Chapter 5: Reducing emissions from transport

Introduction and key messages

In 2012 domestic transport CO_2 accounted for 20% (116 $MtCO_2$) of UK emissions covered by carbon budgets.

In our original 2010 advice on the fourth carbon budget we proposed a scenario in which domestic transport emissions were reduced by 24% by 2025 relative to 1990 levels, and 34% by 2030, based on improving efficiency of conventional vehicles, a shift to ultra-low emissions vehicles (e.g. plug-in hybrid electric vehicles) and some moderation of demand growth. This was our best estimate of the cost-effective path to the UK's target of an 80% emissions reduction by 2050, involving those measures that were cost-effective compared to our carbon price assumptions and/or required to prepare for meeting the statutory 2050 target.

In this chapter we set out new evidence on transport emissions and abatement options and update our assessment of abatement potential accordingly. Specific changes in the evidence base include: new emissions projections produced by DfT; updated projections for the costs of all vehicle types; analysis we have commissioned on consumer barriers to take-up of electric vehicles.

Our updated scenario leads to slightly greater reductions in emissions in the fourth carbon budget period (to 82 $MtCO_2$ in 2025, a 31% reduction compared to 1990 levels). Relative to a path with no progress during the 2020s, this scenario offers a saving of £30-35 billion in present value terms under central case assumptions for fossil fuel and carbon prices.

This reflects the specific conclusions from our new analysis:

- Demand growth has been slightly slower than we expected as the economic slowdown continues to affect travel demand. The latest baseline emissions projections reflect this and have been revised down by 13% in 2030 relative to assumptions in our original advice.
- There is considerable scope for improving conventional vehicle efficiency in cars, to 110 gCO_2/km in 2020 and to 80 gCO_2/km in 2030, as we assumed in our original advice. Recent progress in this area has been strong, and an agreement to limit emissions from all new cars to 95 gCO_2/km by 2021 (95% of cars by 2020), has recently been reached at EU level (to be ratified by the EU Parliament and Member States).
- It remains appropriate to aim for a significant penetration (e.g. 60% of new car purchases) of plug-in hybrid vehicles (PHEVs), battery electric vehicles (BEVs) and hydrogen fuel cell vehicles (HFCVs) by 2030. Our new analysis gives us more confidence that this can be delivered, albeit with a slightly slower trajectory relative to our previous assessment, reflecting projected production capacity.

- There is scope for some use of biofuels in surface transport but, given continued uncertainty over sustainability issues and technologies for advanced biofuels, we continue to limit the take-up of biofuels in the 2020s to a level indicated by the Gallagher Review[1] of between 5-8% by energy in 2020.
- It continues to be appropriate to include cost-effective abatement from measures aimed at reducing demand through eco-driving, modal shift and streamlining freight operations. Together, these measures offer emissions reductions of around 4.5 $MtCO_2$ in 2030.

We set out the analysis underpinning these conclusions in five sections:

1. Current emissions
2. Latest projections for emissions before abatement action
3. Updated evidence on abatement options and cost
4. Projected emissions with abatement – an updated scenario for the 2020s
5. Benefits of delivering the measures in the fourth budget period

1. Current emissions

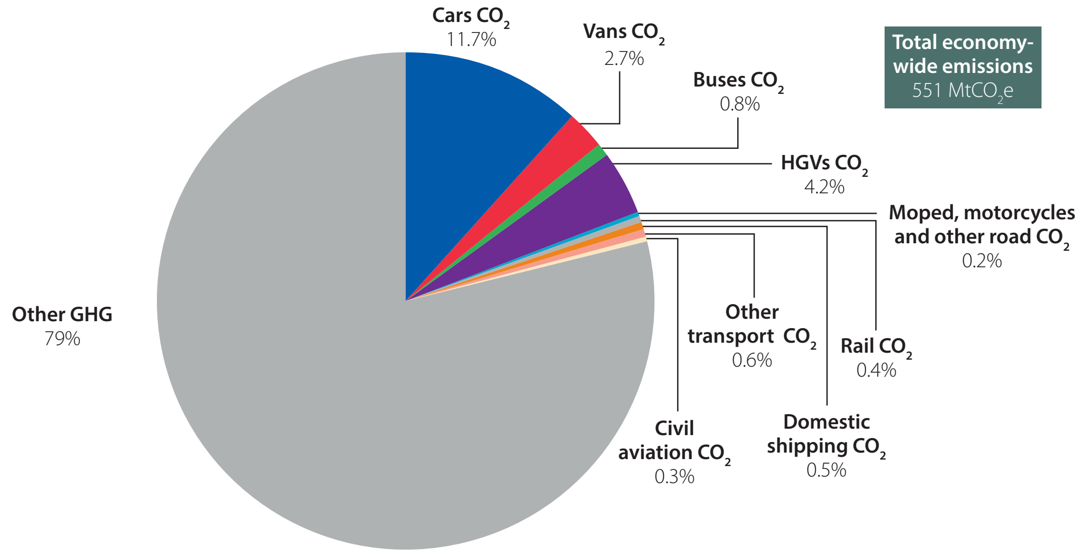
Domestic transport CO_2 emissions were 116 $MtCO_2$ in 2012, down from 117 $MtCO_2$ in 2011, and accounting for 20% of total UK GHG emissions covered by carbon budgets. A breakdown of emissions by mode is not yet available for 2012. However in 2011 (Figure 5.1):

- **Surface transport** emissions were 110 $MtCO_2$. Cars accounted for the majority of these emissions (59%), followed by HGVs (21%), vans (14%), buses (4%), mopeds and motorcycles (0.5%); rail accounted for the remaining 2%.
- **Domestic aviation and shipping** emissions were 4.2 $MtCO_2$ in total.
- **Other** domestic transport emissions were 3.2 $MtCO_2$.

Emissions from international aviation and shipping were 42.5 $MtCO_2$ in 2011. These are not currently included in carbon budgets, but are covered by the UK's 2050 target to reduce emissions by 80% relative to 1990.

1 Gallagher (2008) *The Gallagher review of the indirect effects of biofuels production.*

Figure 5.1: Emissions from transport (2011)



Source: NAEI (2013).
Notes: 'Other road' includes motorcycles and mopeds, liquefied petroleum gas emissions (all vehicles), and other road vehicle engines. 'Other transport' includes military aircraft and shipping and aircraft support vehicles.

Given transport's high share of total emissions and the availability of options to reduce and possibly eliminate emissions, we concluded in our original fourth budget advice that the aim should be to significantly reduce transport emissions to 2030 and keep open the option to fully decarbonise surface transport by 2050.

We now consider the latest evidence on projected emissions and options to reduce these, and then set out an updated assessment of abatement to 2030 in section 4.

2. Latest projections for emissions before abatement action

Our starting point when developing a trajectory to meet our longer-term targets is to assess demand and emissions projections without any action to reduce emissions. To develop this 'baseline', we use road travel demand projections from DfT's National Transport Model (NTM). This allows for changing fossil fuel prices, economic growth and demographics.

