	10	9	9	8	8
Oil	53	53	48	47	45	29	33	33	33	33	31	32	32	32	32	32
Gas	272	267	246	257	213	159	178	183	192	192	186	194	198	202	204	208
Electricity	661	647	635	610	548	400	415	419	423	429	414	427	429	429	423	419
Mineral products																
Coal	738	690	758	758	710	713	665	655	640	620	599	570	540	503	466	430
Oil	216	200	239	223	184	188	231	252	256	258	258	257	255	250	243	235
Gas	1,574	1,531	1,451	1,579	1,293	1,397	14,07	1,422	1,470	1,505	1,537	1,560	1,576	1,574	1,560	1,544
Electricity	686	677	672	656	601	615	680	755	776	793	807	817	821	816	805	793
Chemicals																
Coal	84	84	76	65	59	61	48	43	39	36	33	29	26	23	21	20
Oil	194	188	192	176	156	149	161	177	186	196	201	201	202	203	205	208
Gas	3,102	2,952	2,592	2,681	2,213	2,429	2,428	2,520	2,705	2,891	3,010	3,039	3,078	3,128	3,184	3,246
Electricity	1,816	1,753	1,737	1,633	1,478	1,597	1,675	1,879	1,984	2,094	2,153	2,167	2,183	2,208	2,238	2,271
Other	392	371	480	592	482	482	482	482	482	482	482	482	482	482	482	482

ENERGY DEMAND BY FUEL (KTOE) - 2010 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Mechanical engineering																
Coal	9	9	7	10	10	9	9	9	9	9	8	8	8	8	8	8
Oil	118	106	107	98	88	87	86	86	87	88	88	90	91	91	91	91
Gas	737	703	659	662	555	553	540	538	542	545	543	552	556	556	552	547
Electricity	742	730	727	698	636	604	614	624	636	647	648	663	673	679	680	681
Other	3	2	3	4	0	0	0	0	0	0	0	0	0	0	0	0
Electrical engineering																
Coal	3	4	4	4	3	3	3	4	4	4	4	4	3	3	3	3
Oil	35	85	36	47	41	37	40	42	43	44	43	42	40	38	35	33
Gas	355	337	321	335	279	296	299	304	308	308	304	297	287	277	266	257
Electricity	638	631	627	601	547	569	589	606	621	629	626	616	603	588	572	558
Vehicles																
Coal	35	34	32	31	30	31	31	31	31	31	31	30	30	29	29	28
Oil	139	124	123	116	103	95	97	100	103	106	107	109	110	111	112	112
Gas	856	814	734	741	620	674	705	751	803	857	909	970	1,029	1,079	1,126	1,169
Electricity	502	494	492	474	434	462	445	430	409	379	341	301	257	215	174	136
Food, drink & tobacco																
Coal	19	17	30	28	35	32	36	40	46	50	55	59	64	69	75	80
Oil	323	282	283	293	260	222	238	257	278	291	301	310	317	324	330	338
Gas	2,143	2,039	1,975	2,095	1,725	1,739	1,791	1,783	1,878	1,896	1,892	1,879	1,850	1,805	1,746	1,685
Electricity	1,055	1,042	1,039	1,002	917	932	1,044	1,215	1,220	1,263	1,292	1,328	1,352	1,367	1,371	1,373
Other	1	1	2	8	1	1	1	1	1	1	1	1	1	1	1	1

ENERGY DEMAND BY FUEL (KTOE) - 2010 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Tex., cloth. & leath.																
Coal	50	49	52	53	49	51	46	42	39	36	34	33	32	31	30	29
Oil	110	131	119	104	92	96	86	79	73	68	64	61	60	58	56	55
Gas	605	571	523	524	444	465	417	383	354	331	310	298	289	281	274	268
Electricity	292	291	288	274	248	260	233	214	198	185	173	166	161	157	153	150
Paper, print. & pub.																
Coal	98	99	101	105	71	60	54	49	44	40	36	32	29	27	26	26
Oil	86	59	65	65	61	43	47	48	46	42	38	33	29	26	23	22
Gas	1,521	1,420	1,334	1,427	1,191	1,083	1,004	959	905	862	818	778	742	721	716	734
Electricity	1,137	1,110	1,096	1,028	931	820	765	729	684	647	611	578	549	530	524	535
Other	31	22	1	1	0	0	0	0	0	0	0	0	0	0	0	0
Other industries																
Coal	113	130	135	136	125	136	160	177	187	193	196	197	197	196	196	197
Oil	2,437	2,205	2,386	2,209	1,852	1,899	1,978	2,005	1,969	1,910	1,848	1,782	1,716	1,654	1,605	1,572
Gas	894	848	794	815	691	778	819	845	848	840	831	819	806	793	784	780
Electricity	1,848	1,844	1,916	1,874	1,656	1,765	2,043	2,127	2,125	2,093	2,056	2,015	1,971	1,929	1,897	1,876
Other	405	414	411	406	415	415	415	415	415	415	415	415	415	415	415	415
Construction																
Coal	0	0	0	28	3	2	3	3	3	3	3	3	3	3	3	3
Oil	190	174	169	159	139	125	142	155	153	145	137	133	133	135	138	140
Gas	230	220	204	213	180	168	166	174	167	155	143	136	133	133	132	130
Electricity	166	158	155	148	127	114	119	129	129	126	121	121	124	129	135	140
Unclassified																

ENERGY DEMAND BY FUEL (KTOE) - 2010 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Coal	56	53	62	65	55	57	57	57	57	57	57	57	57	57	57	57
Oil	2,814	3,013	2,797	2,541	2,492	2,615	2,615	2,615	2,615	2,615	2,615	2,615	2,615	2,615	2,615	2,615
Gas	39	34	36	34	36	38	38	38	38	38	38	38	38	38	38	38
Other	187	200	263	377	373	392	392	392	392	392	392	392	392	392	392	392
Air																
Oil	13,856	13,999	13,906	13,426	12,730	13,347	12,867	12,860	13,482	14,072	14,590	15,076	15,544	15,961	16,334	16,720
Rail																
Coal	3	3	3	5	7	6	7	7	7	7	7	7	7	7	7	7
Oil	707	726	700	747	747	724	724	725	728	733	733	741	747	754	758	763
Electricity	758	708	740	779	754	706	712	720	732	748	759	779	799	819	836	853
Road																
Oil	42,390	42,508	42,845	41,331	39,695	39,362	38,960	37,976	37,258	36,780	36,241	35,800	35,406	35,064	34,773	34,557
Other	74	188	362	821	1,009	1,256	1,403	1,682	1,961	1,937	1,911	1,886	1,863	1,844	1,827	1,812
Water																
Oil	1,372	1,814	1,618	1,764	1,570	1,462	1,479	1,431	1,407	1,412	1,424	1,448	1,484	1,520	1,552	1,582
Domestic																
Coal	673	623	665	737	717	707	701	700	701	704	706	710	716	722	728	735
Oil	3,092	32,50	2,876	3,032	3,012	3,031	2,902	2,861	2,852	2,827	2,798	2,788	2,786	2,788	2,790	2,794
Gas	32,836	31,550	30,341	30,916	28,790	28,246	28,179	28,140	27,833	27,628	27,365	27,296	27,279	27,287	27,280	27,281
Electricity	10,809	10,695	10,555	10,818	10,537	9,454	8,910	8,569	8,543	8,568	8,559	8,635	8,732	8,849	8,962	9,090
Other	370	410	452	482	512	495	487	483	479	477	474	474	475	476	477	479
Public admin																
Coal	27	14	10	9	17	13	13	13	13	13	13	13	12	12	12	12