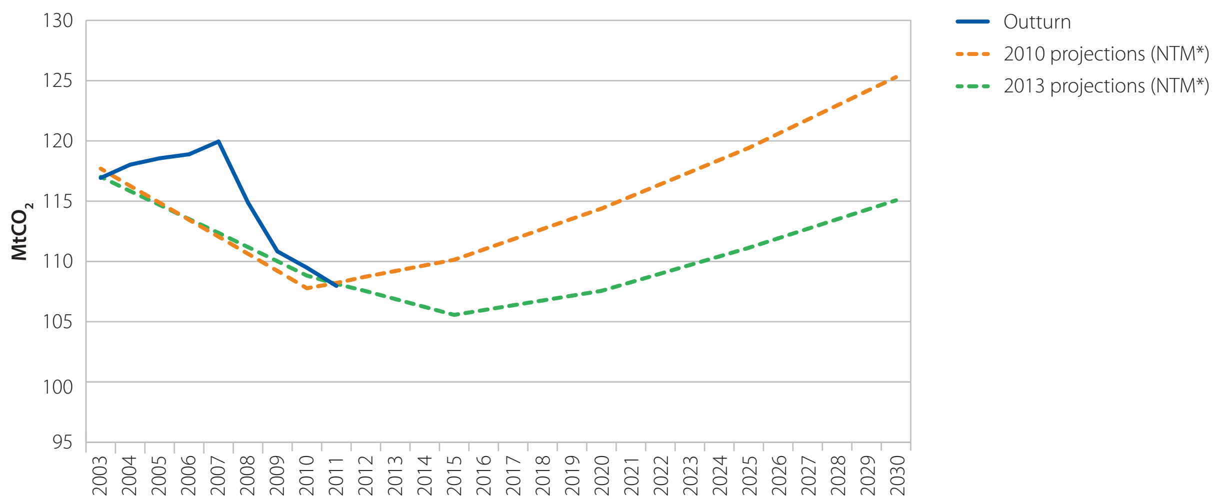
Since our original advice, assumptions for the drivers of travel demand have changed, with slower expected economic growth and a higher projection for the oil price (see Chapter 1). As a result, the NTM now projects lower baseline growth in travel demand for cars and vans, with growth of 13% in car vehicle-kms (previously 18%) and 49% in van vehicle-kms (previously 59%), but slightly higher growth in HGV vehicle-kms (9% versus 7% previously) between 2010 and 2030.

To project emissions, these increases in travel demand are combined with modelled carbon intensities (which are a function of vehicle efficiencies at different speeds, and carbon content of fuels used). Since our original advice, there have been some updates to the assumptions for vehicle efficiencies used in the baseline, reflecting the latest evidence. Greater improvements in vehicle efficiency between 2010 and 2030 are assumed for cars (13% compared to 9% previously) and vans (13% compared to no improvement previously), while smaller improvements are assumed for HGVs (2% compared to 7% previously).

Given these assumptions, the NTM projects growth in road transport emissions of 6% (previously 16%) between 2010 and 2030 in the absence of any abatement policies (Figure 5.2).

However, as we set out in section 4 below, policies to which the Government have already committed will reduce emissions below this level by 2020 and options exist to continue emissions reductions through the 2020s. We now turn to these options.

Figure 5.2: UK road transport emissions, outturn and baseline projections (2003-2030)



Source: NAEI (2013), NTM for CCC (2010, 2013), CCC estimates.
Notes: *Includes projected car, van, HGV and PSV emissions from the NTM plus CCC estimates of emissions from other road transport modes not covered by the NTM, based on their historic share. The NTM projects emissions from a base year of 2003, at five-yearly intervals starting in 2010; intermediate years have been interpolated.

3. Updated evidence on abatement options and costs

In our original advice on the fourth carbon budget we set out detailed assessments of the options for reducing emissions from surface transport. Since then, we have reassessed their costs and potential for deployment. This section sets out that updated evidence.

There is scope for significant reduction in surface transport emissions over the next two decades and beyond, through a range of measures relating to technology and behaviour change. The majority of these measures are either negative cost, or are likely to become cost-effective compared to the projected carbon price over this period. They include:

- Improvements in conventional vehicle efficiency, for example through increased hybridisation, downsizing of engines with turbocharging and use of advanced lightweight materials.
- Uptake of ultra-low emission vehicles, including battery electric, plug-in hybrid and hydrogen fuel cell vehicles.
- Penetration of biofuels, provided these offer emissions reductions on a lifecycle basis, and meet other sustainability criteria.
- Roll-out of Smarter Choices programmes, which aim to reduce car trips through encouraging modal shift, car sharing, remote working etc.
- Uptake of eco-driving, a more efficient driving style which maximises fuel efficiency through more gradual acceleration and braking etc.
- Enforcement of the speed limit on motorways, which helps to improve fuel efficiency.
- Improvements in freight operations to reduce mileage from HGVs for a given amount of haulage.

Additional options which we have identified but not previously incorporated in our scenarios for meeting carbon budgets include road pricing, electrification of rail, reduction of the speed limit on motorways and use of natural gas in HGVs.

In domestic shipping, since 2010 we have published detailed evidence on potential for reducing UK shipping emissions[2]. We have updated our scenarios to take account of the latest evidence and policy developments (see section 4).

Improvements in conventional vehicle efficiency

New evidence on potential to improve conventional vehicle efficiency generally reinforces our previous conclusion that significant improvement is feasible and desirable:

- New car and van efficiency has continued to improve in recent years, largely a result of EU legislation which sets targets for the average emission of new cars and vans sold. As set out in our 2013 progress report, average new car CO_2 in the UK fell by 3.6% to 133 gCO_2/km in 2012, while new van CO_2 fell by 4.9% to 188 gCO_2/km.

2 CCC (2011) *Review of UK Shipping Emissions*, CCC (2012) *Scope of carbon budgets: Statutory advice on inclusion of international aviation and shipping.*

- In 2012, we commissioned AEA Technology to review the potential and costs of increasing vehicle efficiency[3]. This analysis confirmed previous estimates that by 2030 average test-cycle emissions from conventional new vehicles could reach 80 gCO_2/km for cars, 120 gCO_2/km for vans and around 600 g/km for HGVs (410–665 gCO_2/km depending on size). Moreover, the analysis suggested that this could be achieved at lower cost than previously estimated (-£80/tCO_2 versus +£65/tCO_2 previously for cars, £-110/tCO_2 versus £-90/tCO_2 previously for vans and -£150/tCO_2 versus -£110/tCO_2 for HGVs).
- Subsequent work by Ricardo-AEA for the European Climate Foundation[4], building on their modelling for CCC, suggested that costs for light duty vehicles could be even lower (e.g. as a result of revised cost estimates for light-weighting), and that there may be scope for emissions to fall further in the long term. They set out a scenario in which increasing penetration of hybridised cars leads to average test cycle surface emissions of 60 g/km by 2030 required in the longer term.

These efficiency improvements could potentially make a useful contribution to meeting the fourth and subsequent carbon budgets. However there are limits to the emissions reductions available for conventional vehicles. New technologies will be required to achieve the deep cuts in transport emissions.