ENERGY DEMAND BY FUEL (KTOE) - 2010 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Oil	541	489	487	472	373	357	342	329	310	298	288	273	260	248	238	228
Gas	4,380	3,983	3,700	3,712	3,249	3,464	3,375	3,353	3,278	3,284	3,257	3,213	3,192	3,202	3,199	3,206
Electricity	1,722	1,745	1,727	1,724	1,640	1,642	1,647	1,600	1,517	1,457	1,490	1,469	1,452	1,436	1,447	1,440
Other	427	415	422	426	433	435	434	433	432	431	431	431	430	430	430	430
Commercial																
Coal	4	4	4	7	35	31	34	34	35	36	36	37	38	38	39	39
Oil	388	394	409	402	361	327	345	352	357	361	362	368	372	378	383	389
Gas	3,284	2,947	2,846	2,868	2,513	2,270	2,425	2,477	2,523	2,567	2,576	2,627	2,657	2,695	2,723	2,763
Electricity	6,371	6,309	6,280	6,325	6,035	5,348	5,776	5,938	6,086	6,236	6,299	6,466	6,587	6,728	6,845	6,991
Other	29	28	27	19	18	17	18	18	18	19	19	19	19	19	19	20
Agriculture																
Coal	6	3	3	7	0	0	0	0	0	0	0	0	0	0	0	0
Oil	363	306	294	304	291	196	210	204	198	193	182	183	179	176	171	169
Gas	194	173	172	186	158	96	110	110	108	106	101	102	99	98	96	95
Electricity	344	347	355	350	324	227	233	225	220	216	205	208	205	203	199	197
Other	81	90	85	134	136	91	97	95	93	91	86	87	85	84	82	81
Miscellaneous																
Coal	1	3	1	1	2	1	0	0	0	0	0	0	0	0	0	0
Oil	461	340	310	243	228	200	215	210	208	203	198	190	183	176	171	166
Gas	1,721	1,596	1,486	1,509	1,292	1,107	1,156	1,140	1,129	1,111	1,085	1,049	1,012	979	950	927

Source(s) : MDM-E3, Cambridge Econometrics.

Appendix Table B.14: CO2 Emissions – 2010 Run

CO2 EMISSIONS (MTCO2) – 2010 RUN																
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Power Generation	183.4	192.4	188.4	183.9	164.7	154.7	156.3	155.6	157.0	156.2	153.8	152.3	159.2	154.8	159.8	149.9
Transformation/own use	43.6	37.3	38.0	36.2	34.4	40.2	39.9	39.9	39.9	40.0	40.1	40.2	40.2	40.3	40.4	40.4
Iron & steel	6.6	6.9	6.8	5.9	4.4	2.6	2.6	2.7	2.8	2.9	3.0	3.1	3.3	3.3	3.4	3.4
Non-ferrous metals	2.4	2.4	2.2	2.1	1.7	1.5	1.6	1.6	1.7	1.7	1.7	1.7	1.7	1.8	1.8	1.8
Mineral products	17.7	17.4	18.0	17.1	14.6	15.5	15.8	16.1	16.4	16.7	17.0	17.0	17.1	17.0	16.9	16.8
Chemicals	12.3	11.8	11.0	10.7	8.9	9.6	9.6	10.0	10.6	11.3	11.8	11.9	12.0	12.2	12.4	12.6
Mechanical engineering	3.1	2.9	2.9	2.7	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3
Electrical engineering	1.4	1.5	1.4	1.4	1.2	1.2	1.2	1.2	1.3	1.3	1.2	1.2	1.2	1.1	1.1	1.0
Vehicles	3.7	3.5	3.3	3.2	2.7	2.9	3.0	3.2	3.4	3.6	3.8	4.0	4.2	4.4	4.6	4.7
Food, drink & tobacco	8.8	8.3	8.6	8.6	7.2	7.1	7.4	7.4	7.9	8.0	8.0	8.0	8.0	7.9	7.7	7.5
Tex., cloth. & leath.	2.8	2.7	2.6	2.5	2.1	2.2	2.0	1.8	1.7	1.6	1.5	1.4	1.4	1.3	1.3	1.3
Paper, print. & pub.	6.3	5.9	5.9	5.9	4.9	4.4	4.1	3.9	3.7	3.5	3.3	3.1	2.9	2.9	2.8	2.9
Other industries	10.6	10.1	10.7	9.5	8.0	8.5	9.0	9.2	9.2	9.1	8.9	8.7	8.4	8.2	8.1	8.0
Construction	1.4	1.3	1.3	1.4	1.1	1.0	1.0	1.1	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9
Unclassified	8.9	8.8	8.3	7.7	7.5	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9	7.9

CO2 EMISSIONS (MTCO2) – 2010 RUN

	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Air	4.9	4.9	4.8	4.7	4.0	4.2	4.1	4.1	4.3	4.4	4.6	4.8	4.9	5.0	5.2	5.3
Rail	2.2	2.2	2.2	2.2	2.2	2.1	2.1	2.1	2.1	2.1	2.1	2.2	2.2	2.2	2.2	2.2
Road	120.4	120.8	122.0	117.7	113.1	112.2	111.2	108.4	106.4	105.1	103.6	102.3	101.2	100.3	99.5	98.8
Water	5.0	6.3	5.8	6.2	5.5	5.1	5.2	5.0	4.9	4.9	5.0	5.1	5.2	5.3	5.4	5.5
Domestic	84.9	81.8	78.4	81.0	75.8	74.6	74.1	73.9	73.3	72.8	72.2	72.1	72.1	72.2	72.2	72.3
Public admin	11.2	10.7	9.8	10.4	9.4	9.8	9.6	9.5	9.3	9.3	9.3	9.1	9.1	9.1	9.1	9.1
Commercial	11.6	10.9	11.0	11.6	10.3	9.3	9.9	10.1	10.3	10.4	10.5	10.7	10.8	11.0	11.1	11.2
Agriculture	4.6	4.3	4.2	4.2	4.3	3.0	3.1	3.0	2.9	2.8	2.7	2.7	2.6	2.6	2.5	2.5
Total CO2 emissions	557.7	555.1	547.5	536.8	490.2	482.0	483.0	480.1	480.3	479.0	475.0	472.7	478.7	473.8	478.4	468.3

Source(s) : MDM-E3, Cambridge Econometrics.

Appendix Table B.15: Capacity and Generation by Station Type – 2010 Run

CAPACITY AND GENERATION BY STATION TYPE - 2010 RUN

Capacity (TW)	2005	2010	2015	2020
Coal	23	24	22	20
Oil/mixed	10	9	5	0
Gas	24	30	38	40
Nuclear	12	11	7	8
CHP	6	6	7	9
Hydro	2	2	2	2
Other renewables	3	7	12	16
Autogenerators (non-CHP)	1	1	1	1
Pumped storage	3	3	3	3
Imports	2	2	3	3
Total	85	94	99	101
Generation (TWh)				
Coal	110	86	82	93
Oil/mixed	26	16	6	0
Gas	128	112	142	124
Nuclear	82	69	42	50
CHP	29	29	38	45
Hydro	5	6	7	7
Other renewables	11	24	39	52
Autogenerators (non-CHP)	6	7	7	7
Pumped storage	3	4	4	4
Imports	8	3	5	5
Total	407	356	371	386

Source(s) : MDM-E3, Cambridge Econometrics.

Appendix Table B.16: DECC Fossil Fuel Price Assumptions

DECC FOSSIL FUEL PRICE ASSUMPTIONS (2007 PRICES)

2008 run	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Coal (£/tonne)	38.2	39.3	44.2	45.2	46.2	36.0	34.9	33.9	32.9	31.9	30.8	31.0	31.2	31.4	31.6	31.9
Oil (£/bbl)	61.73	72.81	73	75	67.5	65	65.5	66	66.5	67	67.5	68	68.5	69	69.5	70
Gas (p/therm)	28.4	35.2	30.0	40.1	42.4	42.7	42.9	43.2	43.5	43.8	44.1	44.4	44.7	45.0	45.3	45.5
2009 run																
Coal (£/tonne)	40.1	40.7	55.3	89.3	78.3	66.8	63.2	59.5	55.9	52.2	48.6	48.6	48.6	48.6	48.6	48.6
Oil (£/bbl)	64.1	71.9	74.8	99.1	68.0	68.0	69.0	70.0	70.9	71.9	72.9	73.8	74.8	75.8	76.8	77.7
Gas (p/therm)	42.8	42.8	30.1	56.4	51.5	56.4	58.3	59.3	60.2	61.2	61.2	62.2	63.2	64.1	64.1	65.1
2010 run																
Coal (£/tonne)	36.4	36.7	45.3	79.7	43.1	67.4	63.7	60.1	56.4	52.7	49.0	49.0	49.0	49.0	49.0	49.0
Oil (£/bbl)	59.7	69.9	74.5	102.0	60.1	68.6	69.6	70.6	71.6	72.6	73.6	74.5	75.5	76.5	77.5	78.5
Gas (p/therm)	30.1	45.3	30.7	58.2	29.7	57.1	59.2	59.9	60.7	61.4	62.1	62.8	63.6	64.3	65.0	65.7

Source (s) : DECC Model.

Appendix C: Description of MDM-E3

C.1 Introduction

MDM-E3 is a model of the UK energy-environment-economy system

MDM-E3[39] is maintained and developed by Cambridge Econometrics (CE) as a framework for generating forecasts and alternative scenarios, analysing changes in economic structure and assessing energy-environment-economy (E3) issues and other policies. MDM-E3 provides a one-model approach in which the detailed industry and regional analysis is consistent with the macroeconomic analysis: in MDM-E3, the key indicators are modelled separately for each industry sector, and for each region, yielding the results for the UK as a whole. MDM-E3 is one of a family of models which share the same framework, general design, methodology and supporting software; the scope of the E3ME[40] model is European; that of E3MG[41] is global.

To analyse structure, the E3 models disaggregate industries, commodities, and household and government expenditures, as well as foreign trade and investment, and incorporate an input-output framework to identify the inter-relationships between industry sectors. The models combine the features of an annual short and medium-term sectoral model estimated by formal econometric methods with the detail and structure of input-output models, providing analysis of the movement of the long-term outcomes for key E3 indicators in response to economic developments and policy changes. The models are essentially dynamic simulation models estimated by econometric methods.

MDM-E3 retains an essentially Keynesian logic for determining final expenditure, 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.

The model is dynamic, and its parameters are estimated econometrically

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.

In summary MDM-E3 provides:

- annual comprehensive forecasts to the year 2025 for:
  - industry output, prices, exports, imports and employment at an industry level; for household expenditure by 51 categories
  - investment by 27 investing sectors for the nine Government Office Regions, Wales, Scotland and Northern Ireland
- projections of energy demand and emissions, by 25 fuel users and eight main fuel types (in all, 11 fuels are distinguished)

[39] Multisectoral Dynamic Model, Energy-Environment-Economy:
http://www.mdm-e3.com/

[40] Energy-Environment-Economy Model of Europe:
http://www.e3me.com/

[41] Energy-Environment-Economy Model at the Global level:
http://www.e3mgmodel.com/

- full macro top-down and industrial bottom-up simulation analysis of the economy, allowing industrial factors to influence the macro picture
- an in-depth treatment of changes in the input-output structure of the economy over the forecast period to incorporate the effects of technological change, relative price movements and changes in the composition of each industry's output
- scenario analysis, to inform the investigation of alternative economic futures and the analysis of policy

C.2 Economy

MDM-E3 incorporates a disaggregated representation of the UK economy…

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 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.

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.

…at the sectoral level…

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)

…as well as the regional level

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.

The model's accounting framework is consistent with international systems of national accounts

A social accounting framework is essential in a large-scale disaggregated economic model. The early versions of MDM-E3 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.

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.

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.

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.

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.

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 model identifies three main flows of economic dependence

The determination of output in MDM-E3 can be divided into three main flows of economic dependence:

- the output-investment loop
- the income loop
- the export loop

Household expenditure is principally a function of income and prices, although demographic trends are also accounted for

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 51 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.

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

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

Household expenditure is disaggregated by type and region

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.

Feedback from the energy sub-models determines consumption of energy products

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 from the energy and transport sub-models described later. Disaggregated consumption is then scaled to match regional consumption at the aggregate level.

Household expenditure by expenditure category is then mapped to the 41 product categories to derive domestic consumer demand by product category.

Investment is a function of industry output

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.

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.

In MDM-E3 investment data are divided into 27 investing sector categories at the national level. The national investment equations depend on industry output, which is converted from the 41 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.

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.

The level of government expenditure is an exogenous assumption in the model, and must be determined by the model operator

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.

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).

UK exports are driven by (assumed) economic activity in the rest of the world; import demand by the level of domestic demand and relative prices

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 41 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.

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.

Interdependencies between industries are represented in an input-output framework

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. 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.

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-E3 model. An input-output table has been estimated from official data to provide the detail needed to model inter-industry purchases and sales.

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.

Employment is determined by sector and region

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.

Labour productivity is defined on a net output per job basis

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. 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).

Interest rates and exchange rates are exogenous inputs to the model

Previous versions of MDM-E3 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.

Prices are formed as a mark-up on unit costs

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.

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 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.

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.

Following a wage-bargaining model, increases in price tend to drive wages upward

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.

The treatment of wages in MDM-E3 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.

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.

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.

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.

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

Technological progress is represented endogenously in MDM-E3

Technological progress is often represented as exogenous, either as a residual in a neoclassical production function or by using a linear or non-linear time trend approach. Both methods have their drawbacks. The neoclassical approach is somewhat circular in its logic, ie to know a firm's production possibilities one needs to model technological progress, but in modelling technological progress one is already making an assumption about the production process. The time trend approach is also unappealing given its atheoretical background.

The approach to constructing the measure of technological progress in E3ME is adapted from that of Lee et al (1990). It adopts a direct measure of technological progress by using cumulative gross investment, but this is altered by using data on R&D expenditure, thus forming a quality adjusted measure of investment.

C.3 Energy

MDM-E3 incorporates a number of energy sub-models…

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).

MDM-E3 includes a bottom-up (the ETM) sub-model 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 et al (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, 2005).

…with two-way feedback to the economy

Energy-environment characteristics are represented by sub-models 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 interactions.

Energy-economy feedback is an important feature of the model with regard to policy analysis

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.

The energy sub-model 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 road transport is solved using MDM-E3's Transport Sub-model. Fuel use for power generation is calculated in the electricity supply industry (ESI) sub-model, which uses a 'bottom-up' engineering treatment.

C.4 Final energy demand

The main drivers of energy demand are activity, prices and technological progress

Final energy and fuel demand by fuel user is modelled by econometric equations, which are estimated using a standard cointegrating technique. 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 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

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 by Cambridge Econometrics for HM Customs and Excise (CE et al, 2005).

Relative fuel prices are an important determinant of fuel switching

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)

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)

Aggregate energy demand is projected first, and then shared out to individual fuels

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.

Both the aggregate energy/fuel demand equations and the disaggregated fuel share equations are specified as cointegrating equations:

- 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)

The equations for final energy demand are estimated on the data in the Digest of UK Energy Statistics (DUKES) published by DECC.

The wholesale prices of fossil fuels such as coal, oil and gas are assumptions in MDM-E3. Wholesale prices are converted to consumer/retailer prices for each fuel user by applying appropriate levies and taxes.

C.5 Emissions

MDM-E3 distinguishes 14 air emissions, including the six Kyoto greenhouse gases

MDM-E3 distinguishes 14 air emissions, including the six greenhouse gases currently regulated under the Kyoto Protocol. Emissions data are obtained from the National Air Emissions Inventory (NAEI) and the last year of outturn is typically one year earlier than the energy data, published by DECC, that are fed into the model. For example, the last year of data reported in the July 2010 edition of DUKES is 2009 but the last year of NAEI data, published in 2010, is 2008.

The NAEI data for each year are highly disaggregated and classified by fuel type and activity. The data must be aggregated to the 11 fuel types and 25 fuel users distinguished in MDM-E3 and the guiding principle is that, as far as it practicable, emissions should be classified to the industries that use the fuels associated with the emissions eg if off-road vehicles are used mainly for construction, the emissions would be allocated to the fuel user Construction.