Take-up of ultra-low emission vehicles

Coupled with decarbonisation of power generation, battery electric and plug-in hybrid electric vehicles (BEVs and PHEVs) are very promising options for cutting surface transport emissions in the 2020s. The latest evidence on potential battery cost reductions and increased range confirms our previous finding that EVs can be a cost-effective option in the longer term (Box 5.1):

- Work we commissioned from Element Energy on battery costs, combined with analysis by Ricardo-AEA on wider vehicle efficiencies and costs, confirmed that by 2030, from an economic resource cost perspective, EVs would be a cost-effective abatement option against projected carbon prices.
- This would be true even for BEVs with a larger battery and range of 150 miles, compared to the 100 miles we assumed in our original advice on the fourth carbon budget[5].

In addition to cost-effectiveness, however, it is important to consider whether consumers will actually be prepared to adopt the new technology, particularly while it is still developing. For this review, we commissioned a consortium led by Element Energy to assess potential barriers to EV uptake and measures required to overcome them.

3 AEA Technology (2012) *A Review of the Efficiency and Cost Assumptions for Road Transport Vehicles to 2050.*
4 Cambridge Econometrics, Element Energy, Ricardo-AEA (2013) *Fuelling Europe's Future.*
5 At a higher carbon price (e.g. £220/tCO_2 as assumed in Government values for 2050) higher battery capacity would be economic, such that BEVs with a range of 320 km (200 miles) would be cost-effective, and cheaper than PHEVs.

This analysis showed that achieving a high uptake of EVs by 2030 is possible given a good supply of models, and a package of measures to address current financial and non-financial barriers. These could include battery leasing to reduce purchase price premiums, a modest national rapid charging network to complement overnight home/depot-based charging, marketing to improve consumer awareness and acceptance, and provision of financial and/or non-financial 'cost-equivalent' support (Box 5.2).

Box 5.1: Cost-effectiveness of EVs

For our 2012 advice on meeting the UK's 2050 emissions reduction target[7], we commissioned Element Energy to assess scope for reduction in EV battery costs. Element Energy concluded that there was scope for significant reduction, with the implication that both PHEVs and lower-range BEVs are likely to be cost-effective abatement options by 2030:

- Element Energy forecast that battery pack costs for BEV cars could fall from around $725/kWh currently to around $210/kWh by 2030, through improvements in energy densities and economies of scale. PHEV battery pack costs could fall to around $1,325/kWh currently to around $425/kWh by 2030.
- For a C/D segment BEV with a range of 240 km (150 miles), this implies a capital cost premium of £5000 relative to a comparable conventional vehicle. For a PHEV with a range of 30 km (20 miles), it implies a capital cost premium of £3500.
- However, electric cars are cheaper to run than conventional cars, given their significantly greater efficiency. We estimate a cost differential of around 2.4 pence/km for a C/D segment BEV car (1.9 pence/km for a PHEV), assuming EV charging takes place largely overnight using off-peak low-carbon generating capacity.
- The resulting abatement costs are £4/tCO_2 for new C/D segment BEV cars in 2030 and £-20/tCO_2 for new PHEVs, with ranges between £-115/tCO_2 to £+125/tCO_2 for BEVs and £-130 to £+90/tCO_2 for PHEVs depending on assumptions about technology costs, fossil fuel prices and time of day of charging (i.e. peak vs. off-peak).
- This compares to projected carbon prices over vehicle lifetimes of £130/tCO_2.

Looking beyond 2030, rising carbon prices would justify higher battery capacity, such that BEV cars with a longer range of 320 km (200 miles) would be cost-effective by 2050 (and cheaper than PHEVs facing a carbon price).

Energy system modelling for our previous advice on carbon budgets suggests that all cars and vans could need to be ultra-low emissions by 2050 as part of a cost-effective solution to meeting the UK's 80% emissions reduction target relative to 1990. Given stock turnover rates, this implies the need for significant penetration of ultra-low emissions vehicles (e.g. 60% of new sales) by 2030.

Source: Element Energy (2012) *Cost & Performance of EV Batteries*, CCC analysis

6 CCC (2012) *The 2050 target – achieving an 80% reduction including emissions from international aviation and shipping.*

Box 5.2: New evidence on EV uptake

We commissioned Element Energy, with Ecolane Consultancy and Dr Jillian Anable from the University of Aberdeen, to review our uptake scenarios for electric vehicles. The key findings were:

- Costs. Capital costs are likely to remain a key barrier to the uptake of electric vehicles in the period to 2030. The lower running costs of EVs are not sufficient to offset higher purchase costs over required consumer pay back periods (which are much shorter than vehicle lifetimes). However battery leasing could be used to spread the purchase cost premium of EVs.
- Supply. A good supply of EV models and brands across vehicle segments is key to delivering high uptake. Automotive manufacturer announcements on planned releases and production capacity give confidence that this is achievable by 2030. We scale back our assumption on EV uptake in the UK in 2020, however, to better reflect likely share of projected overall EU production.
- Consumer acceptability. Consumer awareness and acceptance of EVs is currently low. A well-designed marketing campaign, complemented with direct exposure to EVs (e.g. through test drives), is needed to ensure all consumers understand EV capabilities. The 'neighbour effect' should also reduce bias against EVs among some consumer segments, as the technology becomes more familiar with increased sales.
- Overnight charging. Certainty of access to charging is a pre-requisite for BEV purchase, and best delivered overnight at home/depot. 70% of vehicle buyers currently have access to off-street parking where this could take place.
- Public charging infrastructure. A public rapid charging network would offer a number of additional benefits: increases the proportion of fleet vehicles for which BEVs are range-compatible, addresses perceived need for public charging among private buyers and reduces minimum charging times which currently act as a barrier to EV deployment.

These interventions can help deliver a high uptake of EVs. Nevertheless, it is possible that 'cost-equivalent' support for EVs may be required to 2030. This could be financial (e.g. grants) and/or non-financial (e.g. preferential access to parking). We will return to policy options for EVs in our 2014 progress report to Parliament.

These findings reinforce our previous conclusion that with appropriate support, high levels of EV penetration can be achieved by 2030, keeping open the option of a near-zero emissions transport fleet by 2050.

Source: Element Energy et al (2013) *Pathways to high penetration of electric vehicles*

Role for hydrogen

New evidence points to greater potential for hydrogen fuel cell vehicles (HFCVs) in the period to 2030 than we assumed in our original advice on the fourth carbon budget:

- Work by Ricardo-AEA, for our 2012 advice on meeting the UK's 2050 emissions target, suggested HFCV costs could be lower than we previously estimated (e.g. around £125/tCO_2 rather than £220/tCO_2 for a medium car).
- Phase 1 of the H2Mobility project, a joint industry and government project to evaluate the potential role for hydrogen in road transport, identified potential early adopters among car and van drivers, and suggested feasible uptake of around 10% of new sales by 2030 (Box 5.3).
- The Element Energy analysis we commissioned for this report suggests a 10% market share of HFCVs in 2030 could make an overall share of 60% for ultra-low carbon cars and vans more achievable, though with caveats around vehicle supply and competition for infrastructure support.