Where available, emissions coefficients for individual fuels and fuel users are applied to the corresponding energy demands to give a first estimate of emissions. A scaling term is applied in the history to ensure that the final output matches official sources. This adjustment is held constant throughout the forecast period. Other emissions are calculated on an implied basis in the last year in which both energy and emissions data are available (2008 in the example above). These coefficients are also typically held constant for the remainder of the period (although they could for example be adjusted to reflect the adoption of emissions-abatement technologies).

Emissions from non-energy use are linked to fuel-user activity indicators or population growth and are thus not differentiated by fuel. Emissions from land use and land use change are not covered.

C.6 Power generation

Electricity generation is handled by an electricity supply industry (ESI) sub-model

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. Changes to the power capacity stock are modelled by the electricity technology sub-model (ETM). Estimation of generation from the capacity stock is modelled by the electricity supply industry (ESI) sub-model.

An Energy Technology Model (ETM) projects the future evolution of UK generation capacity

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.

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

The ETM accounts for learning effects

The ETM considers learning effects, where the cost of building a particular type of new capacity falls as more of that capacity gets built.

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.

The Renewables Obligation is explicitly modelled

The ETM allows the model to project the impact of the Renewables Obligation (RO) including the 'banding' of RO payments. The model considers the contemporaneous and expected future values of RO payments, which are entered as inputs.

Power generation is estimated by the electricity supply industry (ESI) sub-model. 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.

Electricity generation from the ESI sub-model operates on a cost-minimisation basis

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.

There is a separate treatment for CHP

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).

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.

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 sub-models 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.

C.7 Road transport

The Transport Sub-model projects demand for vehicles, travel and fuel for Road transport

MDM-E3 now incorporates a transport sub-model to project energy demand from Road Transport. These results are used in place of the 'top-down' equations previously used, and which are still used to solve energy demand from the other final users. The projections for Road Transport are still derived from a set of econometrically-estimated equations but the degree of disaggregation is far greater, as is the number of explanatory factors considered. The treatment is sufficiently general that the other three modes of transport (air, rail and water) can also be modelled but these elements are not yet operational.

The sub-model is composed of three sets of stochastic equations to explain:

- the demand for travel, expressed in kilometres, disaggregated by vehicle type (eg Cars and taxis, Bus/coach and HGV) and network type (eg Rural A roads, Urban A roads and Motorways)
- annual purchases of new vehicles, disaggregated by vehicle type and technology (eg internal combustion engines that run on Petrol, Diesel or LPG)
- changes in the fuel efficiency of different vehicle categories, differentiated by vehicle type (eg the fuel efficiency of petrol-driven cars is allowed to differ from, and move differently to, the fuel efficiency of petrol-driven buses)

The sub-model contains a representation of the vehicle stock in which additions are determined by the second and third sets of equations and older vehicles are scrapped according to an exponential function such that the rate at which vehicles are removed from the stock increases with their age. The average fuel efficiency of the stock can thus be tracked over time and combined with the demand for travel to derive the demand for fuel in each year. The consequent emissions are calculated on an implied basis using the last year for which data on energy demand and emissions are both available.

The sub-model was designed by the Cambridge Centre for Climate Change Mitigation Research[42] (4CMR) based on a specification outlined in Johnstone (1995) and was implemented and integrated by teams at 4CMR and CE. The work was funded by the Green Fiscal Commission[43] and the UK Energy Research Centre[44].

[42] http://www.landecon.cam.ac.uk/research/eeprg/4cmr/index.htm

[43] http://www.greenfiscalcommission.org.uk/

[44] http://www.ukerc.ac.uk/

Appendix D: Main Classifications in MDM-E3

Appendix Table D.1: MDM-E3 Classification

MDM-E3 CLASSIFICATION

Product/Industry (Q/Y)	**Fuel Users (FU)**	**Fuel Type (J)**	**Emissions (EM)**
Agriculture etc	Power generation	Coal and coke	CO2
Coal	Other transformation	Motor Spirit	SO2
Oil & Gas etc	Energy industry own use	Derv	NOx
Other Mining	Iron & steel	Gas oil	CO
Food, Drink & Tobacco	Non-ferrous metals	Fuel oil	CH4
Textiles, Clothing & Leather	Mineral products	Other refined oil	PM10
Wood & Paper	Chemicals	Gas	VOC
Printing & Publishing	Mechanical engineering	Electricity	PB
Manufactured Fuels	Electrical engineering	Nuclear fuel	N20
Pharmaceuticals	Vehicles	Steam	HFC
Chemicals nes	Food, drink & tobacco	Other	PFC
Rubber & Plastics	Tex., cloth. & leath.		SF6
Non-Metallic Mineral Products	Paper, print. & pub.		
Basic Metals	Other industries		
Metal Goods	Construction		
Mechanical Engineering	Unclassified		
Electronics	Air Transport		
Electrical Engineering & Instruments	Rail Transport		
Motor Vehicles	Road Transport		
Other Transport Equipment	Water		
Manufacturing nes	Domestic		
Electricity	Public administration		
Gas Supply	Commercial		
Water Supply	Agriculture		
Construction	Miscellaneous		
Distribution			
Retailing			
Hotels & Catering			
Land Transport etc			
Water Transport			
Air Transport			
Communications			
Banking & Finance			
Insurance			
Computing Services			
Professional Services			
Other Business Services			
Public Administration & Defence			
Education			
Health & Social Work			
Miscellaneous Services			
Unallocated			

Source(s): MDM-E3, Cambridge Econometrics.

Appendix Table D.2: Mapping from MDM-E3 Industries to Fuel User Classification

MAPPING FROM MDM-E3 INDUSTRIES TO FUEL USER CLASSIFICATION

Product/Industry (Q/Y)	Fuel Users (FU)
Electricity	Power Generation
Coal	Energy Industry
Oil & Gas	
Manufactured Fuels	
Gas Supply	
Basic Metals	Iron & Steel
Basic Metals	Non-Ferrous metals
Other Mining	Mineral Products
Non-Metallic Mineral Products	
Pharmaceuticals	Chemicals
Chemicals nes	
Metal Goods	Mechanical Engineering
Mechanical Engineering	
Electronics	Electrical Engineering
Electrical Engineering & Instruments	
Motor Vehicles	Vehicles
Other Transport Equipment	
Food, Drink & Tobacco	Food, Drink & Tobacco
Textiles, Clothing & Leather	Textiles, Clothing & Leather
Wood & Paper	Paper & Pulp
Printing & Publishing	
Wood & Paper	Other industry
Rubber & Plastics	
Manufacturing nes	
Water Supply	
Construction	Construction
Air Transport	Air transport
Land Transport etc	Rail Transport
Land Transport etc	Road Transport
Water Transport	Water Transport
linked to households' expenditure	Households
Public Administration & Defence	Public Administration
Education	
Health & Social Work	
Distribution	Commercial
Retailing	
Hotels & Catering	
Communications	
Banking & Finance	
Insurance	
Computing Services	
Professional Services	
Other Business Services	
Agriculture	Agriculture
Miscellaneous Services	Miscellaneous

Source(s) : MDM-E3, Cambridge Econometrics.

Appendix Table D.3: Mapping of MDM-E3 and DECC Model Final Fuel Users

MAPPING OF MDM-E3 AND DECC MODEL FINAL FUEL USERS	
MDM-E3 Fuel Users	**DECC Model Fuel Users**
Energy Intensive Industries	Energy Intensive Industries
Iron and Steel	Iron and Steel
Chemicals	Chemicals
Mineral Products	Mineral Products
Non-Ferrous Metals	Non-Ferrous Metals
Mechanical Engineering	Vehicles and Engineering
Electrical Engineering	
Vehicles	
Food, Drink & Tobacco	Food, Drink and Tobacco
Textiles and Clothing	Textiles
Paper and Pulp	Paper and Pulp
Other Industry	Other Industry
Unclassified	
Air	Air
Road	Road
Rail	Rail
Water	Water
Domestic	Domestic
Commerce	Commerce
Public Administration	Public Administration
Commercial	Commercial
Agriculture	Agriculture
Miscellaneous	

Source(s) : MDM-E3, Cambridge Econometrics, DECC Model.