Nevertheless, in the near term, HFCVs do not appear to be as promising as a *mass market* proposition as plug-in electric cars and vans, partly due to higher purchase prices and also because of the challenges relating to a full-scale infrastructure for low-carbon production, transportation and storage of hydrogen[7].

In the longer term, however, hydrogen vehicles could be useful as a complement to plug-in electric vehicles for the long-term decarbonisation of light vehicles. The Element Energy analysis we commissioned for this report suggests two areas where HFCVs could be particularly useful:

- For more demanding duty cycles where even longer-range BEVs may not be suitable.
- For new car buyers without access to off-street parking and hence readily available overnight charging.

In addition to cars and vans, we have previously recognised the potential in the longer term for hydrogen to reduce emissions from buses and HGVs, where battery electric vehicles may be unsuitable (e.g. due to size, weight and cost of the battery required), and if current significant challenges can be overcome (e.g. around hydrogen storage technology).

Meanwhile, there may be an opportunity to reduce emissions through use of natural gas in HGVs, depending on the source of the gas, and provided this does not 'lock out' the option of moving to hydrogen.

- A recent report for the Task Force on Fuel Efficient, Low Emission HGV Technologies[8] identified well-to-wheel (WTW) emissions reductions (relative to diesel) of up to 65% for vehicles using biogas, and between -11% and 16% for vehicles using gas from fossil sources. There may be further benefits in terms of air quality, as particulate emissions from gas-fuelled vehicles are lower than from diesel vehicles.
- Further work is required to assess the overall benefits of switching from diesel to gas in HGVs in the longer term (e.g. if barriers to hydrogen fuel cell vehicles cannot be overcome), given some residual gas demand is likely in 2050 and that biomethane is expected to remain a fraction of overall gas supply.

7 See for example Box 4.4 in CCC (2012) *The 2050 target – achieving an 80% reduction including emissions from international aviation and shipping.*
8 Ricardo-AEA (2012) Opportunities to overcome the barriers to uptake of low emission technologies for each commercial vehicle duty cycle.

Box 5.3: H2Mobility

H2Mobility is a collaborative project between car manufacturers, utility companies and government departments to assess the potential for hydrogen fuel cell vehicles (HFCVs) and to develop an industry roadmap. Findings from Phase 1 of the project were published in April 2013.

- The findings, based on OEM cost and supply data and consumer decision making suggest that annual sales of 300,000 per year or a 10% market share could be achieved by 2030 as vehicles become cost-competitive and the hydrogen refuelling network develops.
- The cost premium, supply of HFCVs and refuelling infrastructure were found to be the biggest barriers to uptake.
  - The purchase price premium of HFCVs relative to diesel is high in initial years but is forecast to decline to near parity by 2030 as global production volumes increase. The study assumes that hydrogen will be offered at a lower price than diesel so that by 2030, total costs of ownership over a four year period are equivalent.
  - The volume and diversity of HFCVs is expected to increase as consumer take-up grows. OEMs are likely to focus on the high mileage, premium market segment where BEVs are less attractive due to battery weight constraints and where consumers are less price-sensitive. HFCVs could also be well suited to vans, many of which require a long range and value the fast charging that H2 offers.
  - To achieve the level of uptake identified, a refuelling network comprising 65 stations in 2015 would need to be developed and expanded over time as demand grows, rising to 1,150 stations by 2030. This would give all the UK access to at least one hydrogen refuelling station within their local authority district and would require funding of £420 million before stations become self-financing.
- There are different methods of producing hydrogen with different implications for emissions savings. The mix of processes used in the project implied 60% CO_2 emissions savings in 2020 relative to diesel and 75% in 2030 on a well-to-wheel basis.

Source: UK H2 Mobility (2013) *Phase I results*

Scope for increased use of biofuels

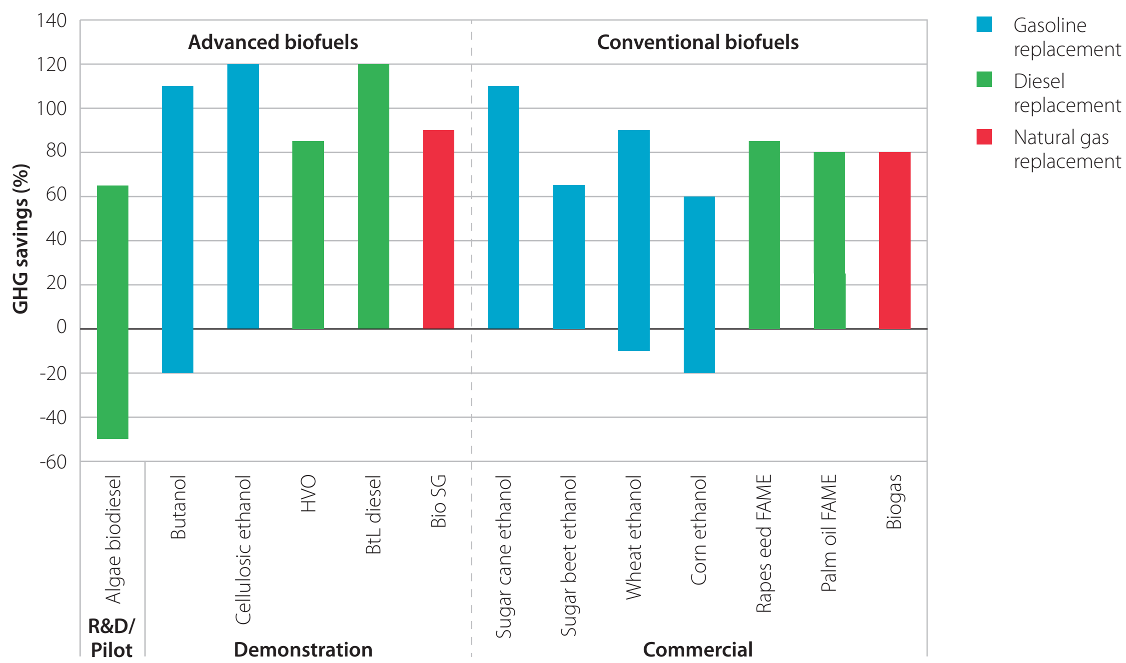
Since our original advice we have further investigated the potential of bioenergy to contribute to carbon budgets and the European Commission has clarified how biofuels will contribute to the EU's 2020 renewables targets:

- We considered feasibility and sustainability constraints on increasing biofuels use in more detail in our 2011 Bioenergy Review. We concluded that biofuels' role in transport should be limited in the long term, but that they could make important contributions during the transition, provided sustainability criteria are met.
  - Land constraints and competition with food are likely to limit the total available supply of sustainable bioenergy in the longer term. Biofuels available for transport are likely to be limited by competition with other sectors, particularly those with few alternatives for decarbonisation.
  - Calculations of emissions reductions from biofuels must consider land use change and be calculated on a lifecycle basis (Box 5.4). Advanced biofuels from wastes and residues offer greater lifetime savings but require significant investment to reduce costs. Reflecting this, the European Commission recently proposed to restrict the contribution of first generation biofuels in transport to 6% with advanced biofuels representing at least 2.5% by 2020.

Box 5.4: Biofuels lifecycle emissions and land use change

Biofuels are counted as zero carbon at the point of combustion (as the carbon released equates to that taken up from the atmosphere during crop growth). However, lifecycle emissions occur in the supply chain of biofuel production through fertilisers used for growing crops, the transport of the crops/fuels, and processing of the fuel. Analysis for our Bioenergy Review suggests that these could significantly erode emissions savings (Figure B5.5).

Figure B5.4: Range of GHG savings of different biofuels compared to fossil fuel



Source: OECD/IEA (2011).
Notes: Exhibit based on 60 "well-to-wheel" lifecycle emissions studies and shows a large range for each biofuel. Excludes land use change emissions.

Bioenergy feedstocks can also lead to emissions released through land use. Land use change (LUC) emissions occur when a portion of land is diverted from other uses to the growing of biofuels. Indirect land use change (ILUC) occurs when the growth of bioenergy crops displaces an existing economic activity to new land which leads to additional emissions being released.

Taking account of these factors can further reduce GHG emissions savings associated with biofuels.

- The extent of direct LUC impact depends on the type of land and crop grown. Where land used for crops was formerly carbon-rich (e.g. tropical rainforest or grassland), resulting emissions can dwarf any savings from bioenergy replacing fossil fuels.
- ILUC emissions are harder to measure and result in a wide range of estimates. Wheat bioethanol can perform well due to the potential for co-products to be used in animal feed. Palm biodiesel can have very significant negative impacts where plantations replaced previously forested areas or peatland.

Source: CCC (2011) *Bioenergy Review*

While there is still considerable uncertainty surrounding biofuel potential, these considerations support our previous assumptions on availability of sustainable biofuels for surface transport that, in line with the Gallagher Review, biofuels could meet 8% by energy of transport liquid fuel demand in 2020.

Cost of biofuels

Biofuel costs are a function of production and feedstock costs and need to be considered relative to the cost of conventional petrol and diesel.

- Biofuel production costs vary by the conversion process used. Current processes such as fermentation and anaerobic digestion are mature technologies which are already widely deployed to produce biofuels at scale. Advanced technologies are currently being developed but they are not yet widely deployed. Given their infancy these technologies are currently more costly than first generation processes and although costs are expected to fall, the degree and pace of any cost reductions are uncertain.
- It is expected that the price of fossil fuels will continue to rise in real terms towards 2030 as declining conventional oil resources force a move toward harder to exploit, and unconventional sources.

Recent evidence supports our previous assumption that biofuel and fossil fuel costs are likely to converge around 2030. However in the nearer term, while bioethanol production costs, can be cheaper than petrol, other fuels such as biodiesel and advanced biofuels are likely to remain more expensive than conventional fuels for most of the 2020s (Box 5.5).

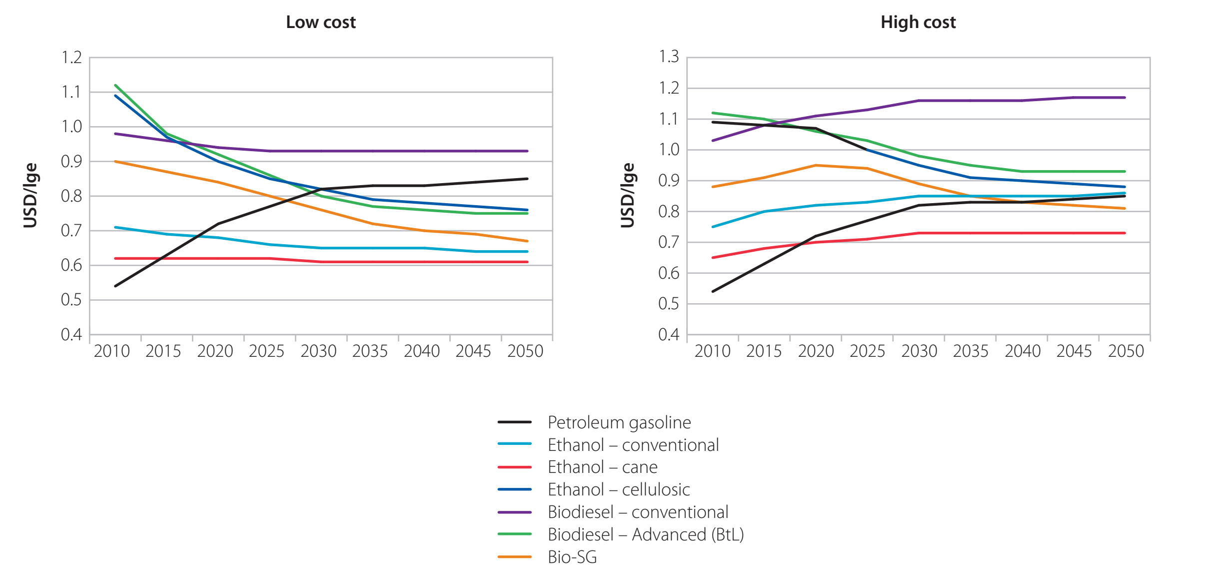
Box 5.5: Biofuel costs

In their Biofuels Technology Roadmap (2011) the IEA present two scenarios for biofuels uptake:

- **Low cost** where rising oil costs have little upward impact on biofuel costs, while economies of scale in biofuel production serve to provide downward price pressure.
- **High cost** which assumes a greater impact of rising oil prices on biofuel costs, and lower economies of scale in biofuel production.

Under the low cost scenario both advanced bioethanol and biodiesel production reach cost parity with petrol and diesel at around 2030. The high cost scenario is less optimistic and predicts biofuels to be marginally more expensive than conventional fuels in 2050 (Figure 5.6).

Figure B5.5: Cost of biofuels to 2050



Source: IEA Technology Roadmap – Biofuels for Transport (2011).

Source: IEA (2011) **Biofuels Technology Roadmap**, IEA (2013) **Production Costs of Alternative Transportation Fuels**

Demand-side measures

As we assumed in our original advice, there is significant potential to reduce demand for travel in order to deliver emissions reduction at low cost.

- **Smarter Choices:** Smarter Choices refers to a range of measures promoting voluntary reductions in levels of car use, achieved through a reduction in trips or modal shift to public transportation, walking and cycling. In our original advice we assumed that wide-spread implementation of Smarter Choices had the potential to reduce vehicle-km by 5%. Many of these schemes have just started and evaluation is on-going but initial results do not point to a change in our assumption at this stage (Box 5.6).