Appendix E: Model Summaries

Model name and version:	E3ME version 4.7 E3MG – variant of version 2 MDM-E3 version 15.2
Operator:	Cambridge Econometrics
Published documentation:	• E3ME: list of published documents - http://94.76.226.154/ModellingTraining/suite_economic_models/E3ME/publications.aspx • E3MG: list of published documents - http://www.camecon.com/ModellingTraining/suite_economic_models/E3MG.aspx • MDM-E3:Junankar, S, Lofsnaes, O, Summerton, P; Cambridge Econometrics (March 2007); MDM-E3: A short technical description - http://www.camecon.com/ModellingTraining/suite_economic_models/MDM-E3/MDM-E3_overview.aspx
Scope (general/partial):	The three E3 models share the same framework, design, methodology and supporting software, but differ in scope. • E3ME – It is a general model at European level. It follows econometric one-model approach, where the aggregate European results are obtained by summing the countries and sectors. It includes both long-term behaviour as well as dynamic year-to-year fluctuations, suitable for addressing issues that link developments and policies in the area of energy environment and the economy.[45] • E3MG – it is a sectoral econometric model for the world. It also provides a single model framework. • MDM- E3 follows one model approach at UK level, where the macroeconomic analysis is consistent with the industrial and the regional analysis. Here, the outcome for

[45] Pollitt, H, Barker, A, Barton, J (July 2009): A Scoping Study on the Macroeconomic view of sustainability: Final report for the EC, DG Environment

		the UK is derived by separately modelling variables for each industry and region.
Dimensions:	Geographical	• E3ME: 29 countries (the EU27 member states, Norway and Switzerland) • E3MG: 20 world regions (which includes US, Japan, China, India, Mexico, Brazil, and the 4 largest EU economies) • MDM-E3: 9 government office regions (GORs), Wales, Scotland and Northern Ireland
	Sectoral	• E3ME[46]: - 42 economic sectors, including disaggregation of the energy sectors and 16 service sectors - Household expenditure by 43 categories - Energy demand split by 19 fuel users, 12 different type of fuels types and environmental emissions - 14 type of air-borne emissions including 6 greenhouse gases monitored under the Kyoto protocol - 13 type of household, including income quintiles and socio-economic groups • E3MG[47]: - 42 industrial sectors based on NACE classification, including 16 service sectors and disaggregation of the energy sectors. - 28 consumer spending categories - 19 separate fuel users and 12 different fuel types - 14 atmospheric emissions • MDM-E3[48]: it includes energy demand, environmental emissions, and the electricity supply industry (including a separate treatment of combined heat and power and a dynamic treatment of emerging non-carbon technology options). - 41 industries - 51 categories for household expenditure - 27 investment categories - 11 fuel types, 13 fuel users - 14 air emissions including the six greenhouse gases covered by Kyoto Protocol

[46] http://www.camecon.com/ModellingTraining/suite_economic_models/E3ME.aspx

[47] http://www.camecon.com/ModellingTraining/suite_economic_models/E3MG.aspx

[48]http://www.camecon.com/ModellingTraining/suite_economic_models/MDM-E3/MDM-E3_overview.aspx

Temporal	• E3ME - historical database covers 1970-2008, and model projects annually to 2050. • E3MG - currently forecasts till 2050, running by period of 10 years. The time horizon has been extended to cover period up to 2100. • MDM-E3 - covers the period 1970-2030
Other	• The E3 models have the following characteristics: - have explicit two-way linkages, including feedbacks, between the economic, energy systems, and the environment - explain behavioural patterns across different parts of the economy - address long-term environmental outcomes as well as the short-term economic costs - use a combination of two modelling techniques -Error Correction Model (ECM) and Computable General Equilibrium (CGE) models
Exogenous inputs:	• E3ME: - For the EU economy: economic activity in non-EU areas, prices in non-EU world areas, economic policy (including tax rates, growth in government expenditure, interest rates, exchange rates) are exogenously specified. - Energy system: outside factors consist of world oil prices, and energy policy (including regulation of energy industries). - Environment: exogenous factors include policies such as reduction in SO emissions from large combustion plants • E3MG - Except for economic activity in non-EU areas and prices in non-EU areas, all above variables are treated as exogenous in the E3MG model • MDM-E3- exogenous factors consist of activity, power generation capacity, nuclear capacity, energy prices (coal, gas, oil), energy policies and energy production.
Other key assumptions:	MDM-E3: • Energy fuel production[49]: - Assumptions for crude oil and gas

[49] Energy report (C111 forecast) - http://www.camecon.com

	production are based on the mid-point of the data published by DTI in Energy report, but are revised regularly based on the latest information[50]. - Coal production is based on the announcements of the companies about the closure of plants • Energy prices: - Oil prices will grow at 2% pa in real terms in the long term because of expected demand from emerging economies - UK gas prices are expected to move in line with international prices, which also drives UK import fuel prices • Policy assumptions: - EU-ETS assumptions: it is assumed that energy producers are able to pass their cost of EU ETS to their customers. It takes into account the fall in EU ETS allowance price since 2008 and the potential for an increase in price in the long term.The sectoral coverage of this scheme is assumed to be fixed in the 2nd phase (2008-2012), except for the introduction of aviation. Phase 3 (2013-2020), will be administered centrally by European Commission (EC), so the model assumes a fall in overall European cap by 1.74% pa spread equally across sectors and countries. - Commercial and household efficiency policy: excludes CRC energy efficiency scheme due to lack of adequate information - Other policies: energy taxes introduced assumed to remain constant throughout the forecast period, road tax fuel assumed constant in real terms, 5% VAT on household energy use, CCL rate is assumed to change in line with the inflation
Specification of technology:	• The technology is endogenous in the E3 models, specified as a function of investment and R & D. The effects of a technological change are included through the input-output structure of the economy.

[50] Junankar, S, Lofsnaes, O, Summerton, P; Cambridge Econometrics (March 2007); MDM-E3: A short technical description - http://www.camecon.com/ModellingTraining/suite_economic_models/MDM-E3/MDM-E3_overview.aspx

Treatment of uncertainty:	• E3ME and E3MG - Proxy variables, affecting investment and household spending, are used for uncertainty that has an impact on people's behaviour. For uncertainty in the model, meta-analysis is done, which looks at sensitivities in model outputs. • MDM-E3: there is no explicit treatment of uncertainty. Errors are held constant over the forecast period with adjustments made only to reflect expert views.
Proposed future developments:	• E3ME: version 5 will expand E3ME to include 4 additional countries ie. Iceland, Croatia, FRYCOM, Turkey[51]. The sectoral classification is expected to change in 2012 to reflect the new NACE codes. This could affect E3MG, so a revised method of estimating model parameters should also be included. • E3MG - the new version will expand regional classification to include Indonesia and also split up the rest of the world. The forestry sector will be separated, and the cost curves will be incorporated to enable modelling reduction of emissions from deforestation and forest degradation (REDD).
Description:	*Include: What the model is used for, how often.* *E3ME* - its main purpose is to assess the impact of environmental policy over the long term for the detailed sectors in each member state. • socio-economic development - it is used for scenario analysis at macro and sectoral economic level e.g. to assess detailed economic impacts (including impacts on international competitiveness and on the labour market) of R&D spending • more focused analysis of policies relating to greenhouse gas mitigation e.g. to assess detailed energy, environmental and economic impacts of energy and carbon taxation and the emission trading scheme • assessing incentives for industrial energy efficiency e.g. the impacts of extra investment in new technologies • analysing sustainable household

[51]http://www.cambridgeeconometrics.com/ModellingTraining/suite_economic_models/E3ME/recent_developments.aspx

	consumption – for example to assess impacts of raw material taxation on household consumption patterns and other economic variables.[52] *How key assumptions affect results.* • E3ME and E3MG: E3ME is usually calibrated to match a set of projections that is published by the European Commission. The scenarios represent alternative versions of the future based on a different set of inputs. By comparing the outcomes to the baseline (usually in percentage terms), the effects of the initial shock can be determined.[53] The model (E3ME and E3MG) elasticities are estimated on historical data sets, so a return to pre-recession behaviour is implicitly assumed. A dummy variable for 2009 is included in the model to pick up the worst effects of the recession. *Linkages with other tools* • E3ME include two baselines that are calibrated to match the results from the PRIMES (2009) baseline and reference case model runs that are published by the European Commission. There are several other examples where E3ME or E3MG results have been used in other models, usually for EC research projects. The ETM used in both models has been incorporated (i.e. a hard linkage) in the code. Various other soft (data) linkages have been used for projects: - E3ME - to the SCENES transport model in the Tipmac project (two-way) - E3ME - to IER's labour market model (one-way from E3ME) - E3MG - to the CIAS software to create an IAM (two-way I think) - E3MG - to IIASA's Globiom forestry model (two-way, via cost curves) *Details of validation exercises –* • E3ME - a carbon tax scenario was set up to test the properties of the new version of the

[52] CE report: Pollitt, H, Chewpreecha, U (March 2009): Revision of the IA Tools Model Inventory

[53] http://www.camecon.com/ModellingTraining/suite_economic_models/E3ME/purpose_and_design.aspx

	E3ME model, assess the effects of the tax in the model and identify errors or modelling issues[54]. *Information on policy exercises -* • E3ME - some examples of its application are as follows: - Impact Assessments of changes to the European Emission Trading Scheme (ETS) and Energy Taxation Directive - labour-market forecasting - an assessment of the economic effects of 1990s environmental tax reform in Europe and of future tax reforms - predicting future ETS carbon prices - analysis of the impacts of increasing R&D spending • The Cambridge Centre for Climate Change Mitigation Research (4CMR), University of Cambridge, has recently used E3ME in two major research projects.[55] • Ex- post quantification of the effects and costs of policies and measures on greenhouse gas emissions European Commission (DG Climate Action), Sustainability scenarios for a resource efficient Europe (European Commission - DG Environment).[56] • E3MG - Model application for post-2012 regime - global policies and EU-27 action (European Commission, DG Environment) • MDM-E3: examples of work that use this model[57] - Evaluating the impact of the Economic recession on UK carbon budgets (Committee on Climate Change). - Projecting CO2 emissions and assessing the economic impacts of carbon budgets (CCC) - Macroeconomic Rebound Effect of Energy Efficiency Policies in the UK Economy (UK Department for Environment, Food and Rural Affairs)

[54] CE working paper (April 2009): Extending the E3ME model to 2050: an introduction to E3ME, version 4.7

[55] http://www.landecon.cam.ac.uk/research/eeprg/4cmr/research/adam.htm and http://www.landecon.cam.ac.uk/research/eeprg/4cmr/research/pastprojects.htm#omega

[56] http://94.76.226.154/Home/ConsultancyCapability/European_sectoral_analysis.aspx

[57] http://www.camecon.com/ModellingTraining/suite_economic_models/MDM-E3/MDM-E3_overview.aspx

	Treatment of structural change and how it affects results. • E3ME and E3MG: structural changes between sectors can be seen in the form of one sector growing while another shrinks are fully incorporated in the models. However, structural changes cannot be included within each sector. In history the models have dummy variables for the most obvious examples of where there are sudden shocks (also the formation of the EU single market), otherwise the parameters of the equations will be biased. The model cannot deal with structural breaks within each sector in the forecast on its own. If necessary, exogenous judgments are made, but these model results reflect the assumptions made rather than the model's own results.

Model name and version:	POLES
Operator:	European Commission - Joint Research Centre's Institute for Prospective Technology Studies (JRC IPTS) (jointly developed by EPE LEPii-CNRS, IPTS, Enerdata)
Published documentation:	• Russ P, Wiesenthal T, Regemorter D.V, Ciscar, Jaun Carlos: Global Climate Policy Scenarios for 2030 and beyond: analysis of greenhouse gas emission reduction pathway scenarios with the POLES and GEM-E3 models; JRC reference reports • Schade B, Wiesenthal T, Comparisons of Long-Term World Energy Studies: assumptions and results from four world energy models, JRC scientific and technical reports • Poles: Prospective Outlook on Long- Term Energy Systems – http://webu2.upmf-grenoble.fr/iepe/textes/POLES8p_01.pdf • POLES model: A World Energy Model - http://www.eie.gov.tr/turkce/en_tasarrufu/uetm/twinning/sunular/hafta_02/5_POLES_description.pdf

Scope (general/partial):		• Poles is a partial equilibrium model for the world energy system with endogenous international prices, based on lagged adjustments of supply and demand by region[58].
Dimensions:	Geographical	• Constructed at world level - 65 world regions, sub regions and countries (including the G7, European Union, Mexico, Brazil, India, China and South Korea).
	Sectoral	• 15 energy demand sectors, where each region is modelled using four modules[59] - Final energy demand by sector - New and renewable energy technologies - Conventional energy and transformation system - Primary energy supply • Supply side: 40 energy generation technologies, of which 30 are power generation technologies (including renewables), and 10 are hydrogen production technologies.
	Temporal	• Historic years from 2000-08, with yearly simulations covering period up to 2050.
Exogenous inputs:		• Population, economic growth in different regions of the world, availability of oil and gas resources are treated exogenously by POLES[60].
Other key assumptions:		
Specification of technology:		• POLES uses endogenous learning curves, where costs decrease along with the cumulative installed capacities.[61]
Treatment of uncertainty:		
Proposed future developments:		

[58] http://www.enerdata.net/enerdatauk/solutions/energy-models/poles-model.php

[59] EnerFuture - Global projections on energy demand and CO2 emissions; Enerdata

[60] http://www.enerdata.net/docssales/press-office-20th-world-energy-congress.pdf

[61] EnerFuture: Global energy & carbon forecasting service; Enerdata

Description:	*Include: What the model is used for, how often.* • The model is used to assess the impacts of economic growth, energy and climate change policy implementation, and new technology on global energy systems. It is used in various projects by the national and international organisations (European Commission, WEC, French Ministries), and major private actors in the energy sector.[62] *How key assumptions affect results.* • The baseline scenario shows that the effects of recession will be short term and not persist in the long run. Therefore, the economy will quickly recover and return to its pre-crises level.[63] *Linkages with other tools.* • World Energy Council (WEC) scenarios use the assumptions and parameters of POLES baseline scenario defined for the 2008 WETO-H2 study.[64] • The baseline of the GEM-E3 model is calibrated to the POLES baseline for growth of GDP and CO2 emissions.[65] *Details of validation exercises.* • The POLES baseline scenario is used to create long-term Marginal Abatement Cost Curves, which reflect the responses of the energy model (in the form of emission reductions achieved) to various carbon prices for each country and sector.[66] • A comparison of the POLES reference case scenario with the International Energy Agency (IEA reference scenario) and the US department of Energy (US-DoE reference case) indicate consistency of the outlook.[67] *Information on policy exercises.*

[62] EnerFuture: Global projections on energy demand and CO2 emissions; Enerdata

[63] EnerFuture: Global energy & carbon forecasting service; Enerdata

[64] http://www.enerdata.net/docssales/press-office-20th-world-energy-congress.pdf

[65] Russ P, Wiesenthal T, Regemorter D.V, Ciscar, Jaun Carlos: Global Climate Policy Scenarios for 2030 and beyond: analysis of greenhouse gas emission reduction pathway scenarios with the POLES and GEM-E3 models; JRC reference reports

[66] EnerFuture MACCs: the unique online service providing Marginal Abatement Cost Curves; Enerdata

[67] Schade B, Wiesenthal T, Comparisons of Long-Term World Energy Studies: assumptions and results from four world energy models, JRC scientific and technical reports