- **Eco-driving:** Eco-driving refers to a range of techniques to reduce fuel consumption, for example ensuring that tyres are properly inflated and sharp acceleration and braking is avoided. In our original advice we assumed that 20% of car and van drivers and 100% of HGV drivers would undergo training in eco-driving techniques by 2030, with fuel savings of 3% for cars/vans and 4% for HGVs compared to untrained drivers. Updated evidence suggests there is no basis to change our original assumption (Box 5.7).
- **Speed limiting:** Data shows that around 50%[9] of car and van drivers exceed the motorway speed limit. This offers an opportunity for reducing emissions through enforcing the speed limit given the significant decline in fuel efficiency as speeds increase from 70 to 80 mph. Our data suggests that if the 70 mph speed limit for cars and vans were more strictly enforced this could lead to emissions savings of 1.4 MtCO_2 in 2020.
- **Freight operations:** Emissions reductions from freight can be achieved through modal shift, supply chain rationalisation and better vehicle utilisation, with many measures resulting in cost-savings for operators. Evidence supports our previous assumption of a feasible reduction in vehicle-kms of 6.5% by 2030 relative to baseline projections (Box 5.8).

Box 5.6: Evidence on effectiveness of Smarter Choices

The Local Sustainable Transport Fund (LSTF) set up by DfT in 2011 provides funding for Local Authorities to operate Smarter Choices schemes in England. There are currently 96 LSTF funded schemes across 77 Local Authorities, with similar measures in place across the Devolved Administrations.

Evidence on the effectiveness of Smarter Choices funded via the LSTF is currently being gathered through a small number of case studies, but is not yet available. Other new evidence suggests these schemes have the potential to reduce driving.

- A report by the Scottish Government on their *Smarter Choices, Smarter Places* pilot schemes implemented in seven regions found those using car driving as their principal mode of transport fell in all regions, with reported decreases ranging from 6% to as high as 40%. This coincided with an increase in cycling and walking in five of the seven regions.
- Centro's Smarter Choices scheme, to be rolled out across the West Midlands, is expected to deliver a reduction in the number of car driver trips of between 4 and 10% by 2015.

Source: Scottish Government (2013) *Monitoring and Evaluation of the Smarter Choices, Smarter Places Programme*, Centro (2011) *Smarter Network Smarter Choices.*

9 DfT (2012) *Free-flow vehicle speeds on non-built-up roads by road type and vehicle type in Great Britain.*

Box 5.7: Evidence on eco-driving

The application of efficient driving techniques can be an effective means of reducing fuel consumption. The effectiveness of eco-training is difficult to measure but evidence suggests cost savings can accrue to drivers when implemented over a long period. Up-take among fleet drivers could lead other groups and there is a role for technology to reinforce good practice.

- The effectiveness of eco-driving depends on a range of factors such as driving conditions, the vehicle and types of road being tested. The RAC suggest that savings of 5-10% are possible, but that there is evidence of a reduction in effectiveness over time (for example one study suggested a reduction from 10% to 3% in fuel saved after one year). It is therefore important that behaviour is reinforced at regular intervals.
- Fleet managers are a good case group for demonstrating the benefits of eco-training as they are particularly sensitive to potential cost savings and they often use more advanced driver training. Employers are in a strong position to compel driver training and there are examples (e.g. UK bus firm Stagecoach) of companies operating financial rewards and other means to maintain performance over time.
- There are simple technology solutions that could help reinforce behaviour and help deliver fuel savings:
  - Gear shift indicators and fuel performance monitors can prompt effective driving.
  - Telematics collect data such as the location, speed and other characteristics of driving and can be fed back to drivers in real time.
  - Tyre pressure monitors help ensure optimal tyre condition.

Source: RAC (2012) *The Effectiveness of Eco Driving*

Box 5.8: Evidence on freight operations

Key measures aimed at reducing freight distance travelled include:

- Modal shift – from HGV road travel to rail or water.
  - Network Rail[10] forecast an increase in rail freight of around 17 billion tonne-kms to 2030. This is more than the equivalent reduction in road freight demand we expect in the fourth carbon budget, suggesting there would be enough additional freight capacity if all of this were to shift to rail.
  - Current investment planned by Network Rail could lead to rail becoming a more attractive option for freight. This includes: provision of longer and heavier trains; increased operating hours; expansion of rail-connected warehousing sites; improvements in ports logistics and connections (e.g. the London Gateway and the Barking rail freight terminal); and delivering new freight capacity.
  - Waterways have the potential to displace some road freight and offer economies of scale particularly for bulk goods and abnormal loads such as waste and aggregates.
- Supply chain rationalisation and better vehicle utilisation – these include use of computerised vehicle routing and scheduling systems (CVRS), better back-loading and optimising distribution centre locations.
  - A survey of Freight Transport Association[11] members using CVRS reported benefits of reduced mileage and fleet size as well as lowering costs to operators.
  - A case study of Alstons Cabinets[11] found better routing enabled the company to reduce its fleet size by 20%.
  - Better siting of distribution centres, double decker trailers and a reduction in empty driving has led to significant reduction in travel demand at Tesco; Asda has improved fuel efficiency by a half since 2005 by investing in measures such as in-cab technology, driver training and double decker lorries[12].

Source: DfT and Network Rail

10 Network Rail (2013) Long Term Planning Process: Freight Market Study.
11 DfT (2005) Computerised Vehicle Routing and Scheduling (CVRS) for Efficient Logistics.
12 http://your.asda.com/sustainability-transport/17-million-miles-better

4. Projected emissions with abatement – an updated scenario for the 2020s

In our previous advice we developed a trajectory of emissions through the 2020s that represented the cost-effective path to the 2050 target. This contained the set of measures that are important on the path to the 2050 target and that are cost-effective compared to expected carbon prices over investment lifetimes. It included improvements in conventional vehicles efficiency, uptake of electric vehicles and emissions reductions from demand side measures. We expected it to reduce transport emissions to 91 $MtCO_2$ in 2025 and 79 $MtCO_2$ in 2030.

Outlook to 2020

In developing our new scenario we follow the same methodology as our original advice. The starting point is a projection of baseline emissions from transport as set out in section 2. We then add measures which the Government is aiming to deliver or has committed to deliver, and our set of cost-effective abatement measures. Compared with our original advice, the new scenario now involves:

- The updated reference projection from the National Transport model.
- Lower EV uptake by 2020 (9% of new car sales and 12% of new van sales, compared to our previous assumption of 16%), reflecting an assessment of the UK's share of projected EU production.
- Updated costs for some measures (see section 3):
  - Updated vehicle technology and battery costs, reflecting the work by Ricardo-AEA and Element Energy for our 2012 advice on meeting the UK's 2050 emissions reduction target.
  - Updated biofuel costs, reflecting latest evidence from the IEA.
- A refined modelling approach, which disaggregates small, medium and large cars, and better accounts for real world vehicle efficiencies[13] and for the 'rebound' effect (i.e. a change in vehicle-km as a result of changes in purchase and running costs of vehicles).

Other assumptions underlying our projection remain unchanged:

- New car CO_2 – we continue to assume new conventional car CO_2 will reach 110 gCO_2/km in 2020.
- Biofuels – we continue to assume, in line with the Gallagher Review, that biofuels will meet 8% by energy of transport liquid fuel demand in 2020.
- Smarter Choices – we continue to assume a 5% reduction in vehicle-km (relative to the baseline) as a result of nationwide roll-out of Smarter Choices programmes.
- Freight logistics – we continue to assume a 6.5% reduction in HGV-kms in 2030 through improved freight operations

13 As we set out in our 2013 progress report, there is evidence to suggest that efficiencies under real-world driving conditions can be significantly lower than measured under the current test cycle, with a larger discrepancy for more efficient vehicles. See for example ICCT (2013) From laboratory to road.