	• It is used to generate global energy scenarios e.g the WETO-H_2 study (EC, 2006) which aimed at developing a reference projection of the world system to test different scenarios for technologies and climate policies up to 2050[68] and World Energy Technology and Climate change policy (WETO) – by EC: 2003. • An evaluation of the diffusion of energy technologies (including renewable, nuclear, WETO 2030 and WETO 2050 projects) was carried out using the POLES model.[69] • Research on energy and climate policy with the POLES model - http://webu2.upmf-grenoble.fr/iepe/Recherche/Recha5.html - the link lists the research work energy and climate policy with POLES model but the links for the publications don't work. *Treatment of structural change and how it affects results.*

Model name and version:	PRIMES Version 4[70]
Operator:	Modelling Laboratory at National Technical University of Athens, Greece
Published documentation:	http://www.e3mlab.ntua.gr/manuals/PRIMsd.pdf http://www.e3mlab.ntua.gr/manuals/PRIMREFM.pdf http://www.e3mlab.ntua.gr/e3mlab/presentations/Capros-E3MLab%20Models.pdf
Scope (general/partial):	It is a parial model. It is modular and allows either for a unified model use or for partial use of modules to support specific energy studies. It is market-oriented: market equilibrium prices drive energy balancing of demand and supply per energy commodity.

[68] http://ec.europa.eu/research/energy/pdf/weto-h2_en.pdf

[69] http://www.enerdata.net/enerdatauk/energy-advisory/forecasting/technologies-forecast.php

[70] See page 73 of http://www.euplastvoltage.eu/uploads/downloads/procedures-and-targets.pdf

Dimensions:	Geographical	35 countries, including the EU27[71]
	Sectoral	*Demand:* - 12 industrial sectors, subdivided into 26 sub-sectors using energy in 12 generic processes - 5 tertiary sectors, using energy in 6 processes - 4 dwelling types using energy in 5 processes and 12 types of electrical durable goods - 4 transport modes, 10 transport means and 10 vehicle technologies *Supply:* - Electricity (148 different plant types per country for the existing thermal plant types; 678 different plant types per country for the new thermal plants; 3 different plant types per country for the existing reservoir plants; 30 different plant types per country for the existing intermittent plants. Chronological load curves, interconnections, network representation; three typical companies per country; Cogeneration of power and steam, district heating) - Refineries: 4 refineries with typical refinery structure defined at the level of country regions; 6 refining unites in each region - Natural Gas
	Temporal	2000 to 2050 by five-year periods. Model results fully calibrated to Eurostat data for the period 1990 to 2005. Projections start from 2010. The equilibrium is static (within each time period) but repeated in a time-forward path, with dynamic relationships.
	Other	- 14 fossil fuel types, new fuel carriers (hydrogen, biofuels) 10 renewable energy types - 7 types of emissions from energy processes
Exogenous inputs:		- Cost-supply curves that are exogenously specified - Some taxation for the environment can be exogenously given (in which case the emissions

[71] See: http://www.e3mlab.ntua.gr/e3mlab/index.php?option=com_content&view=category&id=35%3Aprimes&Itemid=80&layout=default&lang=en

	are not explicitly limited) - Economic activities (GDP, demographics, exchange and interest rates; activity by sector (18 sectors), income of households, transport activity flows) are exogenous - Decommissioning of an old plant is exogenous - Known power plant investments in the future can be introduced exogenously in the model
Other key assumptions:	- Producers and consumers both respond to changes in price - To reflect future technologies, it is assumed that new plant technologies will become available at different points in time (exogenous parameter) - The fuel shares, for each end-use in which there is substitution between fuels, are assumed to represent fuel choice frequencies - The behaviour of economic agents is assumed to involve myopic anticipations - Activity variables related to generation, trade and sales are generally treated as time series, except some of the parameters that are assumed invariant with time.
Specification of technology:	- Parameters and formulations are built in to represent non-economic factors that affect the velocity of new technology penetration. - The PRIMES model incorporates induced technology change (higher profitability of a new technology implies more acceptance at consumer level further inducing lower technology supply costs) in the demand-side of the model. - A major focus of the model is to represent different technologies that are now available or will be available in the future. The model is intended to also serve for strategic analyses on technology assessment. To support such analyses, the model uses a large list of alternative technologies and differentiates their technical-economic characteristics according to the plant size, the fuel types, the cogeneration techniques, the country and the type of producer. A model extension is also designed aiming at representing a non-linear cycle of the penetration of new technologies, for which learning through experience (and other industrial economic features) relates penetration with the technology performance.

Treatment of uncertainty:	It is a complex model, mainly limited to scenario analysis. It is difficult to understand the sensitivities/uncertainties of the model.[72]
Proposed future developments:	Satellite models of PRIMES include: - Prometheus world energy markets and system model - Biomass supply -biorefineries - Hydrogen economy - Detailed PRIMES-TREMOVE Transport model
Description:	*Include: What the model is used for, how often.* PRIMES is a general purpose model. It is conceived for forecasting, scenario construction and policy impact analysis. It covers a medium to long-term horizon. It is modular and allows either for a unified model use or for partial use of modules to support specific energy studies. The model can support policy analysis in the following fields: - standard energy policy issues: security of supply, strategy, costs etc - environmental issues - pricing policy, taxation, standards on technologies - new technologies and renewable sources - energy efficiency in the demand-side - alternative fuels - energy trade and EU energy provision - conversion decentralisation, electricity market liberalisation - policy issues regarding electricity generation, gas distribution and refineries. *How key assumptions affect results.* Policies and measures, the world energy markets, technology and the economy are exogenous and influence behaviours and market equilibrium Policies such as taxes and subsidies, promotion of new technologies (reducing perceived costs) and promotion of energy efficiency(including standards) influence the following decisions by the agents:

[72] See: http://www.ec4macs.eu/home/Methodology_Review_Workshop_1009/Comments_on_Primes051009.pdf

	- choice of equipment (vintages, technologies and learning) - investment in energy efficiency (savings) - purchase of associated energy carriers and fuels *Linkages with other tools.* - The economy system is exogenous and linked with/from GEM-E3 - Transport Activities and flows linked with/from SCENES and TRANSTOOLS - World energy (oil, gas and coal) prices linked with/from POLES and Prometheus - EU power plants linked/from Platts Power; Technologies (TechPol,VGB), EU refineries linked with/from IFP; Renewables potential ECN linked with/from Observer; Energy efficiency Wuppertal linked with/from ODYSEE and MURE databases - Air Quality and non CO2GHG emissions linked with/to IIASA and GAINS *Details of validation exercises.* n/a *Information on policy exercises.* Policies represented are: - Taxes, subsidies, Tradable Permits or certificates - Technology supporting policies - Environmental policy instruments *Treatment of structural change and how it affects results.* The price-setting mechanism (Ramsey-Boiteux pricing) reflects the design considerations for the market clearing regimes. The value of parameters in these cost-pricing modules can be altered, in policy scenarios, to reflect structural change.