- Eco-driving – we continue to assume that by 2020, 12% of cars drivers and 100% of HGV drivers have been trained, and use 3-4% less fuel.
- Enforcing the speed limit– we continue to assume that the 70mph speed limit for cars and vans is enforced on motorways and major roads, saving 1.4 $MtCO_2$ in 2020.

As a result we now assume emissions from road transport are 83 $MtCO_2$ in 2020. We add to this projected emissions from rail, domestic aviation and shipping, bringing total domestic transport emissions to 93 $MtCO_2$. This would be a 22% reduction on 2010 and is 7% lower than the level than we assumed in our original advice (101 $MtCO_2$).

The path from 2020 to 2030

We have revisited our scenario for the 2020s based on the latest evidence. This has generally confirmed our previous analysis, with a small number of updates. In terms of road transport, our scenario now involves:

- The updated reference projection from the NTM (see section 2).
- A slightly revised trajectory for ultra-low emissions vehicles, with only a small net impact on emissions:
  - **Market share of EVs.** We assume the same market share of new car and van sales by 2030 (i.e. 60%). However, the lower market share for 2020 described above leads in turn to slightly lower uptake in 2025, tending to increase emissions.
  - **Balance of BEVs/PHEVs**. We previously assumed that, given expected range constraints in 2030, 70% of people buying an EV would choose a PHEV rather than a pure BEV, based on an analysis of trip patterns; BEVs would be suitable for drivers who rarely make longer trips, or in multi-car households. However, the consumer choice modelling we commissioned from Element Energy for this report suggests, based on stated consumer preferences, that BEVs may achieve a higher market share than we previously assumed (around 40% of EV car purchases and 65% of EV van purchases in 2030), tending to reduce emissions.
- Updated vehicle technology and battery costs, and biofuels costs (see section 3).
- As for 2020, a refined modelling approach, which disaggregates small, medium and large cars, and better accounts for real world vehicle efficiencies and for the ‘rebound’ effect (i.e. a change in vehicle-km as a result of changes in purchase and running costs of vehicles).

Other assumptions underlying our scenario remain broadly unchanged:

- We continue to assume that emissions from conventional new cars will fall to 80 gCO_2/km by 2030, emissions from conventional new vans will fall to 120 gCO_2/km and emissions from conventional new HGVs will fall to around 600 gCO_2/km on average on a test cycle basis.

- We continue to assume that 50% of new buses are hydrogen fuelled by 2030.
- We continue to assume that the quantity of biofuels implied by an 8% share by energy in 2020 is held constant through the 2020s, reflecting uncertainties around sustainability.
- We continue to assume that the demand side measures delivered in 2020 persist (i.e. we assume a 5% reduction in vehicle-km due to Smarter Choices measures, a reduction in HGV-kms due to improved freight operations on rising trajectory to 6.5% reduction by 2030, and emissions reductions from eco-driving and enforcing the speed limit).

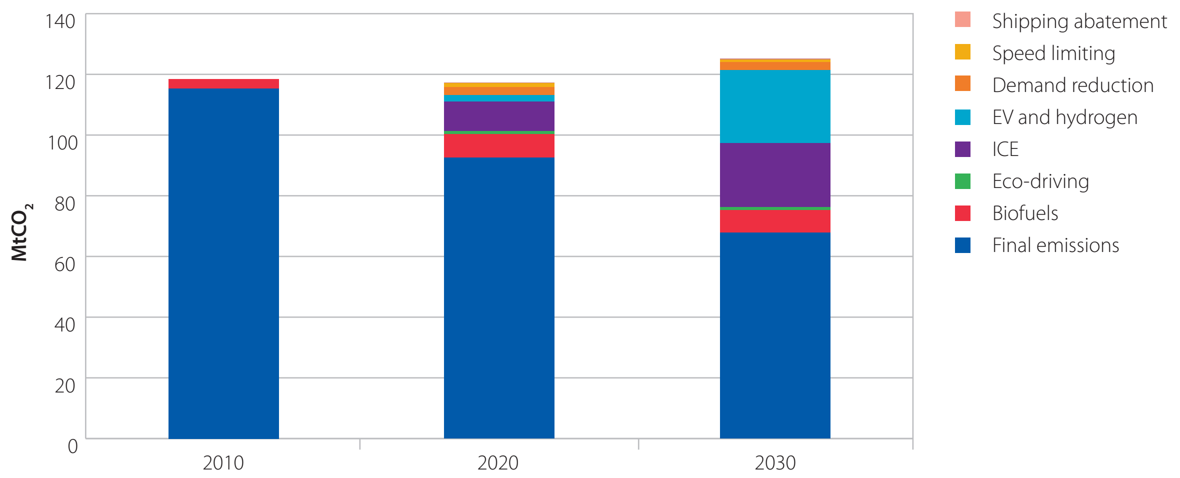
We have also updated our scenario to reflect latest evidence for domestic shipping:

- In 2011 the International Maritime Organisation agreed a global policy to improve energy efficiency of new ships by 30% by 2025. Our emission scenario for domestic shipping reflects this policy development, based on our previous detailed assessments of UK shipping emissions[14].

This scenario now results in domestic transport emissions of 82 $MtCO_2$ in 2025 (i.e. 9 $MtCO_2$ below our previous estimate) and 69 $MtCO_2$ in 2030 (11 $MtCO_2$ below our previous estimate) (Figures 5.3 and 5.4).

We build this updated scenario into our economy-wide analysis in Chapter 1.

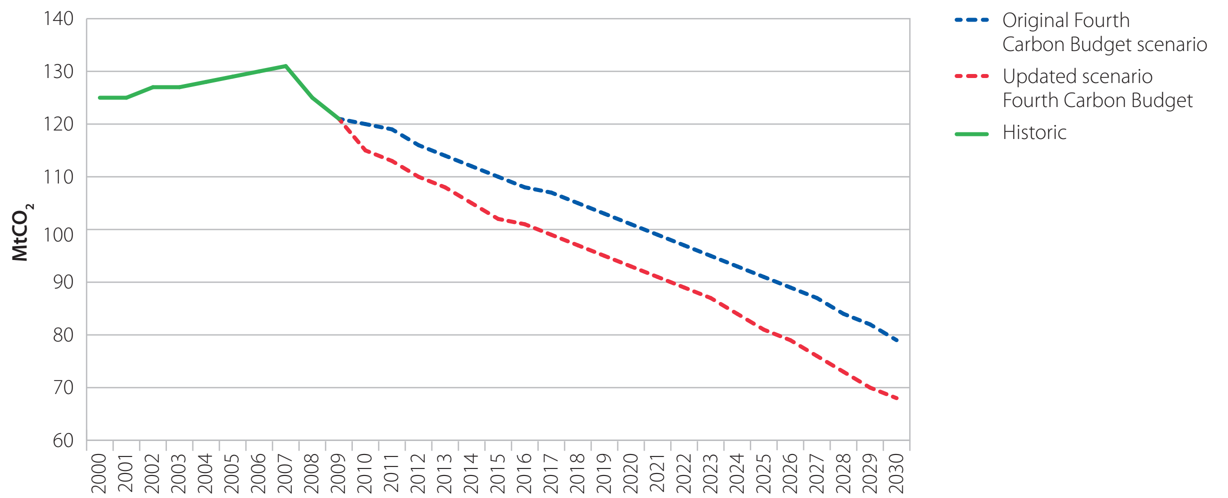
Figure 5.3: Updated abatement scenario for transport



Source: NTM (2013), CCC analysis.

14 CCC (2012) *Scope of carbon budgets: Statutory advice on inclusion of international aviation and shipping*, CCC (2011) *Review of UK Shipping Emissions*.

Figure 5.4: Transport emissions in our original and updated scenarios (2000 – 2030)



Source: NTM (2013), CCC analysis.

Preparing for 2050

Beyond 2030 this scenario would keep open the option of reaching close to zero emissions from surface transport by 2050, which we judge to be feasible given:

- Further uptake of electric vehicles (battery or fuel cell). A zero-emissions light vehicle fleet by 2050 would require all new cars and vans to be zero emissions by around 2035. This is plausible given a high share of sales by 2030 as in our abatement scenario. Rising carbon prices will justify larger batteries and longer ranges for BEVs, while fuel cell vehicles could help address market segments which are the most difficult to electrify, in terms of both range and access to overnight charging.
- Hydrogen and biofuels/biogas for HGVs. Deployment of hydrogen fuel cells in buses offers a stepping stone to potential deployment in goods vehicles in the longer term. While currently there are a number of challenges, it is plausible that these could be addressed, at least for some applications, given ongoing research and investment. Should challenges prove insurmountable in some cases (e.g. for heavy, long-distance goods vehicles) sustainable biofuels and/or biogas could offer a solution, though use of limited bioenergy resources here would need to be traded-off against use in other applications which may offer greater emissions reduction potential (e.g. industrial heat with CCS).

Sensitivities and flexibilities

We have also considered various sensitivities around the updated scenario:

- **Higher fuel or carbon prices.** Under high assumptions for carbon prices or fossil fuel prices, the costs of measures in our scenario would be lower, implying some scope to go further in terms of deployment. For example, under high fossil fuel prices, the difference in lifetime cost of a C/D segment BEV car compared to relative to a conventional car with today's technology would fall from around £+1500 to £-600 in 2025, making it easier to achieve higher consumer uptake. Further improvements to conventional vehicle efficiency would also become more cost effective, although lead-times in product development may mean some delay in bringing more efficient vehicles to market. Were the share of EVs in new car and van sales to reach 70% in 2030, and conventional new car efficiency to reach 60 g/km on a test cycle basis, emissions from domestic transport would be 4 $MtCO_2$ lower over the fourth carbon budget period than in our core abatement scenario.
- **Low oil or carbon prices.** Under low assumptions for fossil fuel prices or carbon prices, abatement costs associated with our updated scenario would increase. However, efficiency improvements, demand-side measures and biofuels would all remain negative or low-cost. EVs may no longer be cost-effective in the 2020s, but their deployment would still be required in order to prepare for a near-zero emissions light vehicle fleet by 2050. Deployment of measures in our updated scenario, and resulting domestic transport emissions, would therefore be largely unaffected.
- **Deliverability barriers.** Uptake of EVs is a key area of our updated scenario where there are delivery risks, reflecting the barriers to consumer uptake described in section 3 above. For example, there may be constraints on access to overnight charging for tenants, consumer acceptance of EV capabilities may be slower than anticipated, or battery cost reductions may be more gradual than expected. We have therefore considered an illustrative sensitivity where the share of EVs in new sales reaches only 30% in 2030. Emissions in this case would be 14 $MtCO_2$ higher over the fourth carbon budget period compared to our abatement scenario.

As set out in Chapter 1, the fourth carbon budget involves flexibility to accommodate these sensitivities. Firstly, lower delivery in some areas could be offset by increased delivery elsewhere. Secondly, there is some 'headroom' in the budget, such that some under-delivery overall can be accommodated within the economy-wide budget.

3. Benefits of delivering the measures in the fourth budget period

The measures in our updated abatement scenario are cheaper than the expected carbon price or are required to prepare for 2050 (Table 5.1). A delay in their deployment would therefore increase costs. We have quantified the cost for such a delay:

- The improvements in conventional vehicle efficiency in our updated scenario save money even before carbon savings are included.
- Deployment of electric vehicles in the 2020s is needed to prepare for a near-zero emissions light vehicle fleet by 2050. In addition, EVs are expected to be cost-effective relative to the carbon price by 2025, with electric vans offering emission reductions at negative cost.

- Overall, our updated scenario delivers a net present value of £30-35 billion compared to a scenario where deployment of measures through the 2020s is delayed to 2030[15]. To the extent that carbon prices or fossil fuel prices are higher than our central assumptions, this benefit would increase. Even under low assumptions for carbon prices, our updated scenario would still offer benefits relative to delayed action, and under low fossil fuel prices would be low to zero cost. It is therefore a low-regrets option (Table 5.2).

Table 5.1: Benefits of measures in our updated abatement scenario

		Average £/tCO_2 in 2025	**Importance to 2050**
Conventional efficiency improvements	Cars	3	
	Vans	-51	
	HGVs	-123	
Electric vehicles	Cars	156	Significant deployment required by 2030 to allow full penetration of the fleet by 2050, given stock turnover rates. A zero emission car fleet is likely to be part of the cost-effective solution to meeting the UK's 80% reduction target.
	Vans	-57	
Biofuels		42	
Demand side measures		Likely to be cost-effective given low costs of implementation and resulting fuel savings.	

Source: CCC analysis.
Note: unit abatement costs are average across measures deployed up to and including 2025; abatement costs are generally higher for measures deployed in earlier years.

Table 5.2: Net present value under different carbon price and fossil fuel price assumptions

	Central assumptions	**Low carbon price**	**High carbon price**	**Low fossil fuel price**	**High fossil fuel price**
NPV of our updated scenario versus delayed action £bn (2012)	30-35	15-20	40-50	-15-0	55-70

Source: CCC analysis.

It is therefore appropriate to aim to deliver significant abatement in the transport sector, as included in our updated abatement scenario. This will require policy strengthening to ensure that incentives for investment are in place and that barriers to deployment are addressed. We will consider policy in more detail in our 2014 progress report to Parliament, as part of our review of progress over the first budget period.

15 The range reflects different assumptions for the extent to which deployment of EVs is delayed. The upper end of the range corresponds to the share of EVs in new car and van sales remaining fixed through the 2020s. The lower end of the range corresponds to the share of EVs increasing to 26% for cars (22% for vans) in response to falling technology costs but in the absence of policy measures.