Model name and version:	World Energy Model (WEM) Version 14
Operator:	International Energy Agency (IEA)
Published documentation:	http://www.worldenergyoutlook.org/docs/weo2010/World_Energy_Model.pdf http://www.worldenergyoutlook.org/docs/weo2007/WEM-ECO_Description.pdf
Scope (general/partial):	WEM is a large scale mathematical partial equilibrium model, which is used to explain the functioning of energy markets[73].
Dimensions: Geographical	- 24 country/regions, with a special focus on the Caspian region in the latest version of the WEM[74]
Sectoral	- It has 6 main modules[75]: 1. Final energy demand: It is a function of activity variables (GDP or GDP per capita), end-user prices and other variables accounting for structural and technological changes. It is calculated by multiplying energy intensity with activity variables. It consists of the following sub-sectors: - 5 industrial sub-sectors - Residential energy demand divided into 5 end-uses by fuel (space heating, water heating, cooking, lighting, appliances) - Services demand - Transport demand modelled by mode (road, aviation, biofuels) and fuel Each sub-sector has 6 fuel types (coal, oil, gas, electricity, heat and renewables). Oil products are modelled separately and used as an input in the refinery module. 2. Power generation: - This module calculates electricity generation, electricity demand, costs of baseload technologies

[73] See http://www.worldenergyoutlook.org/docs/weo2007/WEM-ECO_Description.pdf

[74] See Appendix 2 for regional definitions - http://www.worldenergyoutlook.org/docs/weo2010/World_Energy_Model.pdf

[75] See page 8 - http://www.worldenergyoutlook.org/docs/weo2010/World_Energy_Model.pdf

	- The model incorporates supply curves for 16 renewable technologies for each region 3. Refinery and other transformation 4. Fossil fuel supply 5. CO2 emissions 6. Investment
Temporal	- The historic period for WEM is 1970-2008. It also includes 2009 data where available. The projection period runs to 2035
Other	- WEM 2010 now includes improved modules relating to oil-supply and renewable based electricity generation as well as the freight module of the transport[76]. - It also includes a better developed Universal Modern Energy Access module, which consists of detailed data on rural and urban electrification[77] - Biomass fuel model was improved in WEM 2010 and the biomass price was included in the residential and services sub-sector.
Exogenous inputs:	- The key exogenous inputs of WEM are as follows[78]: • Economic growth - in the short and medium term, these assumptions are based on OECD, IMF and World Bank calculations. An annual long-term rate is determined based on changes in demographic and productivity trends, macroeconomic conditions and technology. In long-term, the growth rates for each region are expected to converge to this annual long-term rate. • Demographics - the rate of growth in population is based on the medium-fertility variant projections provided in United Nations Population Division report (world population

[76] See http://www.worldenergyoutlook.org/model.asp

[77] See http://www.worldenergyoutlook.org/database_electricity10/electricity_database_web_2010.htm

[78] See http://www.worldenergyoutlook.org/docs/weo2010/World_Energy_Model.pdf

	prospects: 2008 revision), and combined with world urbanization prospects to get estimates of rural/urban split for each region. • International fossil fuel prices - these assumptions are used to derive end-use prices for each fuel, which are in turn used in final energy demand, power generation and other transformation sectors[79]. • Technological developments
Other key assumptions:	- Capital cost assumptions include the impact of primary materials and increase in commodity prices in each region. - In the Fossil fuel supply module, a set of economic assumptions are used to determine the level of oil production economic assumptions related to discount rates and price thresholds used in the economic analysis of potential projects, drilling costs, rate of re-investment of industry cash flows and share of exploration in total investments.
Specification of technology:	- Technology is treated endogenously in the model: • In the renewables module, the model uses dynamic cost- resource curves, which are based on an assessment of potential and actual costs from each renewable energy source. Financial parameters are built in to represent the impact on cost of producing electricity from various generating technologies. The generation costs are also based on technological learning rates. This means that an increase in the production and sale of new technology will lead to a decrease in price. For specific technologies, these learning rates are assumed every decade[80]. • The renewable module within WEM

[79] See page 6 - http://www.worldenergyoutlook.org/docs/weo2010/World_Energy_Model.pdf

[80] See Page 15 and 16 - http://www.worldenergyoutlook.org/docs/weo2010/World_Energy_Model.pdf

	now includes an endogenous estimate of subsidies to renewables. For each country, the model accounts for feed-in- tariffs by technology and calculates the impact of renewable subsidies on end-user electricity prices[81].
Treatment of uncertainty:	- Due to uncertainties relating to changing government policies, WEM provides 3 different scenarios[82]. • The baseline scenario ('current policy scenario') consists of projections based on those policies which are already implemented by the government. • The 'new policy scenario' projections are based on the inclusion of announced policies, plans and pledges that have not yet been implemented. • The 450 scenario sets the ideal energy trajectory required to prevent the average global temperature to increase to 2 degree Celsius.
Proposed future developments:	
Description:	*Include: What the model is used for, how often.* - WEM is used to provide projections by sector and region for various scenarios. It has three main scenarios (New policy, Current policy and 450 scenarios), which are used to observe future energy trends.[83] - WEM is used to analyse the impact of policy and technology changes on energy demand, supply, trade, investments, and emissions, in particular the development and diffusion of less carbon-intensive technologies[84]. - It provides analysis of global energy prospects by sector and fuel, which includes trends in demand, availability

[81] See http://www.worldenergyoutlook.org/docs/weo2010/World_Energy_Model.pdf

[82] See http://www.worldenergyoutlook.org/docs/weo2010/World_Energy_Model.pdf

[83] See http://www.worldenergyoutlook.org/model.asp

[84] See http://www.worldenergyoutlook.org/docs/weo2010/World_Energy_Model.pdf

	of supply and constraints, international trade and energy balances. - It is used to estimate the investment in the energy sector - It also helps to estimate the impact of energy use on environment. *How key assumptions affect results.* - The policies and measures included in the WEM are exogenous and influence behaviour. - For each sub- sector, the policy variable included in the energy demand equation represents the impact of policies and measures that reduce energy intensity, promote energy efficiency as well as fuel switching in favour of low carbon intensive fuels. *Linkages with other tools.* - In World Energy Outlook (2007), the model was integrated with a general equilibrium model (GEM) called WEM-ECO to assess economic and trade issues related with different energy policies and scenarios[85]. *Details of validation exercises.* *Information on policy exercises.* - It uses 3600 energy-related policies and measures in OECD and non-OECD countries to analyse their impact on energy demand, trade, investment, supply costs and emissions[86]. *Treatment of structural change and how it affects results.* - The fuel shares for each end-use and energy-intensity are used in combination with output levels for each sub-sector (modelled separately) to calculate energy consumption from the fuel sources. The energy intensity variable is linked to the average end-use energy prices. Therefore, the value of these parameters helps to analyse the impact of structural changes on energy

[85] http://www.worldenergyoutlook.org/docs/weo2008/WEM-ECO_Methodology.pdf

[86] See policy database - http://www.iea.org/textbase/pm/?mode=weo

	consumption trends.

Model name and version:	Med – Pro Environment
Operator:	Enerdata
Published documentation:	• EnerData website: http://www.enerdata.net/enerdatauk/energy-advisory/forecasting/demand-forecast.php
Scope (general/partial):	• It is a national energy demand forecasting model. It provides partial equilibrium analysis and follows a bottom up approach.
Dimensions: Geographical	• Used for 50 countries[87]
Sectoral	• Disaggregated into sectors: Power sector, industry, transport, residential, services, agriculture, other[88] • Provides a detailed account of consumption usage[89]
Temporal	• Historic years from 2000-08, yearly simulations covering period up to 2050.
Other	• It is the same as the Enerdata's generic model called MEDEE which is a sectoral end-use type model)
Exogenous inputs:	
Other key assumptions:	
Specification of technology:	
Treatment of uncertainty:	

[87] http://www.enerdata.net/enerdatauk/energy-advisory/forecasting/demand-forecast.php

[88] EnerFuture - Global projections on energy demand and CO2 emissions; Enerdata

[89] http://www.enerdata.net/enerdatauk/energy-advisory/forecasting/demand-forecast.php

Proposed future developments:	Planning to standardise the model
Description:	*Include: What the model is used for, how often.* • MedPro's baseline scenario is used to assess the impact of the development of current socio-economic factors such as GDP, value added, population, equity ratio, employment, etc as well as the recent GHG mitigation policies. • It also uses the baseline scenario to evaluate the changes due to energy efficiency, energy substitutions and GHG mitigation policies. • It also forecasts electricity load curves and GHG. *Linkages with other tools.* • The POLES model was used jointly with the MEDPRO energy-demand and environmental model to produce a medium term (2030) energy scenario for France, in a project called 'Emission reduction scenario for France' (2003-04)[90] *Details of validation exercises.* *Information on policy exercises.* *Treatment of structural change and how it affects results.*

[90] Chewpreecha, U, Pollitt, H (March 2009): Revisions to the IA TOOLS Model Inventory